Promotion of Scientific Literacy in Bangladesh: Teachers' Perspectives, Practices and Challenges

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Abstract

In line with a current global trend, junior secondary science education in Bangladesh aims to provide science education for all students to enable them to use their science learning in everyday life. This aim is consistent with the call for scientific literacy, which argues for engaging students with science in everyday life. The study for this thesis explores how scientific literacy is promoted through junior secondary science education in Bangladesh. It looks at four areas: teachers' perspectives of scientific literacy; the translation of their perspectives into teaching practices; the values they consider in science teaching in relation to scientific literacy, and the issues they perceive as challenging in their teaching for promoting scientific literacy. To explore these four areas, this research followed a mixed methods design where qualitative approaches, including interviews with teachers, lesson observations and focus group interviews with students, dominated the overall research process.

This study reveals that whilst participating teachers held a range of perspectives of scientific literacy, including some naive perspectives, in practice they demonstrated limited capacity to translate their perspectives into their classroom teaching practices. Many of their teaching practices promoted a culture of academic science that resulted in students' difficulty in finding connections between the science they study in school and their everyday lives. This study also reveals that teachers found difficulties in conceptualising many of the curriculum-identified values and consequently, found it difficult to find, develop and implement suitable teaching approaches to promote the values. The difficulties also included teachers encountering tension between their religious values and science values while they were teaching science in a culture with a religious tradition. These results may contribute to understanding how teaching for scientific literacy is challenged by an academically oriented curriculum, large class size, limited resources, traditional examination-oriented education and limited teacher development programmes.

CHAPTER 1
Introduction to the Research

1.1 Introduction

During the 1980s, Fensham's (1985) call for a *Science for All* was recognised worldwide as a commitment to provide science to all students, not just to the elite. Subsequently, this slogan has been modified to one of *Scientific literacy* (Law, Fensham, Li, & Wei, 2000), which is advocated worldwide as a goal of school science education as for example in the USA (American Association for the Advancement of Science [AAAS], 1993), in the UK (Millar & Osborne, 1998), or in Australia (Goodrum, Hackling, & Rennie, 2001). In line with this global trend, junior secondary science education in Bangladesh aims to provide a good foundation in science for all students to enable them to use their science learning in everyday life (National Curriculum and Textbook Board [NCTB], 1995). This aim is consistent with the call for scientific literacy, which argues for engaging students with science in everyday life (Tytler, Osborne, Williams, Tytler, & Clark, 2008).

This research aims at exploring how scientific literacy is promoted through junior secondary science education in Bangladesh. In this chapter, I introduce the research focusing on my personal motivations for investigating the topic, the research context and the significance of the study.

1.2 My Personal Motivations

My personal motivations for conducting this research have been influenced by my experiences as a school student, as a school science teacher, and as a science teacher educator.

When I was a school student, I experienced science as a large body of information only. I could hardly distinguish science from other school subjects, even though the science textbooks included a number of hands-on activities entitled *"Esho Nije Kori"* (Let's do). While those activities were intended to provide students with opportunities for learning by doing (Tapan, 2010), I have scant memory of being involved in such activities in school. Rather, my science teachers emphasised memorising the science content from the textbooks. I can still remember how I memorised the definition of friction though I did not know that we encounter the effect of friction each and every day. Most of my science teachers used to explain science content diligently so that we could prepare ourselves for the exams, but they rarely – if ever – explained how the content knowledge could be used in our lives. Exams were mostly based on memorisation and recall tasks rather than tasks that involved everyday contexts in which we could use our science learning. Sometimes teachers described a brief history of scientific inventions or discoveries to gain our attention and raise our interest. But in doing so they presented scientists as revered persons with considerable authority, almost hero-like. As a result, I thought of science as a matter for special people (scientists) rather than something that could be linked with my life. In spite of all this I continued my study in science, as it was generally perceived as a high status subject, and most importantly, my parents wanted me to study science. At my age, and in my culture, it was often the case that parents made incontrovertible decisions about their children's future study direction.

As a part of my undergraduate study in science education I spent six months in a secondary school for my professional placement. While teaching science as a student-teacher I noticed a tension in my science class. At the very beginning, I asked my students the purposes for which they thought they were studying science. Some students replied that it would help them for further studies in science. A number of students expressed their lack of clarity regarding its purposes; they did not wish to study science in future, because it was very "difficult" for them. Very few students, on the other hand, expressed the view that science is very important, because our society is built on it. Nevertheless, they could not articulate how society is built on science. Because of these comments I included in my class some other purposes for studying science, such as how science learning could be used in everyday issues and how science learning could help us think in a rational way. In response, the students commented that they knew about some of these ideas from their science class and from the TV and newspapers, yet, they explained, in school they studied science mostly for exam purposes and had found few topics in science to be useful and important in their lives. I could remember the same tension had prevailed in my school life, too.

In the teachers' common room, I met with the science teacher who had actually taught science in that class before I started my job as a placement teacher. I discussed with him the students' views about their learning of science. He professed understanding the students' difficulty in finding the relevance of many of the science topics for their lives. This he attributed to the ways the structure of the science curriculum and many other factors limited his scope to present many of the science topics as useful in, and relevant to, students' lives.

After completing my undergraduate and graduate studies in science education, I started my professional career as a teacher educator in a University. I conducted a course, "Teaching of Science", designed for both in-service and pre-service school science teachers. In the discussions of what the aims of school science education should be, or what the teachers should teach and what they usually teach, or how they teach, I observed a variety of views among my student-teachers. Most of them expressed the notion that science must be relevant to the students, and that the students need to understand how they could use their science learning in different life situations. On the other hand, some argued that science is mostly abstract in nature, and thus the students might not see the use of much of their science learning in real life. I started thinking of how their views would influence their teaching to promote scientific literacy.

The experiences described above raised many questions in my mind. For example, what are the curriculum-intended purposes of science education in school? How do teachers perceive the purposes and teach in their science class? What persuades teachers to think of science as abstract in nature and as unconnected to students' everyday lives? How do students perceive what is taught to them? Do they think their school science learning important and valuable? These questions are central to scientific literacy and the context of my research.

1.3 Context of the Research

In Bangladesh, the education system consists of three major levels: primary, secondary and higher education (see Appendix 3 for the education structure in Bangladesh). The primary level is a five-year cycle, and starts at age six. Secondary education comprises seven years of schooling with three sub-stages: junior secondary (grades VI–VIII), secondary (grades IX and X), and higher secondary (grades XI and

XII). From Grade IX, students choose their future study direction from the streams of Science, Humanities, and Business Studies. If students choose a non-science stream (i.e., Humanities or Business Studies) at the secondary level, they would not be allowed to pursue any formal science education later in life. The focus of this study is the junior secondary level, in which all students follow the same curriculum.

The National Curriculum and Textbook Board [NCTB] prepares the curriculum for the junior secondary level and provides textbooks for each grade from grades VI to VIII (Ministry of Education, 2000). 'General Science' is a compulsory course for all students at this level, constituting 10% of the total curriculum (National Curriculum and Textbook Board [NCTB], 1995). Whilst this course is prescribed to integrate content from physics, chemistry, biology, geography and population education (Mosir Uddin, 2009), in practice, the course falls far short of this aim (Rahman, 2011). Textbook units are not arranged according to any integrated theme but with emphasis on content mainly from physics, chemistry and biology. A detailed discussion of the textbook content is presented in Chapter 3.

In the Bangladesh Junior Secondary Curriculum Report, it has been agreed that "in these days, the importance of acquiring scientific knowledge and skills is unavoidable for improving the quality of lives, solving everyday problems and making decisions" (NCTB, 1995, p. 353). In order to provide such knowledge and skills, the General Science course is compulsory for all students. It is also noted in the curriculum report that the General Science course is to build a strong foundation for the students who wish to take the Science stream and pursue further studies in science (NCTB, 1995). An additional aim of the course is to promote some values through science education, for example, open-mindedness, rational thinking, respect for others' opinions, intellectual honesty, and curiosity (NCTB, 1995, p. 354). However, it seems that promoting such values through science education does not match with the values set out in the general aims of education, as explained below.

The first two general aims of education for secondary education are:

- to build a *firm faith and belief in the Almighty Allah* (God) in students' minds so that this belief plays as an inspirational source for their every thought and work
- to raise spiritual, social and moral values in students' minds *on the basis of faith and belief in the Almighty Allah*

(NCTB, 1995, p. 11, my translation, emphases added)

As is seen in the above two aims, God has been named as "Allah" and has been described as "the almighty". According to the Islamic view, it is the tradition for Muslims to praise God. Whilst the majority of Bangladeshis are Muslims, a number people profess other religions, for example, Hinduism, Christianity and Buddhism (Bangladesh Bureau of Educational Information and Statistics [BANBEIS], 2006a). Thus it is reasonable to ask whether a Hindu/ Christian/ Buddhist student has to regard God as "the almighty" and build "a firm faith and belief in him" as does a Muslim student. Moreover, if students' values are developed based on the beliefs in God, it is reasonable to ask "how would they develop values, such as open-mindedness or curiosity?" If students are guided by the value of curiosity, they may be curious about the existence of God or about his power. Such a curiosity is not encouraged in the religious values. Moreover, most religions, for example, Islam, obligate people to keep faith in some aspects; there is no scope for being open-minded and looking for other alternatives. If a person does this and chooses the best option among the alternatives using his/her own judgement, he/she would be regarded as a "non-believer".

The mismatch between the aims of science education and education in general as presented above may have occurred because the science curriculum in Bangladesh is more or less Western in nature, while the Bangladeshi society has an Islamic tradition. This has resulted in a conflict of embedded values. Such a conflict may also be present in science classrooms and may impact upon science teaching and learning, in practice. Here is a story from a science class in Bangladesh. I heard this story from one of my professors while I was pursuing my master degree in education.

> The topic of the lesson is the consequences of over-population and its controlling measures. The teacher discusses the issues with students very diligently and provides plenty of real life examples. Students also seem to be very enthusiastic in participating with the teacher in the discussion. At the end of the lesson, the teacher asked the students, "what I have discussed today is for the sake of science; the fact is that you have to rely on Allah; if he blesses your family with a birth, he will supply the basic livelihood. Nothing to be worried about"!

The story presented above may exemplify how science teaching in a country like Bangladesh is challenged by the conflict of different value systems. In the story, the teacher was guided by his religious values even though he was teaching in a science class. The socio-cultural context of Bangladesh may be a contributing factor to the conflict of different value systems (e.g., religious values and science values). Therefore, it is reasonable to examine how teachers consider the different value systems in science classes and how they negotiate such differences if conflict arises between the value systems.

As noted previously, whilst the General Science course at the junior secondary level caters for all students, almost 75% students choose the non-science groups (i.e., Humanities or Business Studies) at the secondary level (Bangladesh Bureau of

Educational Information and Statistics [BANBEIS], 2006b). This is quite similar to what is seen in other educational systems (Driver, Leach, Millar, & Scott, 1996). The junior secondary General Science curriculum therefore should provide a good foundation in science for all students including those who will take further studies in science. The emphasis in the curriculum needs to cater for both of these groups as the former group needs a solid foundation in science in preparation for being effective citizens, while in addition to this the latter group needs a good foundation to prepare them for further study in science. This emphasis, however, does not always remain in balance in the curriculum, with teachers often focussing more on the good foundation for the future science study group (Sarkar, 2009).

In Bangladesh, school education is exam-driven because the success of teachers and schools is measured by students' results in the public exams (Holbrook, 2005). As the public exams mostly demand memorisation and recall of the content from the textbooks (Holbrook, 2005), the power of exams reinforces teachers to encourage students in rote learning (Tapan, 2010). Teachers, therefore, often work on preparing students for the exams and feel reluctant to find ways to enhance student engagement in science classes.

Large class size is another challenge for teachers in ensuring student engagement in science classes. Whilst in the National Education Policy 2000 (Ministry of Education, 2000) class size is recommended to be kept to 40 students per class, this recommendation is rarely heeded. Particularly, in government schools class size often exceeds 100 students per class (Holbrook, 2005). In such a situation, teachers often resort to the transmissive approaches (for example, lecturing) that hinder the opportunity of student engagement.

Science teaching in Bangladesh is also challenged by the limited resource facilities (Asia and the Pacific Programme of Educational Innovation for Development [APEID], 1991a). The government does not supply adequate resources to schools, yet teachers also fail to seek low-cost resources due to their lack of motivation, interest and training to improve their teaching practice (Tapan, 2010). Tapan has suggested that such a lack of motivation might be due to the teachers valuing the teaching practices that they had experienced in schools as students. As a result, most of the science classrooms are still equipped with the traditional chalk-duster and textbooks. Similarly, in many schools there are no science labs and those schools where there are science labs are not well-equipped to provide students with experiences of lab activities (Tapan, 2010).

My personal experiences and the existing context described above raise many questions about the teaching and learning of science in relation to scientific literacy. These questions need to be addressed and are outlined below.

1.4 Research Questions

This research explores how scientific literacy is promoted through junior secondary science education in Bangladesh. In order to do this, four subsidiary research questions have been framed:

1. How do teachers perceive scientific literacy?
2. How are teachers' perspectives of scientific literacy translated into classroom teaching?
3. What values do teachers consider in relation to scientific literacy and how are they considered in science classes?
4. What issues do teachers perceive as challenging in their teaching for scientific literacy?

1.5 Significance of the Research

The research on scientific literacy has its own general value in the context of school science education. For example, Fensham (2004) reviewed the case for promoting scientific literacy through school science education for the enhancement to the lives of the students as individuals as well as for the benefits to the society, nation and science (more detail is presented in the next chapter). Scientific literacy therefore has been widely accepted as a primary goal of school science education. However, research reveals that in many cases school science education is not likely to promote scientific literacy, as for example in Australia (Goodrum, et al., 2001). What about in Bangladesh? This research is aimed at looking at this issue since to the best of my knowledge there is no research regarding scientific literacy in Bangladesh; this is the first such initiative. Moreover, not much research has been done in the contexts of developing countries on how teachers perceive scientific literacy and translate their perspectives into classroom teaching, what values they consider in their teaching for scientific literacy, and what issues they perceive as challenging in their teaching. Thus, this research may make a significant contribution to the current understanding of the issue of scientific literacy in the context of developing countries, particularly in Bangladesh. The policy makers, curriculum and textbook developers, science teachers and teacher educators from Bangladesh and other developing countries might gain insights regarding issues in the development of scientific literacy from this research.

1.6 Thesis Outline

This thesis comprises eight chapters. Following this introductory chapter, literature is presented in Chapter 2 on the purposes of school science education, the importance and conceptions of scientific literacy, teaching approaches and students' perceived experiences of school science to provide a theoretical basis for this research. Chapter 3 presents an analysis of science textbooks used at the junior secondary education level in Bangladesh in order to set up a curriculum context for exploring how scientific literacy is promoted through school science education in Bangladesh. The methods used in this exploration and the underpinning methodological issues are discussed in Chapter 4. Results of this research are presented in Chapters 5 and 6. While Chapter 5 illustrates a general overview of teachers' perspectives of scientific literacy and their teaching approaches and challenges associated with its promotion, Chapter 6 probes further to gain in-depth understanding of the issues. The significance of the results presented in Chapters 5 and 6 are discussed in Chapter 7 in relation to the research questions and the aspects of literature presented in Chapter 2. In Chapter 8, conclusions are drawn in relation to the science educational practice and research.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter discusses theoretical understandings of scientific literacy and underlying concepts to be used in this study. The discussion begins with the purposes of contemporary school science education. I then provide an account of the case for scientific literacy as a primary purpose of school science education for all students; the historical development of the idea of scientific literacy; my conceptual understanding of scientific literacy as synthesised from the literature; teaching approaches to promote scientific literacy in science classes and associated challenges teachers may encounter, and students' perceived experiences of school science education.

2.2 Purposes of Contemporary School Science Education

The concept of *curriculum emphases* can be useful to frame the content of the science curriculum in terms of different knowledge emphases, which eventually, can determine the purposes of school science education. Roberts (1982) defined the phrase "curriculum emphases" in science education as "a coherent set of messages to the student *about* science" (p. 245). He argued that if the students are to become aware and confident that their learning of science has a coherent and meaningful purpose rather than providing isolated pieces of information, this purpose must be communicated to them either explicitly or implicitly. Explicit communication can be found in classroom activities, while implicit communication can be found in the intentions related to what is implied or excluded (Roberts, 2007). Roberts (1982) identified seven curriculum emphases in science education practice in North America prior to 1982: "Everyday Coping; Structure of Science; Science, Technology, and Decisions; Scientific Skill Development; Correct Explanation; Self as Explainer; and Solid Foundation" (Roberts, 1982, p. 246). Later, Fensham (1997, cited in Fensham, 2001b) proposed an additional three emphases to capture some of the curriculum movements that had taken place within this time period: "*Science in Application, Science as Nurturing,* and *Science through Technology*" (pp. 30–31, emphasis in original). Table 2.1 provides an overview of these ten emphases.

Corrigan (1999) has argued that the stakeholders' different purposes for giving priority to different emphases and at different times in their intended curricula can result in a number of continua relating to curriculum purposes. One such continuum includes providing future scientists and science professionals at one end and providing scientifically literate citizens at the other. While this is often seen as a continuum, there are some questions as to whether these two purposes need to be in opposition to each other (Fensham, 1997). In reality however, this is often the case. For example, Solid Foundation, Correct Explanation, and Scientific Skills Development were given priority for content and/or pedagogy in the teaching programs developed in the 1960s that aimed at preparing future scientists and science professionals (Fensham, 1997, cited in Fensham, 2000). Consequently, school science curriculum in that age was dominated by a large number of concepts, facts and principles that were often not relevant to students' everyday lives. Such a curriculum had the flavour of specialist science courses at university or college levels rather than the elements of a school level science curriculum designed for all students.

Table 2.1

An Overview of Curriculum Emphases

Curriculum emphasis	Explanation
Everyday coping	The prime focus of this curriculum emphasis is on creating a knowledge system necessary for understanding and controlling everyday situations, as for example, health, nutrition and environmental hazards.
Structure of Science	This curriculum emphasis focuses on creating a cumulative and self-correcting system of conceptual and procedural schemes of science that explains natural phenomena.
Science, Technology, and Decisions	This curriculum emphasis pays attention to the "limits of science in coping with practical affairs" (Roberts, 1982, p. 247) and is concerned with both the nature and the limitations of scientific and technological knowledge in decision making.
Scientific Skill Development	This curriculum emphasis focuses on the development of the investigative skills and procedures. It tries to convey a message to the students that the skilful use of science processes (means) will inevitably give a correct product (end).
Correct Explanation	This curriculum emphasis focuses on the products of science (e.g., theories and concepts). This is a common emphasis in textbooks largely known as "master now, question later" (Roberts, 1982, p. 248).
Self as Explainer	The character of science as a cultural institution and as expression of humans' many capabilities; students can be given the message that their explanations can be seen as contextually reasonable.
Solid Foundation	Science instruction needs to be organized to facilitate students' understanding for future science instruction. This curriculum emphasis focuses on preparing the most talented students to become future scientists and science professionals.
Science in Application	Science teaching begins with applications of science; science is learned in order to understand its applications.
Science as Nurturing	Focused on the science knowledge and skills that have great potential to improve the quality of human life and environment.
Science through Technology	Making technological products and using technological processes involving scientific principles.

Note. Based on Roberts (1982, pp. 246–249) and Fensham (1997, as cited in Fensham, 2001b, pp. 30–31)

In contrast, the *Science for All* movement in the 1980s prioritised Science in Application, Science as Nurturing, and Science through Technology. By shifting the emphases, a *Science for All* curriculum emphasised developing an informed, scientifically literate citizenry (Sadler & Zeidler, 2009). It may be worth mentioning that this thesis does not intend to look at different science curricula reform movements (e.g., *Science, Technology and Society [STS]* and *Science for All*) intensively, but recognises their notion of providing a science education that is accessible and useful to all students in their everyday lives.

Preparing future scientists as the purpose of school science education in the 1960s has been widely critiqued on democratic grounds (Millar & Osborne, 1998; Reiss, 2007) as this purpose generally intends to meet the needs of a minority of students who study further science or take science-related careers (Millar, 1996). Indeed, such a purpose fails to meet the needs for all students, since it does not provide them with an interest in, and the knowledge and skills of, science to be used in their everyday lives, nor does it help them to appreciate the importance of science in society (Holbrook, 2009). As Holbrook has argued, a scientific literacy perspective acknowledges such needs for all students irrespective of their future study or career aspirations. More recently, many school science curricula worldwide have advocated scientific literacy as a primary purpose of contemporary school science education. The rationale for advocating this goal is discussed below, with an emphasis on the importance of scientific literary for the individual and society.

2.3 Importance of Scientific Literacy

The United Nations Educational Scientific and Cultural Organization [UNESCO] (1993) recognised scientific literacy as essential for achieving sustainable development, which has also been advocated in Bangladesh's National Education Policy 2000 (Ministry of Education, 2000) as the main objective of science education in this nation. Sustainable development may be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations [UN], 1987, p. 54). This notion of sustainable development takes account of how ecological processes in the natural environment occur in such a way that the environment is not harmed and future generations can use environmental resources to meet their needs. Use of energy resources can be an example of this notion of sustainable development. Energy resources can be classified into two types: non-renewable and renewable. A non-renewable resource, such as fossil fuels, is a natural resource that cannot be produced or generated and as a result, once depleted, it will not be available for future needs. A renewable energy resource, on the other hand, is derived from natural processes and is continually being replenished, such as solar energy (using sunlight) and wind power (using wind). According to the International Energy Agency [IEA] (2007), use of renewable resources (instead of non-renewable resources) provides opportunities to mitigate greenhouse gases in the atmosphere, and thus helps avoid the potential greenhouse effects that are harmful for the environment. In order to promote sustainable development for the environment, IEA thus urges people to use renewable energy sources. So, people's notions of sustainable development could be seen as reflected in how they make decisions about the use of energy resources. Holbrook (2009) argued that the role of science education for all students in school needs to include such issues of sustainability so that students' decisions can promote sustainable development.

Fensham (2004) discussed how the arguments for promoting scientific literacy for all have been presented in the science education literature as related to several different grounds, for example, personal well-being, democratic well-being, economic well-being, socio-cultural well-being and the well-being of science. The arguments have emphasised the importance of scientific literacy for enhancing the lives of the individual as well as for the benefits of the society or science, as discussed below.

Personal well-being.

The personal well-being argument for scientific literacy recognises that an understanding of science is important for the betterment of personal life (Fensham, 2004). Millar (1996) argued that an understanding of science allows people to be "better equipped to make decisions about diet, health, safety, and so on, to evaluate manufacturers' claims and make sensible consumer choices" (p. 9). Quoting from the report of the Royal Society of London (1985, p. 9, as cited by Laugksch, 2000):

> [scientifically literate people] significantly improve the quality of public decision-making, *not* because the 'right' decisions would then be made, but because decisions made in the light of an adequate understanding of the issues are likely to be better than decisions made in the absence of such understanding (p. 85).

The notion of scientific literacy may include providing students with understandings of how they can deal with science-related issues in their everyday lives (Tytler, et al., 2008). Thus wide-spread scientific literacy may enable students to deal with science-related everyday issues with more confidence (Laugksch, 2000; Lehr, 2007).

Democratic well-being.

In general, democracy offers all citizens the right to hold and express their views about the decisions that affect their lives. As science is often supported from the public fund and as the products of scientific research influence many aspects of public life (for example, transport, energy and environment), people have the democratic right to know about how science operates and what may be the consequences of scientific research in their lives (Thomas & Durant, 1987 as cited in Laugksch, 2000, p. 85). Knowledge about science and scientific research can be provided through science education for all students in school. In contrast to this policy, Fensham (1985) discussed how science education traditionally prioritised the needs of a minority of students (the future science study group or future scientists group) and overlooked the needs of science for all students by omitting socially useful aspects of science. Due to this omission, as Fensham argued, to the majority of students' science learning in school becomes "mysterious" rather than something that is useful in their lives (p. 417).

In Bangladesh, as mentioned previously, about three-quarters of the students at the junior secondary level abandon the pursuit of a specialised science course after this level (i.e., secondary level). So, if the science curriculum caters for only one-quarter of the students to prepare them for future science study, most students may be deprived of an adequate science education for citizenship. As scientific literacy advocates science education for citizenship and citizenship education is important to all students irrespective of their future study or career aspiration, this approach to science teaching and learning recognises the notion of democratic rights for all students (Longbottom & Butler, 1999).

Economic well-being.

Whilst economic well-being has been presented as an argument for promoting scientific literacy in science education literature, Millar (1996) has criticised this argument in the case of scientific literacy. The economic argument refers to the economic well-being of a nation depending upon the status of science and technology and the supply of science and technology related professionals to that nation (Millar, 1996; Rothapfel, 2004; Shortland, 1988). Millar (1996) noted that this argument promotes the traditional notion of a science curriculum aiming to provide students with a pre-professional training in science. Such a traditional science curriculum caters for only a minority of students and goes against the democratic rights for all students in terms of getting an education for scientific literacy as noted previously.

Nevertheless, there may be an indirect relationship between economic well-being and scientific literacy. Laugksch (2000) argued that the increasing development of science and technology has resulted in an increasing number of new products on the market and supply of these products may depend on peoples' understanding of how they use them. As Laugksch argued, a minimal level of scientific literacy is required for using the science and technology related products. Moreover, it is argued that scientific literacy helps people participate more intelligently in the productive sectors of the economy (Walberg, 1983). For example, in an agriculture dependent country like Bangladesh, a greater understanding of science might help the agricultural community improve their harvest, which in turn would improve the economy of the country. For instance, school science may provide students with knowledge related to hybrid crops and more sustainable approaches to agriculture, such as the proper use of pesticides and fertilizers in the field. As many of the students of Bangladesh live in rural areas and many help their families in farming, students can pass this knowledge on to them for improving harvest yields in sustainable ways. In sum, if students are provided with agriculture-related science knowledge in their school, the knowledge may be shared with the agricultural community and thus may contribute to the national economy by improving harvest yields.

Socio-cultural well-being.

UNESCO (1993) recognises science as an integral part of social life and culture. Maddock (1981), from an anthropological viewpoint, described science and science education as cultural enterprises which form a part of the wider cultural matrix of society. This notion of the cultural matrix, as Maddock argued, requires that educational considerations concerning science must be made in the light of its social and cultural roles. Aikenhead (1996) argued that in terms of learning science in school, students encounter a "cultural border crossing" from the subcultures of their peers and family to the subcultures of science and school science. For example, before starting learning science in school, students' worldviews (how they make sense of their natural world) may be shaped within the culture of their families. Each family embraces a set of norms, values, beliefs, expectations and actions that denotes the culture of the family. In a similar vein, science has its own norms, values, beliefs, expectations and actions that are generally shared in various ways by communities of scientists and that represent the culture of science. Science education in school, as Aikenhead argued, is an attempt at transmitting a scientific culture to students' worldviews. Aikenhead stated that this cultural transmission can occur in two ways (enculturation and assimilation) and that both of them require cultural border crossing into the culture of science. If the culture of science generally harmonises with a student's worldview, science instruction will tend to support the student's worldview. This notion is referred to as enculturation with the culture of science. In contrast, if the culture of science is generally at odds with a student's worldview, science instruction will tend to replace or marginalise the student's worldview. This notion is referred to the assimilation with the culture of science. It should be noted that, while the culture of science is actually quite diverse in that many different communities among scientists hold differing values, there is a common set of values among them focussing on systematic, yet creative thinking and the importance of evidence and openness to new explanations (these matters are discussed in detail in the section of "the nature of science").

Like in many other developing countries (Nargund-Joshi, Rogers, & Akerson, 2011; Rampal, 1994), there are many superstitious beliefs embedded in Bangladeshi society (Hossain, 2010). Hossain mentioned some common superstitious beliefs held by Bangladeshi people, for example, wearing a "tabeej" (amulet) or ring for protection from evil spirits; having pens blessed by a priest before an exam; and using a "tabeej" or voodoo dolls and trying to bring harm to enemies by using "kufri kalam", which is a common sign of black magic. As members of Bangladeshi society, many of the students' worldviews may be shaped by such superstitious beliefs. In learning science in schools, cultural transmission may help students to replace or marginalise their superstitious worldview and assimilate with the rational culture of science. An appreciation of science as a result of cultural transmission may in turn lead to greater support for science, which is discussed in the section below.

The well-being of science.

Barnes (1985), as cited in Corrigan and Gunstone (2007), noted that the authority of science is accepted by society and that funding for scientific research should be for the purposes of being beneficial to society. When people know about and value scientists' work as beneficial to society, they are more likely to provide scientists with financial support from public funds, according to Asimov (1984), as cited in Shortland (1988).

The promotion of scientific literacy may reduce people's unrealistic expectations from science. Because of the development of science and technology and the potential of scientific understanding to be applied to the solution of a wide range of problems, "it would not be surprising if sections of [the] public were to acquire unrealistic and unrealizable expectations of science" (Shortland, 1988, p. 307). Such expectations are very common among the people of developing countries, who view science as the major vehicle of social and economic mobility (Sjøberg & Schreiner, 2005). However, science does have limitations and cannot answer all questions or solve every problem (Buaraphan & Sung-Ong, 2009). So, if people are not aware about such limitations, "there is a risk of loss of confidence, cynicism, and eventual withdrawal of support" when people's unrealistic expectations of science are not met (Shortland, 1988, p. 307). An increased level of scientific literacy, developed through people having a better understanding of science, including its limitations, might neutralise this potential disappointment with and hostility towards science (Jenkins, 1990, 1997; Laugksch, 2000).

The arguments for the importance of scientific literacy present in the contemporary science education literature have been discussed in this section. The discussion focuses on why scientific literacy is advocated worldwide as a primary purpose of contemporary school science education and how it is equally important to look at what scientific literacy may mean if we are to appreciate how it can contribute to personal, democratic, economic, socio-cultural and science well-beings. The meaning of this concept and the ways it has been shaped over time are now explored in greater depth.

2.4 Meaning of Scientific Literacy

The term "scientific literacy" has been used since the late 1950s to describe a required familiarity with science on the part of the general public (DeBoer, 2000). In 1958, Paul DeHart Hurd first used this term as a major theme of science education in a publication entitled *Science literacy: Its meaning for American schools* (Bybee, 1997; Laugksch, 2000). As cited by Bybee (1997), Hurd referred to scientific literacy as "an understanding of science and its applications to social experience" (p. 47). Since then there have been many attempts to define scientific literacy but no consensus exists for universal acceptance (DeBoer, 2000; Hand et al., 2003; Jenkins, 1990; Osborne, 2007; Roberts, 2007). DeBoer (2000) argued that an important reason behind this lack of consensus may be that many historically significant educational themes encompassing the nature of science and scientific literacy have shifted over time. Therefore, to develop a contemporary meaning of scientific literacy it might be important to discuss how the concepts of the nature of science and scientific literacy have shifted over time. Section 2.4.1 discusses the contemporary nature of science while Section 2.4.2 presents a brief account of the historical development of the idea of scientific literacy.

2.4.1 The nature of science.

Grandy and Duschl (2005) argued that the nature of science has shifted from a logical positivist view to the present model-based explanations. According to their argument, hypothetico-deductive explanations value the logical positivist view and suggest viewing scientific activity in a straightforward way with some fixed steps. A typical example of hypothetico-deductive explanations could include the following steps:

1. Make observations
2. Formulate a hypothesis
3. Deduce consequences from the hypothesis
4. Make observations to test the consequences
5. Accept or reject the hypothesis based on the observations

(Grandy & Duschl, 2005, p. 4)

On the other hand, as Grandy and Duschl argued, in the present model-based explanations science is regarded as a cognitive, social and epistemic practice. Model-based explanations recognise the role of models and data construction in the scientific processes and also recognise the social processes and contexts that shape how knowledge is discovered and communicated. In this view, in model-based explanations, the scientific community is an integral part of the scientific processes (Grandy & Duschl, 2005).

While the nature of science has always been part of school science curriculum, the shift in nature of science has not been reflected in the curriculum. It has remained similar to the 1950s view and has not evolved in the same way that the nature of science has evolved in practice. Corrigan and Gunstone (2007, p. 139) have labelled these evolved views the *"contemporary views"* of the nature of science. Corrigan and Gunstone (2007) argued that the contemporary views of the nature of science include both epistemological (e.g., the place for revision and subjectivity in science) and sociological perspectives (e.g., social and cultural embeddedness of science). Inclusion of these two perspectives was evident in Lederman's views of nature of science as below.

Lederman (2004) suggested that the phrase "nature of science" may refer to the epistemology of science or the principles and beliefs inherent in the development of scientific knowledge. Beyond this general characterisation, there is lack of agreement among the philosophers of science, historians of science, sociologists of science, scientists and science educators about a specific definition for the nature of science (Abd-El-Khalick & Lederman, 2000a, 2000b) and this may be due to the multifaceted and complex nature of scientific endeavour (Abd-El-Khalick, Waters, & Le, 2008). However, Lederman (2004) suggested that school curriculum should (and has in the past, to some extent) include some aspects of the nature of science, as outlined in Figure 2.1, that are non-controversial, accessible to and useful for all students. It should be noted that while the aspects might not be viewed as exhaustive, they could be viewed as a subset of the multifaceted nature of science. Moreover, the aspects are consistent with the views of the nature of science recommended by science educators (e.g., Duschl, 1990; Hodson, 1988; Smith, Lederman, Bell, McComas, & Clough, 1997), science philosophers (e.g., Kuhn, 1996), and recent science education reform documents (e.g., American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). These aspects will now be discussed.

Scientific knowledge is subject to revision
Scientific knowledge is inferential
Scientific knowledge is theory-driven and subjective
Scientific knowledge involves human inference, imagination, and creativity
Scientific knowledge is socially and culturally embedded
Scientific work is a cooperative and collaborative activity
Scientific theories and laws are different in nature and function
Scientific inquiry is not represented by "The Scientific Method"

Figure 2.1. The aspects of nature of science (based on Lederman, 2004)

Scientific knowledge is subject to revision.

Even though scientific knowledge is durable, it is never absolute or certain (Lederman, 2004; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). When new evidence is found against existing knowledge, as a result of conceptual and technological advances, or old evidence is reinterpreted in the light of a new advanced theory, existing knowledge can be altered (Lederman, 2004). Further, uncertainty of scientific knowledge is observed because it is inferential, subjective, creative and culturally embedded in its nature.

Scientific knowledge is inferential.

Although scientific knowledge is "derived from, and/or consistent with observations of natural phenomena" (Abd-El-Khalick, et al., 2008, p. 838), it is also inferential in nature. "Observations are descriptive statements about natural phenomena that are 'directly' accessible to the senses (or extensions of the senses)" (Lederman, 2004, p. 304). For example, if we release an object above ground level, we can observe its tendency to fall and hit the ground. On the other hand, the object tends to fall to the ground due to gravity, which is not accessible to our senses and "can *only* be accessed and/or measured through its manifestations of effects" (Lederman, 2004, p. 305, emphasis in original). Thus, the idea of gravity is inferential.

Scientific knowledge is theory-driven and subjective.

Scientists are human and hold biases (Laugksch, 2000). Aspects of the background of scientists, such as theoretical knowledge, training, experience, commitments, religious or other beliefs, political convictions, sex and ethnic origin can form a mindset (Lederman, 2004), which may influence them in what they observe (and do not observe) and how they interpret the observations (Kuhn, 1996). Observations help get answers to the questions derived from within certain theoretical perspectives, which guide how the observational data is interpreted (Hodson, 2008).

Scientific knowledge involves human inference, imagination, and creativity.

Science is not a completely "rational or systematic activity" (Abd-El-Khalick, et al., 2008, p. 838). Despite having an empirical basis of scientific knowledge, it involves scientist's imagination and creativity (Lederman, 2004). For example, the concepts of atoms, black holes, force fields and species are not faithful copies of reality, rather they are functional theoretical models as a result of integrating the creative nature of science and its inferential nature (Abd-El-Khalick, et al., 2008).

Scientific knowledge is socially and culturally embedded.

Science is a human enterprise embedded and practised in society (Abd-El-Khalick, et al., 2008); therefore, science affects and is affected by different cultural elements, such as social values, power structures, politics, socio-economic factors, philosophy and religion (Lederman & Lederman, 2004). Influence of these factors can be observed by the mechanism of public funding for scientific research.

Cooperation and collaboration are important in science.

Scientific work is a collaborative and collective activity (Lederman, 2004; Osborne, et al., 2003). Although individuals may make significant contributions, scientific work is often carried out in groups. New knowledge claims are generally shared and must go through a double-blind peer review process to be accepted by the scientific community.

Scientific theories and laws are different in nature and function.

Scientific laws are “statements or descriptions of the relationships between observable phenomena”, while scientific theories are “inferred explanations for observable phenomena” (Lederman, 2004, p. 305). A theory often answers the ‘why’ question; for example, Boyle’s law predicts the behaviour of the pressure of a gas to its volume at a constant temperature, but this law cannot explain why it happens. The kinetic molecular theory can explain this prediction. Moreover, a theory is much more complex and dynamic as it presents the inferred explanations, and it often includes a law(s). For example, in Einstein's theory of relativity, gravity plays a crucial role. In this theory, the basic law of gravity is intact, and the theory expands it to include various and complex situations involving space and time. It is noteworthy that theories and laws are supported by empirical data, are regarded as different kinds of knowledge and one does not become the other (Abd-El-Khalick, et al., 2008). However, there are myths that after being empirically tested a hypothesis becomes a theory (Haidar, 1999), and when enough supporting evidence is accumulated, theories become laws (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000). Similarly, there is a myth about scientific inquiry as explained below.

Scientific inquiry is not represented by "The Scientific Method".

The myth set out in the label "The Scientific Method" is often manifested in the belief that there is a recipe-like stepwise procedure followed in all scientific inquiry. However there is a general agreement among academics that no single "scientific method" would guarantee the development of scientific knowledge (Abd-El-Khalick & Lederman, 2000b; Abd-El-Khalick, et al., 2008; Bell & Lederman, 2003; Lederman, 2004; McComas, Clough, & Almazroa, 1998). Also, there is no single sequence of practical, conceptual, or logical activities that will accurately lead to valid claims in developing scientific knowledge (Abd-El-Khalick, et al., 2008). Moreover, there is a belief that only experimental research characterises scientific inquiry. However, scientific inquiry may take other forms, such as descriptive and correlational studies (Lederman, 2004). Scientific questions guide the approach employed in getting answers to the questions and the approaches vary widely within and across scientific disciplines.

2.4.2 Historical development of the idea of scientific literacy.

During the 1960s the term "scientific literacy" started to be used by many science educators and science education reform organisations (e.g., NSTA in the USA) as an expression of overall purpose of science education (Bybee, 1997). Consequently, several initiatives were undertaken clarifying the term and synthesising the various aspects encompassing the term. P. Johnson (1962) discussed the goals of science education in relation to the need for developing scientific literacy and provided a conceptual frame for scientific literacy on the basis of "knowledge that is much broader than mastery of detailed information" (p. 239). P. Johnson added a dimension of values (e.g., curiosity, accuracy of observation and interpretation, and open-mindedness) to the knowledge dimension of scientific literacy and argued that these values must be founded on knowledge. Considering knowledge and values, as P. Johnson stated, a scientifically literate person

> will be curious about the how and why of materials and events. He will be genuinely interested in hearing and reading about those things that claim the time and attention of scientists, and his interest will not be lessened by unwelcome ideas and events. He may never *create* any ideas pertaining to science, but he will be *conversant* with the ideas that are being considered in the intellectual marketplaces of the world. (P. Johnson, 1962, p. 239, emphasis in original)

Pella, O'Hearn, and Gale (1966) synthesised the meanings of scientific literacy used by the science education community in the 1960s. They devised a framework of six "referents", which were assumed in advance to be related to scientific literacy, and determined the frequency of occurrence of those referents in 100 systematically selected papers published between 1946 and 1964. In summary, they characterised a scientifically literate individual as one with an understanding of the (a) interrelationships of science and society, (b) ethics that control the scientist in his work, (c) nature of science, (d) basic concepts in science, (e) differences between science and technology, and (f) interrelationships of science and the humanities. Based on the frequency of occurrence of these referents in the literature Pella et al. further claimed that to achieve scientific literacy, knowledge of the first three aspects was more important than of the latter three.

By the mid-1970s, the science education community consistently referred to scientific literacy as a purpose of science education (Bybee, 1997). For example, Agin (1974) proposed three purposes of science education: (a) prepare future scientists, (b) prepare technological professionals, and (c) prepare scientifically literate citizens. Using a triangular model to represent the proportion of the general population, he argued that the third purpose should be represented in the largest part of the triangle, which suggested his argument for the greater emphasis to be placed on preparing scientifically literate citizens. Moreover, Agin (1974) viewed scientific literacy as a process of growth and argued that people at an early age may not understand the interrelations among the domains of science knowledge, science processes, and society; rather "as they become more mature, they should become increasingly aware of the interrelatedness of these domains" (p. 414). A notion of this process of growth for scientific literacy may also be seen in the US science education reform document, National Science Education Standards (NSES) (National Research Council [NRC], 1996).

The NSES published by the National Research Council in the USA, described a vision to build a scientifically literate society and presented criteria for science education to achieve the vision (NRC, 1996). Unlike another science education reform document in the USA, i.e., the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993), the NSES included less content and argued that less content could be taught better. The Standards defined the level of understanding and the abilities that all students – regardless of background, future aspirations, or interest in science – should develop "for personal decision making, participation in civic and cultural affairs, and economic productivity" (p. 22). This notion of scientific literacy was further elaborated as follows:

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (NRC, 1996, p. 22)

Whilst the above definition of scientific literacy entails a number of abilities, it is argued that development of the abilities should be seen as a process of growth that "expands and deepens over a lifetime" with different degrees and forms (NRC, 1996, p. 22). In order to enable students to cope with the process, the NSES focused on developing the values and attitudes through the early years of science education that would help shape a student's development of scientific literacy as an adult. This notion of scientific literacy could also be seen in the multi-level scientific literacy framework proposed by Bybee (1995, 1997) as outlined below.

Bybee (1997) proposed a four-level framework for scientific literacy, of which the lowest two levels are "nominal" and "functional" scientific literacy. Nominal scientific literacy consists of a minimal knowledge of names and terms from general areas of science, which may often represent "a misconception, naive theory, or inaccurate concept" (Bybee, 1997, p. 84). Functional scientific literacy refers to using scientific vocabulary in limited contexts, for example, defining a scientific term on a test and following a media report on science.

The third level of the framework, "conceptual and procedural" scientific literacy, refers to demonstrating "an understanding of both the parts and the whole of science and technology as disciplines" (p. 85). In addition, this level includes abilities and understandings relating to the procedures and processes of scientific inquiry to be used in scientific problem solving. Using a DNA example, Koballa, Kemp, and Evans (1997, p. 28) illustrated this level of literacy as an ability to decide "whether the experimental procedures used to pin DNA down as the genetic material (putting a DNA-destroying enzyme into a cell) were properly done".

The top level of the framework, "multidimensional" scientific literacy, "consists of understanding the essential conceptual structures of science and technology as well as the features that make that understanding more complete, for example, the history and nature of science" (Bybee, 1997, p. 85). In addition, as Bybee argued, multidimensional literacy includes an understanding of the relationships among science, technology and society. Using the DNA example of Koballa, et al. (1997, p. 28), this level of literacy could be exemplified as an understanding of "how the scientific culture of the 1940s could ignore the work of Barbara McClintock, who showed early on that certain pieces of DNA 'jump' from one chromosome to another". This example demonstrates the role of understanding the history and nature of science to understand the influence of human culture on science and science's influence on human culture.

In discussing the implications of this multi-level framework, Bybee (1997) argued that developing scientific literacy is a "lifetime task" and therefore, "some will develop further than others at all levels or within one, depending on their motivation, interests, and experiences" (p. 85). Acknowledging Bybee's (1997, p. 85) claim that this framework is "complex and comprehensive", Roberts (2007, p. 742) viewed it as "very much an idealised, complete and comprehensive universe of meanings [of scientific literacy] from which curriculum developers can choose". As a result, this framework has been used in recent scientific literacy assessment programmes, for example, in the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA).

The PISA framework of scientific literacy was based on Bybee's 'conceptual and procedural' level and the assessment was aimed at placing students along a continuum of development within this level (Fensham & Harlen, 1999). In defining scientific literacy (for this level), it is considered in the PISA 2006 assessment as the mental processes that are involved in addressing scientific issues, the knowledge that is required in using these processes, the situation in which these processes can be applied, and the attitudinal aspects of students' responses in using their knowledge and processes. Considering these aspects PISA defines scientific literacy as referring to an individual's:

> • Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
>
> • Understanding of the characteristic features of science as a form of human knowledge and enquiry
>
> • Awareness of how science and technology shape our material, intellectual, and cultural environments
>
> • Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen
>
> (Organisation for Economic Co-operation and Development [OECD], 2006, p. 23)

For assessment purposes, this definition was characterised as consisting of four interrelated aspects: context, knowledge, competencies, and attitudes. OECD's rationale for including these aspects is summarised as follows:

Context: The PISA framework acknowledged that whatever the scientific knowledge and processes students needed to know, they would have to be consistent with the student's world, which PISA calls context. Context was defined as situations relating to the personal, social and global life in five areas of application: health, natural resources, environment, hazard, and frontiers of science and technology.

Knowledge: In the PISA framework, scientific knowledge referred to two types of knowledge: one is *knowledge of science*, which includes the fundamental scientific concepts, laws, theories (etc.), and the other is *knowledge about science,* which includes the epistemological aspects of science, largely known as the 'nature of science'. Importantly, science knowledge was not considered as context free or isolated, rather this knowledge is embedded in different contexts. Eventually, PISA assessed students' "ability to actively use knowledge in new situations" rather than their "passive stores of knowledge" (Fensham, 2009, p. 885).

Competencies: The PISA framework included three competencies, which students needed to demonstrate in science-related situations: identifying scientific issues, explaining phenomena scientifically, and drawing evidence-based conclusions. It was argued that these competencies are neither concept-free nor decontextualised. Students would show these competencies in a science-related situation and they would require both *knowledge of science* and *knowledge about science*. It was also argued that these competencies are broad and include aspects that relate to personal utility, social responsibility, and the intrinsic and extrinsic value of scientific knowledge. In assessing these competencies, the PISA framework included issues "to which scientific knowledge can contribute and which will involve students, either now or in the future, in making decisions" (OECD, 2006, p. 22).

Attitudes: The PISA framework included attitudinal aspects of students' responses to scientific issues. Students' attitudes were assessed in three areas: interest in science, support for scientific inquiry, and responsibility towards resources and environment (OECD, 2006, p. 35).

A close correlation of the scientific literacy conception of PISA could be found in some other prominent literature in Australia (Goodrum, et al., 2001) and in the UK (Nuffield Curriculum Centre, 2002). For example, in researching the status and quality of science teaching and learning in Australian schools, Goodrum et al (2001) defined scientific literacy as

> the capacity for persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well being. (p. 15)

In a very similar way, in the UK, the project *21st Century Science* defined scientific literacy as some abilities of a person to: appreciate and understand the impact of science and technology on everyday life; take informed personal decisions about things that involve science, such as health, diet and use of energy resources; read and understand the essential points of media reports about matters that involve science; reflect critically on the information included in, and (often more important) omitted from, such reports; and take part confidently in discussions with others about issues involving science (Nuffield Curriculum Centre, 2002).

A closer look at the two definitions above, suggests that scientific literacy requires more than having science knowledge; rather scientific literacy requires being an informed user and consumer of science knowledge for informed decision making in science related issues.

The discussion on the historical development of the idea of scientific literacy as summarised above exposes the debate among the science education community about operationalising the meaning of scientific literacy. Some literature (e.g., AAAS, 1993) emphasises the learning of science content to being scientifically literate, while some (e.g., NRC, 1996) emphasises the development of values in the early years of science education, which may influence students' development as informed users and consumers of science knowledge for informed decision-making in science-related everyday issues, and eventually, may shape their development of scientific literacy as an adult. Based on this summarised view of scientific literacy, the conceptual understanding of scientific literacy used in this research is presented.

2.5 Conceptual Understanding of Scientific Literacy

As described in the previous sections, there is a tension among the science education community about setting the primary purpose of science education between preparing future science professionals and preparing scientifically literate citizenry. This tension is reflected in formulating educational policy that eventually influences educational practice to promote scientific literacy. An implication of such policy and practice is well articulated in Roberts' (2007) notion of Vision I and Vision II approaches, and therefore has shaped the conceptual understanding of scientific literacy I used in this research.

2.5.1 Roberts' Vision I and Vision II approaches.

Roberts (2007) created a heuristic framework to track the different meanings attached to scientific literacy. His framework is a continuum between two extremes, which he called Vision I and Vision II. At the one extreme, Vision I starts with the products and processes of science for science teaching and learning. These products and processes of science are then exemplified by situations or contexts in which science may have a role. In this manner, contexts are used as add-ons to traditional academic content that is often abstract and is not connected to immediate applications. The other extreme, Vision II, starts with situations or contexts, and then reaches into science to find the relevant content. In this manner, Vision II focuses on the context in which science is embedded rather than considering the science content in isolation. This Vision II aims "to enculturate students into their local, national, and global communities" (Aikenhead, 2008, p. 1). Table 2.2 illustrates the practices of these two Visions in relation to scientific literacy.

As Table 2.2 shows, in Vision I, science curriculum is designed for the students who wish to take a science-related career; content mostly comes from pure academic sciences, and is often irrelevant to the students' lives and abstract in nature; learning is more teacher-centred. In contrast, in Vision II, as for many other school subjects, science curriculum is designed to enculturate students into their local, national, and global communities; content is mostly applied in students' life contexts and thus is functional in nature, and learning is student-centred. Providing students with everyday contexts for learning science, the Vision II approach helps students continue and sustain this learning along their entire life (Roth & Barton, 2004) and has a strong influence on the use of their science knowledge (Layton, Davey, & Jenkins, 1986).

Table 2.2

Vision I and Vision II Approaches

Vision I	Vision II
Curriculum is aimed to educate the future scientific community (pre-professional training)	Curriculum is aimed to enculturate students into their local, national, and global communities
Content is often abstract and is not connected to immediate applications	Content has obvious need to function effectively in everyday life
Learning science occurs through direct transfer of science content to students from teachers or prescribed curriculum materials	Learning science occurs as a result of placing learners at the heart of instructional exchanges
Students find difficulty in relating science to their everyday lives	Students find the relevance of science for their everyday lives

Note: The concepts in this table were drawn from Aikenhead (2008) based on Roberts (2007).

In discussing the implication of these two visions, Aikenhead (2008) argues that a Vision I approach results in a traditional academically oriented school science curriculum, which provides assessment based education on a narrowly defined scientific literacy. While this approach can be a way of promoting scientific literacy if one defines scientific literacy in a Vision I manner, as indeed many curriculum developers and teachers of senior physics and chemistry seems to do, defining scientific literacy in this manner is largely critiqued in science education literature (e.g., Roberts, 2007; Aikenhead, 2008). In this sense, Aikenhead (2008) argues that a Vision I approach results in little scientific literacy achieved by the students along with decreased enrolment in science. A Vision II approach, on the other hand, "seeks to enhance students' capacities to function as life-long, responsible, savvy participants in their everyday lives" (Aikenhead, 2008, p. 1), and hence can promote scientific literacy to a reasonable degree. Whilst a Vision II approach is sounder to promote scientific literacy, in an extensive review of curricula to determine whether and how they might nurture scientific literacy, Roberts (2007) could identify only two curriculum examples that were clearly based on a Vision II approach. These include the *21st Century Science* in the UK (Nuffield Curriculum Centre, 2002; Ratcliffe & Millar, 2009) and a Grade 10 science course in the Netherlands (De Vos & Reiding, 1999). The reason for this minimum adoption of Vision II approaches includes the influence of political power in education, which often contradicts educational soundness (Aikenhead, 2006). For example, due to power politics, the Vision II oriented science course in the Netherlands finally adopted a *science-oriented approach* at the implementation level, which eventually failed to demonstrate the principles of a Vision II approach and acted like a Vision I oriented course (De Vos & Reiding, 1999).

As a result, school science education worldwide traditionally follows the Vision I approach. As Roberts (2007) pointed out, such a Vision I approach does not include Vision II, however, a Vision II approach "subsumes Vision I" (p. 768). Hence the most realistic approach to meeting the dual purpose of science education (i.e., preparing future science professionals and preparing scientifically literate citizenry) is, as Aikenhead (2008) seems to have dubbed, Vision I-II, which is a balance between the two extremes. There is evidence of science curricula that follows the Vision I-II approach, as for example, the *National Science Education Standards* in the USA (Roberts, 2007). Such a curricular orientation tends to satisfy the dual purpose of science education within a common curriculum as in Bangladesh (NCTB, 1995). Satisfying the dual purpose within a common curriculum can be perceived to be conflicting with each other as reported by Fensham (1985) and Millar (1996, 2008), while some do not find conflict between these two (e.g., Goodrum, et al., 2001). Goodrum et al. argued that if it is possible to provide an exciting, interesting and relevant science education to all students in school, then more students might be expected to study further science and to engage in a science related career. In addition, life-oriented, relevant science education might provide them with the science knowledge to use in science-related everyday decision making.

2.5.2 Science knowledge for scientific literacy.

Experts in science education agree that students must have some science knowledge to be scientifically literate (e.g., AAAS, 1989, 1993; Bybee, 1995, 1997; Chiappetta, Fillman, & Sethna, 1991; Millar, 1996; Miller, 1983; NRC, 1996; OECD, 2006; Osborne, 2007; Pella, et al., 1966; Shamos, 1995) and this knowledge must be understood and applied in contexts that individuals come across in everyday life (Bybee, Fensham, & Laurie, 2009).

Science knowledge is important for both intrinsic and instrumental justifications as suggested by Millar (1996). Intrinsic justification refers to cultural aspects, i.e., scientific knowledge can help people satisfy their curiosity about the natural world, which is also very important in learning (Howes, 2001; G. Murphy, 2009). On the other hand, the instrumental justification refers to the utilitarian aspects, that is, scientific 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). Instrumental justification may also include the importance of science knowledge in following public discussions on science-related issues (Miller, 1983).

Whilst both of these justifications suggest promoting science knowledge that has relevance to, and importance in students' everyday decision-making as well as helping to satisfy their curiosity about the natural world around them (i.e., aims consistent with

Vision II scientific literacy), a case may still be made for academic science knowledge (e.g., structure of atom). This academic science knowledge may not have immediate application in students' everyday lives but may have importance in accommodating some students wishing to study further in science and to take a science related career. Thus it is argued that in a common curriculum for all students, for example, in Bangladesh (NCTB, 1995), the curriculum orientation could adopt a Vision I-II approach. In a Vision I-II curriculum orientation, it is not intended that the pure content disappears, but is argued that the curriculum needs to have more emphasis on science knowledge that has relevance to, and importance in students' everyday lives (Aikenhead, 2008). Such an emphasis may help students to become informed users and consumers 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 the conclusions;
- to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately; and
- make informed decisions about the environment and their own health and well being.

(Summarised from Goodrum, et al., 2001; NRC, 1996)

However, people's choice of action is formed by the values they pose (Tan, 1997) and therefore, their decision-making is often guided by their values (Rennie, 2005, 2007). Values have therefore been considered as an important facet of scientific literacy (Graber et al., 2001; Koballa, et al., 1997; Organisation for Economic Co-operation and Development [OECD], 2006) and are discussed below.

2.5.3 Values for scientific literacy.

Since scientific literacy is perceived as related to the making and evaluating of decisions and arguments, values, therefore, are crucial for the conceptions of scientific literacy in this research and have been defined as

> principles, fundamental convictions, ideals, standards or life stances which act as general guides or as points of reference in decision-making or the evaluation of beliefs or action and which are closely connected to personal integrity and personal identity. (Halstead, 1996, p. 5)

The junior secondary General Science curriculum in Bangladesh states five values to be fostered: open-mindedness, rational thinking, respect for others' opinions, intellectual honesty, and curiosity (NCTB, 1995, p. 354). This research focuses on these five values. Whilst there may be other values that could be considered, for example, Hodson and Reid (1988b, p. 106) listed 17 values to be incorporated in school science curricula for designing appropriate learning experiences, these five should be represented in any science endeavour, including in the science classroom. Moreover, these values might be viewed as important in making decisions and arguments, and therefore as important for scientific literacy as explained below.

Hare (2009) argued that promoting open-mindedness requires 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 argument. Also, open-mindedness requires a person to consider all available alternatives (Hare, 2009); additionally, rational thinking would help this person to choose among the alternatives (Tan, 1997), and help him/her to reach an informed decision or a conclusion (Hare, 1979). Moreover, an individual's willingness to communicate a consistent conclusion based on evidence is associated with the value of intellectual honesty (APEID, 1991b).

Despite holding such a reasoned view, however, the open-minded person recognises the unavoidability of diversity in people's ideas and beliefs (Hare, 2009), and thus respects others' right to hold or express their own opinions or views. In this sense, the values of open-mindedness and respect for others' opinions are very much related to each other. It may appear from the above discussion that the five values considered in this research may influence people to use science knowledge in making and evaluating decisions and arguments and therefore, are important for scientific literacy. However, it is important to understand the meaning of these values more deeply.

2.5.3.1 Open-mindedness.

Open-mindedness refers to a consideration of alternative ideas and proposed solutions to an issue (Hare, 2009) that one may not have previously entertained (Loughran, 1994). Open-mindedness, therefore, is the willingness to change one's mind in the light of new evidence as well as willingness to suspend judgment if there is insufficient evidence (Hildebrand, 2007; Hodson & Reid, 1988a). This notion of open-mindedness is inherent in the revisionary nature of science, which suggests that scientific knowledge is never absolute or certain; rather it is always open for revision (Lederman, 2004; Osborne, et al., 2003). Moreover, open-mindedness may facilitate an understanding of subjectivity in science, which acknowledges that different scientists can have different conclusions after interpreting the same data because of their different commitments, training, knowledge and experiences (Lederman, 2004). Thus it would be reasonable to argue that if teachers consider and appreciate subjectivity and the revisionary nature of science in teaching, students may also appreciate keeping their minds open to accept new or different ideas. As possible manifestations of open-mindedness in the science classroom, Siddique (2010) suggested that science teachers show a willingness to accept students' alternative conceptions and not to present science or any other knowledge or source of knowledge as absolutely true but rather as an acceptable view.

2.5.3.2 Respect for others' opinions.

Respect for others' opinions may refer to one's admiration for others' right to hold or express their opinion. This notion of respect acknowledges the notion of diversity in people's ideas and therefore, could be seen as associated with the notion of open-mindedness. Thus respect for others' opinions might be manifested in the science class through encouraging students to present their views and ideas and encouraging them to respect their counterparts' views and ideas in classroom discussion or any group activity. This value could be seen as very important in this diverse world, because if there is less respect for the diversity of opinions and ideas, this may lead powerful people to force their opinions and ideas on everyone else. Therefore, APEID (1991b) suggested that promoting people's freedom to express ideas should be a concern of science education. This notion of respect for others' opinions further encourages the democratic rights of people and thus may contribute to the democratic well-being as discussed previously.

2.5.3.3 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). As noted previously, the importance of rational thinking is that it helps people evaluate alternative ideas and reach an informed conclusion based on their evaluation. This notion of rational thinking can be manifested in science classrooms by encouraging students to be involved in arguments, debate and deductive reasoning (Siddique, 2010).

2.5.3.4 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). Curiosity leads people to ask questions and seek answers, which also lead to new questions to explore (Osborne, et al., 2003). This notion of curiosity may be manifested in science classrooms through encouraging students to raise 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 inquiring 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 allow for sufficient 'wait time' for students and listen carefully to students' responses. Wait time provides the opportunity for student reflection whilst listening to students' responses helps teachers understand the thinking behind the responses, which eventually helps teachers ask follow-up questions to extend students' thinking.

2.5.3.5 Intellectual honesty.

In APEID's (1991b) report, intellectual honesty has been described as one of the "great human virtues and indispensable factors for the healthy growth of knowledge" (p. 62). As discussed in this report, the notion of intellectual honesty may consist of different levels: an honest reporting of observed facts and phenomena (e.g., an experiment) may constitute the primary level; higher levels of intellectual honesty may consist of "an honest reporting of opinions, views and preferences, if these impinge upon ones [sic] personal belief" (p. 62) and avoiding fabrication and intentional interpretation of data to suit one's beliefs. Intellectual honesty also involves the practice of recognising and acknowledging contributions made by other people.

Intellectual honesty can be manifested in science classrooms through encouraging students to communicate a consistent conclusion based on the evidence. For example, in order to promote intellectual honesty teachers may encourage students to report results from an activity (e.g., an experiment) honestly rather than report the correct result by manipulation, which is a common practice in the teaching-learning context in Bangladesh (Siddique & Rahman, 2007). It would be reasonable to consider that promotion of intellectual honesty could challenge this practice in Bangladesh.

2.5.4 A summary of conceptual understanding of the meaning of scientific literacy.

An overview of the discussion above suggests that since Vision II can include Vision I, but the reverse is not necessarily so, the most realistic approach to meeting the dual purpose of science education (satisfying the need for both a future science study group and scientific literacy for all) is Vision I-II. This Vision I-II orientation could provide a life-oriented and relevant science education to all students that would encourage more students to study further in science and engage in a science related career. Providing such life-oriented and relevant science education could help students become informed users and consumers of science knowledge where values would play a vital role. However, the choice among these Visions (Vision I versus Vision I-II) in practice may determine the teaching approaches for promoting scientific literacy as discussed in the next section.

2.6 Teaching for Scientific Literacy

The most important factor in improving the students' learning is the teacher (Goodrum, et al., 2001), who plays a vital role in promoting scientific literacy. This section reviews the literature dealing with teaching approaches for promoting scientific literacy and the associated challenges, which teachers may encounter in adopting such approaches.

2.6.1 Teaching approaches to promote scientific literacy.

Goodrum (2004, 2007) argued that if there is a commitment to teach for scientific literacy then there are some expectations about the way the science is taught in classrooms. These expectations are outlined in Table 2.3.

The aspects in Table 2.3 on which Goodrum suggests less emphasis should be placed are related to a Vision I practice, while the aspects to be given more emphasis are related to a Vision I-II practice. For example, Goodrum suggested that if teachers intend to promote scientific literacy, they need to place less emphasis on memorising textbook-dependent abstract science content, recipe-like activities, individual assignments, lecture and demonstration methods, and grading-oriented summative assessment. Such an emphasis on memorising abstract science content in a teacher-dominated and textbook-oriented teaching-learning context suggests a Vision I practice. On the other hand, as Table 2.3 illustrates, Goodrum's suggested emphasis on presenting science content as relevant and applicable to students' everyday life in a multiple resource based teaching-learning context could be seen as aligned with a Vision I-II practice.

Table 2.3

Teaching for Scientific Literacy

Teaching for scientific literacy requires:	
less emphasis on	more emphasis on
science being interesting for only some students	science being interesting for all students
covering many science topics	studying a few fundamental concepts
theoretical, abstract topics	content that is meaningful to the student's experience and interest
presenting science by talk, text and demonstration	guiding students in active and extended student inquiry
asking for recitation of acquired knowledge	providing opportunities for scientific discussion among students
individuals completing routine assignments	groups working cooperatively to investigate problems or issues
activities that demonstrate and verify science content	open-ended activities that investigate relevant science questions
memorising the name and definitions of scientific terms	learning broader concepts that can be applied in new situations
learning science mainly from textbooks provided to students	learning science actively by seeking understanding from multiple sources of information, including books, internet, media reports, discussion and hands-on investigations
assessing what is easily measured	assessing learning outcomes that are most valued
assessing recall of scientific terms and facts	assessing understanding and its application to new situations, and skills of investigation, data analysis and communication
end-of-topic multiple choice tests for grading and reporting	ongoing assessment of work and the provision of feedback that assists learning

Source: Goodrum (2004, p. 57).

Table 2.3 also illustrates Goodrum's suggested assessment practices in teaching for scientific literacy. The importance and challenges of different types of assessment practices in science education are discussed extensively in the science education literature (Black, 1993, 2005; Black & Wiliam, 1998; Duschl & Gitomer, 1997; Orpwood, 2001). For example, Black (1993) criticised the traditional pencil-and-paper-based summative assessment practice and suggested teachers consider formative assessment practices that would focus on assessment for learning. In a similar vein, Goodrum (2004) suggested teachers place more emphasis on formative assessment over summative assessment in teaching for scientific literacy.

A central tenet of teaching for scientific literacy is that it needs to be student-centred (Goodrum, et al., 2001). Thus, learning science needs to be occurring as a result of placing learners at the centre of any instructional exchange. In order for students to become such active learners, teachers may need to employ a great deal of creativity to arrange the learning environment (Chiappetta & Koballa, 2006). For such learning environments teachers are suggested to take an 'inquiry-based approach' where students would have opportunities to be involved in reaching evidence-based conclusions (AAAS, 1989; Goodrum, et al., 2001; Trowbridge, Bybee, & Powell, 2004). Yet these activities need to be conducted within a context that is relevant to students' everyday lives (Goodrum, et al., 2001).

Linking students' everyday lives and interests with science was accorded attention in the *Science in Schools Research Project* in Victoria, Australia (Department of Education Employment and Training [DEET], 2001). In this project, it was suggested that teachers can demonstrate the linkage of science with students' lives and interests by bringing students' personal interests into science classroom (e.g. exemplifying science in sports, music etc.), using various popular media and using science fiction in presenting science content. Tytler, et al. (2008) suggested that students' science learning along with their interest in science may be stimulated through certain activities, such as going on study tours, participating in science competitions and science fairs, engaging in various science projects, and belonging to a science-related club.

Teachers, therefore, are suggested to use a wide variety of teaching approaches (Millar & Osborne, 1998). Various teaching approaches, including question-answer, discussions, debate, group work, study tours and science projects can provide opportunities for students to "interact with each other in a variety of ways to provide feedback to each other, to develop their learning skills, and to practice the language and culture of science" (Goodrum, et al., 2001, p. 20). However, as in many other Asian contexts, for example, Vietnam (Ng & Nguyen, 2006), in Bangladesh teachers mostly use transmissive teaching approaches, such as lecturing (Gomes, 2004). In addition, teachers in Bangladesh only occasionally engage students in group discussion (Gomes, 2004). This group discussion approach is suggested to be useful in promoting scientific literacy (AAAS, 1989; Solomon, 2001) and, in particular, in providing students with opportunities to exercise values such as respect for each others' opinions and open-mindedness.

As teaching for scientific literacy requires the substantial engagement of students, the *Science as Story* approach, which presents science to students as a number of key explanatory stories (Millar & Osborne, 1998), may also be a useful teaching approach for scientific literacy. Fensham (2001a) argued that this could be a powerful approach in the teaching of science in both developed and developing countries. He argued that behind every advance in science there is a human story that can enhance people's interest and engagement in science:

> The story of the deciphering of the double helix structure of DNA by Watson and Crick in the 1960s was as exciting as any detective story. When Mary Curie's life story and her struggle to isolate the new element radium was published and then made into a film it inspired a generation of young women in the 1940s to enroll for scientific studies. (Fensham, 2001a, p. 2)

Another plausible approach to enhance students' engagement in science is the *Case Study* approach, which would also be useful in promoting scientific literacy (Millar, 2008). As Millar argued, case studies are valuable in providing contexts for science knowledge as well as providing opportunities for discussion and debate in science classrooms. He stated that,

> [such] discussion can increase students' motivation to come to terms with abstract ideas and specialist terminology, and acts as a powerful reminder of the links between taught science ideas and the issues one hears about outside school. … [This discussion also helps students] realise that everyone is entitled to have and to express a view about such issues, but that views are more persuasive when they are grounded in sound understanding of the underlying science and follow established patterns of argumentation. (Millar, 2008, p. 13)

Learning to make arguments in science classes may also be useful in promoting certain values, as for example, rational thinking as discussed previously. In this manner, along with providing contexts for learning science and engaging students, case studies can also be useful in promoting values according to Allchin (1999) and APEID (1991b).

Teaching approaches to promote scientific literacy as presented in the contemporary literature have been reviewed and presented in this section. However, adopting the suggested approaches is not a straightforward matter; rather, teachers often encounter challenges in adopting such approaches. These are discussed below.

2.6.2 Challenges in teaching.

As an approach to promote scientific literacy, Vision I-II suggests more student engagement in teaching-learning processes. To enhance student engagement, as discussed previously, science educators suggest teachers adopt inquiry-based approaches. However, research reveals that many issues may challenge teachers in adopting inquiry-based approaches. For example, Zhang et al. (2003) reported the pressure on Chinese teachers to prepare students for the college level entrance exam as the major stumbling block in this regard. In China, traditionally, exam scores are used in determining students' eligibility for college entry, so, there is tremendous pressure on teachers to ensure students' eligibility. As the exams have traditionally assessed students' memorisation ability rather than students' performance in science inquiry, both teachers and students have placed emphasis on memorising science content and showed reluctance in adopting science inquiry approaches and strategies. Other issues that have challenged Chinese teachers in adopting inquiry approaches have included large class size and limited resources (Zhang, et al., 2003). Similar issues were also perceived by Indian teachers as impacting on their teaching practice, which is often quite different to their teaching orientation (Nargund-Joshi, et al., 2011). Moreover, similar kinds of issues are also present in science teaching in Bangladesh as mentioned in Section 1.3. In this context research has revealed how an exam-driven education system and large class sizes with insufficient resources persuade teachers to adopt transmissive teaching approaches and hinder student engagement in science classes (e.g., APEID, 1991a; Holbrook, 2005; Tapan, 2010).

The lack of an existing culture to conduct inquiry-based lab activities in Bangladesh could also serve to restrict student engagement. In most cases, recipe-like activities are conducted in schools where students engage in verifying the result of the lab activities

(Siddique & Rahman, 2007). Siddique and Rahman also reported that teachers emphasise the 'correct' result rather than how the data are collected and reported. This practice could motivate students to report the 'correct' result by manipulation, and this in turn may hinder their opportunity to develop certain values, such as intellectual honesty.

As scientific literacy has many facets – for example, knowledge, skills and values – teachers need to deal with all of these. But research (Collette & Chiappetta, 1989) claims that many science teachers deal only with science concepts or facts and neglect the other important aspects of scientific literacy. For example, teachers often face difficulties in teaching values explicitly (Ratcliffe, 2007). In a recent study in Bangladesh, Siddique (2010) also found that science teachers struggle to teach values in science classes. Ratcliffe (2007) argued that the sole emphasis on scientific knowledge in science curricula and assessment practices may be a possible reason for this difficulty. As a result, the value-free representation of science has often failed to foster students' recognition and understanding of the values of science (Thelen, 1983, 1987).

Moreover, most science teachers are equipped for teaching through their own education in the academic sciences, where theoretical science knowledge was emphasised rather than the application of science in a everyday world (Fensham, 2009). As most science teachers do not have direct experience of either scientific research or investigating problems of the everyday world (Fensham, 2009), they may lack science knowledge involved in everyday world applications (King, 2007; Roehrig, Kruse, & Kern, 2007). With this lack of knowledge teachers may also lack interest and motivation to find ways in which to help students see the applications of science in their everyday world (Tapan, 2010) as this has not been part of their own science experiences. In a review of science education in Bangladesh, Tapan has suggested that lack of interest and motivation coupled with lack of functional science knowledge reinforces science teachers' tendency to teach in the same way they had been taught when they were students. Moreover, because of the existing assessment culture, achieving good marks in the exams is regarded as the hallmark of a successful student and teachers also enjoy recognition through this kind of student success. In such a culture, it may be natural that teachers fail to see the value of helping students learn by exploring the applications of science in their everyday world.

However, given the teachers' challenges in teaching for promoting scientific literacy, it is reasonable that if scientific literacy is seriously advocated as a goal of school science education, teachers need to meet the challenges they encounter. If teachers have the capacity to overcome the challenges, their teaching practice may help shape more positive experiences of science classes for students. The next section presents a review of the literature on students' perceived experiences of science classes in school.

2.7 Students' perceived experiences of school science.

As students are generally the focus of educational improvement or change, their voices should be heard; their perceptions of the significance, relevance and usefulness of school science are important. Reiss (2000) claims that the success of school science depends on students' belief that what they are taught in school is of worth to them in their everyday lives. This belief in their ability to use science in everyday life is an integral component of scientific literacy. Thus, if scientific literacy is intended to be promoted in the curriculum and is implemented in classrooms, a reflection of how it has been implemented should be able to be found in students' accounts of their experiences.

Whilst students' views on their school science experiences have been the subject of intensive research in the last decade (Bennett & Hogarth, 2009; Darby, 2005; Jenkins, 2005; Jenkins & Nelson, 2005; Lindahl, 2003; Lyons, 2006a, 2006b; Osborne & Collins, 2001; Sjøberg & Schreiner, 2005), there is limited research exploring students' perceived school science experience from a scientific literacy perspective. Nevertheless, the research relating to students' views on their school science experiences conducted in a variety of educational contexts may provide some important insights for this research, and therefore, are discussed in this section.

Much of the research on students' views on their school science experiences has focused particularly on the early years of secondary education, which is equivalent to junior secondary level in Bangladesh. The reason for this particular focus may be because this is the period when students' dispositions to pursue science subjects and careers in science are formed (Osborne & Collins, 2001; Speering & Rennie, 1996; Tytler, et al., 2008) and their views of science are highly impacted by their science teachers (Osborne & Collins, 2001). Therefore, how teachers teach science at the level of junior secondary education in Bangladesh could be seen as a contributing factor to how the students perceive their school science experiences.

Attitudes, interests and out-of-school experiences of secondary students were explored in the *Relevance of Science Education (ROSE)* project, which involved over 30 countries, including Bangladesh (Schreiner & Sjøberg, 2004). This study showed that in the developed countries, science is less popular than most other school subjects, especially to girls, while in the developing countries such as Bangladesh, students viewed school science much more positively as they viewed science as a vehicle of social mobility (Sjøberg & Schreiner, 2005). A recent quantitative study in Bangladesh (Sarkar & Bhowmik, in press) has also reported Bangladeshi students' overall positive views towards school science and science outside school. In addition, this study has reported that students hold a much more positive view towards science outside school than towards their school science.

In the UK, Bennett and Hogarth (2009) developed and used the *Attitudes to School Science and Science* questionnaire to explore students' views about school science and science outside school. Adapting the Views on Science-Technology-Society (VOSTS) approach (Aikenhead & Ryan, 1992), this questionnaire explored students' views regarding school science through their responses to science lessons, individual subjects within science, teacher effects and the importance of science in the curriculum. At the same time, the questionnaire explored students' views of science outside school through their responses to science as presented in the media, reading about science, careers in science, the misrepresentation of science, and personal and impersonal responses to science. This study found that students viewed their school science experience less positively than science outside school. Such less positive views to school science are also reported in the same context in a detailed qualitative study by Osborne and Collins (2000a, 2000b, 2001) as presented below.

Osborne and Collins (2000a, 2000b, 2001) qualitatively explored 16-year-old students' views about the kinds of scientific knowledge, skills or understandings they need for dealing with everyday life, interesting and valuable aspects of the curriculum, and desirable future curriculum content. Osborne and Collins argued that as their research sought insights into the experiences, views and beliefs of pupils, the data required were essentially qualitative; and they adopted the method of focus groups. This study elicited the following key findings of the students' perspectives:

- Though science is a prestigious and important subject to students for their career aspirations and to be considered educated individuals, they find difficulty in making connections between school science and their everyday lives.

- Science curriculum is content-dominated, overloaded and examination-driven, with too much repetition and too little challenge for students. Much of the science content (particularly from chemistry) is abstract and irrelevant to contemporary needs and their everyday lives. For many such topics, students perceive the instrumental value is only for passing an exam. Moreover, this curriculum requires too much copying and provides few opportunities for discussion.
- Amongst the sciences, biology has more relevance to personal life. Topics on astronomy and space, and contemporary scientific and socio-scientific issues are found interesting by all students.

Osborne and Collins argued that students' school science experiences as summarised above, are the product of a content-dominated and examination-driven curriculum. As students' exam scores are regarded as a determinant of school achievement and teacher competence, an overloaded content-dominated curriculum leads teachers to rush their students through the science disciplines. In such a classroom, students are often involved in simply copying science ideas that the teacher presents. This teacher-centred practice often fails to make a connection between school science and students' everyday lives (Osborne & Collins, 2000b), and as a result students find difficulty in relating school science to their lives. As discussed previously, this practice seems to be aligned with a Vision I approach, which is at odds with engaging students with science in everyday life.

Australian students also had similar kinds of experiences of their school science (e.g., Goodrum, 2006; Goodrum, et al., 2001; Lyons, 2006b; Rennie, Goodrum, & Hackling, 2001; Rosier, Banks, & Australian Council for Educational Research, 1990). For example, Lyons (2006b) found three major aspects that characterise Australian students' perceptions of school science, as reported below.

1. Transmissive pedagogy: Students viewed school science as a teacher-centred and content-dominated subject, in which they passively receive science content transmitted from expert sources.
2. Decontextualised content: Students mostly viewed the school science content as irrelevant to everyday life and boring.
3. Unnecessarily difficult: Based on their own experience of junior physical science courses and from the comments by teachers, parents, seniors and peers, students anticipated senior physics and chemistry courses as being difficult.

Lyons (2006a) further examined the implications of these similar experiences of school science reported by students in Australia (Lyons, 2006b), the UK (Osborne & Collins, 2000a, 2001) and Sweden (Lindahl, 2003). As Lyons argued, students' experience of school science as teacher-centred content transmission may have a number of consequences for students' engagement with science: first, many students may not perceive this transmissive approach as good for understanding science concepts; second, this approach may frustrate students regardless of whether they think the topic itself interesting, and third, this approach leaves a narrow scope for in-depth discussion among students. Further, such transmissive pedagogy, by implication, suggests teachers adopt a teacher-directed laboratory environment as evident in many educational contexts (Fraser, 1994; Goodrum, et al., 2001) including Bangladesh (Siddique & Rahman, 2007). Such teacher-directed laboratory environments may fail to sustain students' interest in science practical activities (Braund & Driver, 2005; Cleaves, 2005).

Moreover, unengaging, decontextualised science curriculum lacks the capacity to make school science meaningful in students' everyday lives (Lyons, 2006a) and may result in declining student interest in science (Aikenhead, 1996; Aikenhead, Barton, & Chinn, 2006; Fensham, 2006; Leach, 2002; Logan & Skamp, 2008). It seems that these experiences reported by Lyons (2006a), which students have encountered in school science, are consistent with a Vision I practice, which is not conducive to promoting scientific literacy in a manner that emphasises engaging students with science in everyday life (Aikenhead, 2008; Roberts, 2007).

2.8 Chapter Summary

This chapter has discussed the theoretical issues underpinning this study. Specific attention has been paid to discussing the purposes of school science education and conception of scientific literacy to be used in this study. In addition, how teachers can teach to promote scientific literacy, what issues may challenge their teaching approaches and how students perceive their experiences in science classes have also been discussed. This discussion will be used as a basis to explore the major research question and subsidiary questions as outlined in the previous chapter. While the methods used in this exploration will be described in Chapter 4, Chapter 3 will look at the curriculum context for science education in Bangladesh, which provides the context for this study.

CHAPTER 3

Curriculum Context for Science Education

3.1 Introduction

This chapter provides an account of the curriculum context for science education at the junior secondary level in Bangladesh. As a centralised curriculum guides the teaching-learning activities in school, an exploration of the curriculum sets the context of this study seeks to identify how scientific literacy is promoted through junior secondary science education in Bangladesh. Various aspects of the curriculum in Bangladesh are described, justifying the focus on a particular representation of the curriculum (i.e., textbooks) for a detailed analysis. The subsequent sections present the analytical framework used in this analysis and the results in relation to the different emphasis on content that appeared in the textbooks as a representation of the curriculum.

3.2 Science Curriculum at the Junior Secondary Level

In Bangladesh, school curriculum is governed by a centralised body – the National Curriculum and Textbook Board [NCTB] (Ministry of Education, 2000). The NCTB was formed in 1983 by merging the Bangladesh School Textbook Board and the National Curriculum Development Centre with the aim of making the curricula and syllabi increasingly relevant in the context of national and global changes. In 1995, NCTB revised the curriculum for the junior secondary education level and published an official curriculum report. Textbooks and the teacher's guides based on this curriculum report were available for students and teachers from 1997.

3.2.1 Official curriculum report.

In the official curriculum report for the junior secondary level (NCTB, 1995), "General Science" has been recommended as a compulsory course for all students. As noted previously, whilst this course is prescribed to be an integrated course, in practice the course does not consider arranging the content according to any integrated theme. Rather, it includes chapters/ units focused on exclusive subject areas in a particular discipline (e.g., physics). Table 3.1 is an example of how the course deals with the subject area, "Electricity", to include the Specific Objectives, Learning Outcomes and respective Content.

Table 3.1

Specific Objectives, Learning Outcomes and Content for the Unit "Electricity" of Grade VIII

Specific Objectives	Learning Outcomes	Content
Become informed about the units of electric pressure, charge and electric flow Understand and gain experience about electric pressure and electric flow Gain knowledge and understanding about electric circuits Gain knowledge about home electrification	Learners will be able to – define electric pressure, electric flow, charge and resistance mention respective units of electric pressure, electric flow, charge and resistance use voltmeter and ammeter in measuring electric pressure and flow describe what parallel and series circuits are and how are they connected describe the merits and demerits of parallel and series circuits in home electrification define alternating current (AC) and direct current (DC)	Electric pressure, electric flow, charge and respective units of these Measurement of electric pressure and electric flow – ammeter and voltmeter Electrical resistance and its units, units of electrical power and energy Electric circuits – parallel and series circuits Alternating current (AC) and direct current (DC) Home electrification

Table 3.1 (continued)

Specific Objectives	Learning Outcomes	Content
Understand the uses of electricity	describe the sources of alternating current and direct current and uses of them in day-to-day life	Uses of electricity – electric bell, iron, lights, fans
	explain the uses and importance of a fuse, switch, circuit breaker and earth wire describe why electrical accidents may occur and how they can be prevented	Electrical accidents, preventive measures, importance of a fuse, switch, circuit breaker and earth wire
	describe construction and working procedures of some electric appliances used in day-to-day life (electric bell, iron, lights, fans)	

Source: NCTB (1995, pp. 386, 393, 399-400, my translation)

Table 3.1 illustrates how Specific Objectives relating to electricity have been divided into Learning Outcomes and the Content that has been intended as focus for learners to achieve the Learning Outcomes. The teacher's guides, prepared for the General Science course provide suggestions for teachers on how they can teach to achieve the Learning Outcomes.

3.2.2 Teacher's guides.

There is one teacher's guide for the General Science course, published by the NCTB, for each of the grades from VI to VIII. At the very beginning of each of the teacher's guide, some guiding principles are given as "General Directions", which teachers are suggested to follow in teaching science. How teachers are expected to teach the specific chapters is then articulated. Each of the chapters is divided into several lessons, where one lesson is designed for one class period. Teaching-learning strategies including assessment techniques are presented for every lesson.

Whilst the official curriculum report and the teacher's guides are supposed to be sent to every school in the country, there is evidence that these teacher's guides are not sent to many schools (Tapan, 2010). Also, there is little evidence to suggest that in practice teachers have access to them or use them in preparation for teaching. For example, as a science teacher educator, I observed that very few of the student-teachers in my class (many of them were in-service teachers) were informed about the official curriculum report or the teacher's guides. In addition, the official curriculum report and the teacher's guides were prepared in 1995 and 1997 respectively, and no revision or modification has been carried out to date. In contrast, textbooks have been revised and refined a number of times since 1997. As a result, in many cases, gaps are found between the official curriculum report, teacher's guides and textbooks. For example, "Creative Questions" have been incorporated in the textbooks from 2009, but this incorporation is not suggested by the official curriculum report and no guidance or suggestions for teachers appear in the teacher's guides in this regard. In this sense, textbooks could be considered as an updated version of the curriculum in Bangladesh.

3.2.3 Textbooks.

NCTB prepares one textbook for each of the grades, and each textbook is published in two languages: one in Bengali, the state language in Bangladesh, and the other in English for the schools that follow English as the medium of instruction. The Bengali version of textbooks are used by most of the students and teachers in Bangladesh (Rahman, 2011). The existing embedded practice of using textbooks in Bangladesh suggests that textbooks could be considered as the "de-facto curriculum" in

Bangladesh. Siddique (2007, 2008) also reinforces this notion of textbooks as the de-facto curriculum for the following reasons.

While textbooks can play a vital role in the teaching and learning of school science (Chiappetta & Koballa, 2006; Collette & Chiappetta, 1989; Wellington, 2001), in many cases teachers can rely too much on the assigned textbooks (Chiappetta, Fillman, et al., 1991). In Bangladesh, teachers tend to rely on this single textbook as the official curriculum suggests that "the teacher has to read the textbook content well before teaching in the classroom" (NCTB, 1995, p. 401, my translation). The provision of a single textbook often means that students also rely heavily on this single textbook in learning science (Holbrook, 2005). Students are assessed by the items taken from the textbook (Holbrook, 2005), and tests often demand answers to be copied from the textbook (Holbrook & Khatun, 2004, cited in Siddique, 2007). Such an approach reinforces the need for teachers and students to rely almost exclusively on this recommended textbook. Therefore, an analysis of science textbooks provides a good context for exploring how scientific literacy is promoted through junior secondary science education in Bangladesh.

3.3 Science Textbook Analysis

As noted earlier, in practice, it is common that a Vision I-II orientation of scientific literacy is used to emphasise the content that has more relevance in students' everyday lives (Aikenhead, 2008). In contrast, an emphasis on pure academic content, which characterises a Vision I orientation, may challenge students in drawing links between the science they study in school and their everyday lives, and would thus also challenge the promotion of scientific literacy (Aikenhead, 2008). This textbook analysis, therefore, has focused on exploring whether the content in the textbooks has been presented as relevant to students' everyday lives. For this analysis, a structured, document analysis approach was adopted and Bailey's (1978) framework was used with modifications.

3.3.1 Framework to analyse the emphasis on content: Bailey's framework.

Bailey (1978) developed and used a framework to explore shifts in emphasis of chemistry curricula in Victoria, Australia for the period of 1932–1972. Later Corrigan (1999) adapted the framework to examine the shifts in emphasis of chemistry curricula in the same region for the period of 1973–1998 in her doctoral thesis. More recently Siddique (2007) modified this framework and applied it to identify the changes in priorities in the proposed secondary science curriculum as compared to the existing curriculum in Bangladesh. This framework as used by Siddique was considered appropriate for this analysis.

In Bailey's (1978) framework, the "product" dimension was referred to as "the set of assertions or knowledge statements (laws, theories, hypotheses, definitions, facts, etc.) generated by the scientific process" (p. 12). In this dimension, science content was classified into two components: pure content and socially applied content, which together form opposite ends of a continuum. Within the socially applied content there were two sub-dimensions in Bailey's original framework – industrial versus domestic application in one dimension, and social ideology in the other. Domestic and industrial applications of science referred respectively to how science is linked with the learner's own life and how science is linked with the learner as s/he is a member of the broader community, while the sub-dimension "social ideology" shows how science is portrayed as interacting with society. The sub-dimension of industrial application (e.g., production of steel) referred to content relating to industrial production and is related to the "wider community of the learners" (Bailey, 1978, p. 13), where the "wider community" may refer to people beyond the learners' family and peer groups. On the other hand, the content of the domestic applications sub-dimension is more directly related to the life of the learners – for example, hardness of water. In the analytical frame for this research, these sub-dimensions appeared quite limiting given the study's focus on promoting scientific literacy. For example, the Programme for International Student Assessment [PISA] (OECD, 2006) considers broader contexts that seem more appropriate and have been adopted and included, replacing both industrial and domestic application of science content due to the following reasons.

In the PISA study, context is characterised by two aspects: life situations and areas of application of science. Three life situations of learners have been considered: personal life (relating to the self, family and peer groups), social life (relating to the community), and global life (relating to life across the world). These three life situations represent life situations of the learners as self (personal life) and as a member of the "wider community" (social and global life). Also, the PISA contexts cover a wide range of possible areas of application that learners might encounter, such as "health", "natural resources", "environment", "hazards", and "frontiers of science and technology". These areas of application of science have particular importance to individuals and communities in promoting and sustaining quality of life and in the development of public policy (OECD, 2006). So the PISA framework for contexts is broader than industrial and domestic applications of science only and also encompasses better representation of the communities within which science operates. I have, therefore adopted PISA contexts in the present analytical framework as in Figure 3.1 replacing Bailey's (1978) industrial and domestic application of science content.

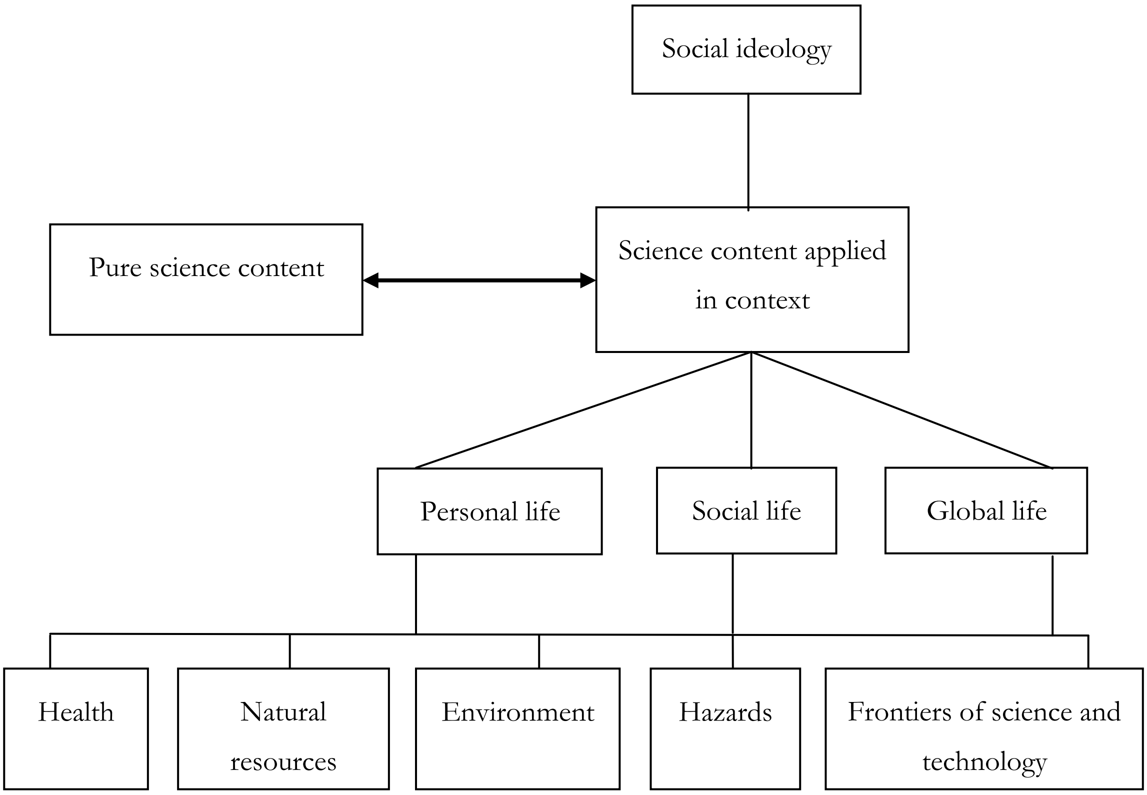

Figure 3.1. The analytical framework used in textbook analysis (modified from Bailey, 1978, p. 12)

Another sub-dimension of socially applied science content in Bailey's (1978) framework, "social ideology", is characterised by the effects of science and technology on the society. These effects can be either to improve the quality of human life by solving problems, or to decrease the quality by leading to problems. For example, science has saved many lives by inventing effective medicines and treatments against various diseases. This may indicate the positive social ideology of science. On the other hand, CFC is one of the agents responsible for ozone layer depletion, which may cause various health hazards, such as skin cancer, cataracts and eye problems (World Health Organization [WHO], 2008). Such an effect can be regarded as the result of a negative social ideology of science. Since science is highly related to society, the sub-dimension social ideology is very significant in this framework and thus this sub-dimension appears unmodified in Figure 3.1.

3.3.2 Using the analytical framework.

This section discusses how the analytical framework described in Section 3.3.1 was used to analyse the junior secondary textbooks in Bangladesh. In particular, Section 3.3.2.1 describes the use of the framework for making judgments about the nature of the content while Section 3.3.2.2 further extends the understanding of how to make judgments about the emphases placed on content in different contexts as represented in the target textbooks in Bangladesh.

3.3.2.1 Making judgments about the representation of content.

In a science textbook, content can be classified into two types:

- pure science content, e.g., facts and principles of science (I have termed this Type I content)
- content with potential to be applied in everyday life (I have termed this Type II content)

Examples of each type of content are illustrated in Table 3.2. Based on this classification of content, in this analysis, units/ chapters in the General Science textbooks were classified into two categories:

- Category A type units (units having an emphasis on Type I content)
- Category B type units (units having an emphasis on Type II content).

The purpose of this categorisation is to determine the emphasis placed on content in a textbook unit/ chapter, which consequently will help determine the overall emphasis in a whole textbook. Table 3.3 exemplifies how judgments about these categories of the units were made.

Table 3.2

Representative Textbook Excerpts Corresponding to the Judgment Made about the Content

Content	Illustrative quote from the textbook	Rationale for judgment
Type I content	Take a big glass flask. Close it with a cork. Insert a narrow glass tube through the cork. Drop into the tube a few drops of coloured water. You will see that the drops of water go down through the tube a little and come to rest at a point … in the tube. Now rub your hands several times to make your palms hot and hold the flask tightly in your hands. You will observe that the coloured drops of water have gone up to a point … [higher than the previous point]. This is because heat from hands made the air inside the flask hot. As the hot air expands in volume, the drops of water go up to make room for the expanded gas. The expansion of gaseous substance is much higher than the expansion of a solid or liquid for the same amount of increase in temperature. (Shamsuddoha, Miah, Ohab, Khan, & Chowdhury, 2008, p. 9, my translation)	This 'recipe-type' experiment illustrates how an expansion in gases occurred due to the heat. There is no discussion in the textbook about the purpose or importance of learning this content. As well, no application of this content, thermal expansion of gases, is presented in the textbook although it could be. For example, this content could start with illustrating a scenario that in the very hot summer, tyre pressure in the wheels of a motor car is often suggested to be kept lower than the pressure in the winter as hot roads in the summer may cause air inside tyres to expand and there may be a danger of the tyre bursting. The conception of the higher expansion in gases could thereafter be presented. Further, an application of the expansion in gases as compared to solids and liquids could be exemplified through presenting the idea of a gas thermometer. Therefore, it seems that such possible applications of this content were overlooked in presenting the topic in the textbook.
Type II content	Boiling water for 20/25 minutes after filtrating mud, clays and insoluble floating substances can kill the germs in impure water. Boiled water prepared in such a way is safe for drinking. However, it is important that the boiling container should be cleaned and then dried by heating. This method of purifying water is suitable, dependable and cheaper for obtaining drinking water. (Shamsuddoha, Miah, Ohab, & Khan, 2008, p. 43, my translation)	The discussion may provide students with knowledge about a method of water purification that can be used in purifying impure water at home. Use of such purified water may help students keep away from possible health hazards that may result if the non-purified water were used. This knowledge would reasonably be seen as important in Bangladesh where there is a challenge to ensure people's access to suitable drinking water (Government of Bangladesh, 2005).

Table 3.3

Making Judgments about the Categorisation of a Textbook Unit

Unit Category	Rationale for judgment
Category A unit	The unit "Magnets" in the Grade VII textbook mostly deals with Type I content (pure content), such as magnetic induction, magnetic field, magnetic lines of force and neutral points. An example of such Type I content (concept and properties of magnetic lines of force) is illustrated in Table 3.1. More than four pages of this five-page unit are dedicated to presenting such Type I content. In addition, this unit includes some Type II content (for example, a brief discussion on the uses of magnets in different appliances, such as in a microphone, speaker and dynamo; uses of these appliances in everyday life). However, such Type II content is presented as add-ons to the Type I content and was represented in only about quarter of a page of this unit of five pages in total. This unit, therefore, was judged to be a Category A type unit.
Category B unit	The unit "Water" in the Grade VI textbook was judged to be a Category B type unit. This unit covers a total of five pages in the textbook. About three and a half pages of them are dedicated to presenting Type II content, such as the importance of water in everyday life, different sources of water, causes and prevention of water pollution and naturally occurring methods of water purification. The importance of this knowledge to all people is emphasised in the textbook clause, "the other name of water is life" (Shamsuddoha, Miah, Ohab, & Khan, 2008, p. 39, my translation), and everyday life situations are considered in the presentation of content. In addition to such Type II content, a portion of this unit (about two pages) deals with Type I content, such as the properties of the constituents of water (hydrogen and oxygen) and method of decomposing the constituents of water. No attempt to relate this knowledge with everyday life is made in the textbook. For example, this unit does not include a discussion on how this knowledge may be applied in a desalination plant. However, since Type II content, in terms of page coverage, covers the majority of space of this unit, it was reasonable to consider this unit a Category B type unit.

3.3.2.2 Making judgments about the emphases on content applied in everyday life.

In this analysis, dimensions of the content applied in context (Figure 3.1) were rated following the same scheme that Bailey (1978) used in his research. Bailey rated each of the dimensions except "social ideology" in his framework on a Likert-type five-point scale: *very weak*, *weak*, *moderate, strong,* and *very strong*. Social ideology was rated on a three-point scale: *positive, neutral*, and *negative*. In a very similar way to that used by Bailey, the emphases in each of the dimensions and their associated components were determined through rough estimations made by

- counting the number of times aspects appeared in the textbooks; and
- if a particular unit or section was dedicated to a particular aspect.

However, I concur with Corrigan's (1999) argument that the position of a curriculum on a scale can only be determined with moderate precision since there is unavoidable heterogeneity in the materials used to make the estimations. Thus it is acknowledged that in this analysis, the emphases in the different dimensions and their associated components have been judged with moderate precision. Some examples are given below of how a judgment was made about the content applied in a particular context. The first and second examples illustrate how particular aspects were judged to have *very strong* and *very weak* emphasis respectively. Examples of the two extreme ends of the scale provide an idea of how judgements for the other points of the scale were made. The third example illustrates how a judgment was made regarding social ideology.

Example 1: Health related knowledge has been presented in at least six units (about 25%) of the Grade VII textbook. Knowledge in these units has been presented to be useful for the learners to maintain their personal health. Much of this knowledge has been presented within the social and global contexts. For example, knowledge of controlling dysentery was presented as important in a Bangladeshi context by emphasising that dysentery is a very common disease in Bangladesh. Similarly, the spread of infectious diseases like AIDS has been presented as a global issue in the textbook by saying: "*the entire human civilization* is facing a severe threat because of AIDS – a deadly disease"(Shamsuddoha, Miah, Ohab, Khan, et al., 2008, p. 185, my translation, emphases added). A discussion is presented on how AIDS is a concern for the human population as members of a global community and how the effects of AIDS can transcend borders and be shared among diverse human societies. This textbook, therefore, has been judged as placing a very strong emphasis on various life situations (personal, social and global) in the area of "health".

Example 2: The Grade VI textbook has not included any exclusive unit regarding the area of "frontiers of science and technology". This textbook has mentioned some technological products (e.g., tractor, power tiller and hydroelectric plant) without considering student's personal, social and global contexts. They have been presented as isolated information rather than something relevant to students' life situations. The Grade VI textbook, therefore, has been judged as having very weak emphasis on various life situations (personal, social and global) in the area of "frontiers of science and technology".

Example 3: The Grade VIII textbook has been judged as positive regarding social ideology. A number of instances in this textbook illustrate how science contributes in improving the quality of human life by solving problems. Here is a textbook excerpt in this regard:

> The contribution of science is enormous in protecting health, in preventing premature death, in attaining sound physique and prolonged longevity. With the advancement of medical science, severe infectious

> diseases such as malaria, cholera, small pox, plague etc. have almost been eliminated from the world. ... Prevention of diseases like measles, whooping cough, polio, diphtheria and tetanus has also been possible with the invention of vaccines. (Shamsudduha, Miah, Wahab, Khan, & Morshed, 2008, p. 117, my translation)

In this textbook, there is no example of how science may decrease the quality of human life by leading to problems. This textbook, therefore, has been judged as positive regarding social ideology.

Using the analytical frame as described in this section, this textbook analysis elicited the following results.

3.4 Results from the Textbook Analysis

Results from this analysis have been presented in two sections. The first section examines whether the textbooks under study have generally placed emphasis on "content applied in context" that may be applicable in everyday life, while the second section presents the rating assigned to different aspects of "content applied in context".

3.4.1 Emphasis on pure content versus content applied in context.

Figure 3.2 illustrates the percentages of Category A and Category B type units appeared in the textbooks from Grades VI to VIII. It is seen that all of the textbooks from Grades VI to VIII included primarily Category A type units. This finding may indicate that in general terms the analysed textbooks mostly emphasised the academic content and theoretical aspects of science and were not connected to students' everyday lives. This emphasis on academic content as manifested in Bangladeshi science textbooks concurs with what has been observed in some science textbooks in many educational contexts, for example, in the USA (Chiappetta, Sethna, & Fillman, 1991), Australia

(Wilkinson, 1999), Canada (Orpwood & Souque, 1985) and the UK (C. Murphy, Beggs, Hickey, O'Meara, & Sweeney, 2001). Such observations can be quite dated, for example, Orpwood and Souque's (1985) textbook analysis was undertaken more than two decades ago. This suggests that science textbooks in Bangladesh still follow a dated orientation emphasising the academic content. Such an emphasis could be considered as consistent with a Vision I orientation (Roberts, 2007), which may reinforce the notion to students that the science they learn in school has concentrated on the concepts of science in ways that may suggest they have limited importance and relevance in everyday life (Aikenhead, 2008).

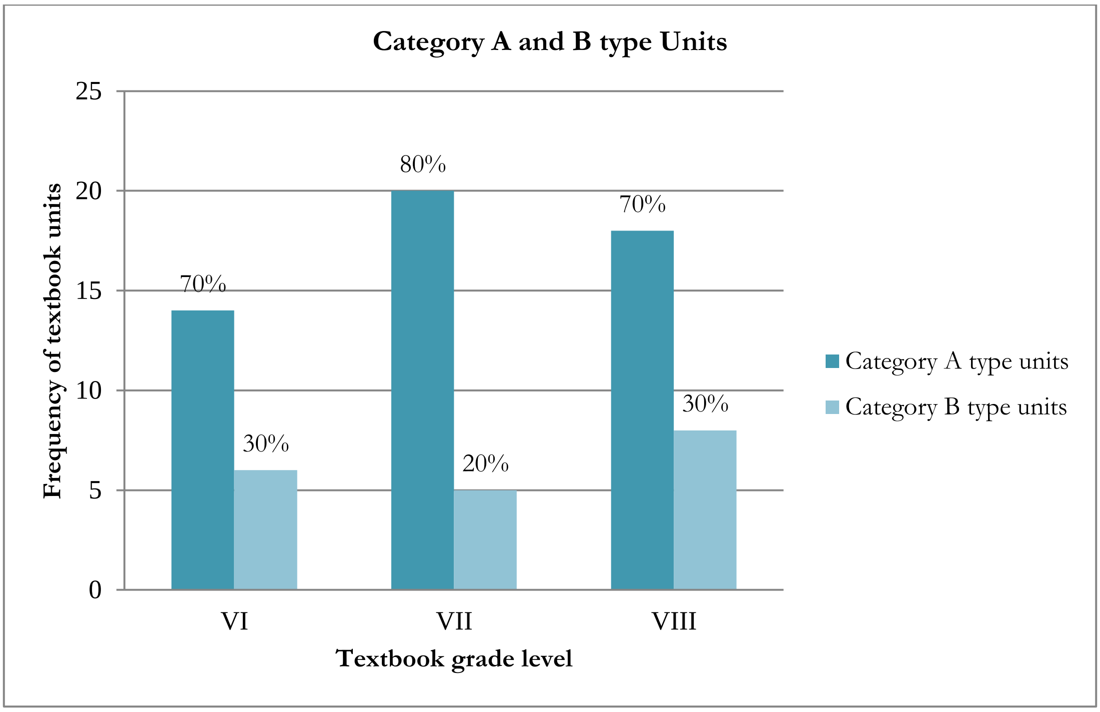

Figure 3.2. Percentages of Category A and Category B type units

Whilst science textbooks in this analysis have generally emphasised content that is mostly academic and irrelevant to students' everyday lives, more specifically they have also included content that may be applicable in everyday life. For example, 30% of the units of both the Grades VI and VIII textbooks and 20% of the units of the Grade VII textbook were deemed Category B type units as they emphasised content that may be applicable in students' everyday lives. The next section presents the rating of the emphases placed on different aspects of such content.

3.4.2 Representation of different life situations and application areas of science.

A comparative analysis of how different life situations and application areas of science have been emphasised in the analysed textbooks is summarised in Table 3.4 below. Relative emphasis on these aspects (life situations and application areas of science) was determined through estimations made by counting the number of times aspects appeared in the textbooks and if a particular unit or section was dedicated to a particular aspect.

As seen in Table 3.4, the areas "health" and "environment" were accorded a higher consideration in the textbooks as there were a number of units dealing exclusively with health and environment related content. Some other units also have included health and environment related content. For example, in addition to dedicating two units to health related content, some other units of the Grade VIII textbook also included such content. Much of this content was presented as related to students' personal life (e.g., hygiene to maintain personal health), social life (e.g., social influences such as peer pressure associated with drug use and addiction and the social transmission of infectious diseases) and global life (e.g., AIDS has been presented as a global issue). Similar life situation examples, which could be encountered in students' life situations, were also found for the content related to the area "environment". Thus, consideration of all of the three life situations in these textbooks' presentation of content in the areas of "health" and "environment" may help students see the applications of health and environment related science knowledge in everyday life. This could be seen as particularly important in the context of Bangladesh, where science textbooks play a vital role in developing students' ideas of science.

Table 3.4

Relative Emphasis on Science Content Applied in Context

Areas of application	Grade	Personal life	Social life	Global life	Social ideology
Health	VI	Very strong	Very strong	Very strong	Grade VI: Positive Grade VII: Positive Grade VIII: Positive
	VII	Very strong	Very strong	Very strong	
	VIII	Strong	Strong	Strong	
Natural resources	VI	Weak	Weak	Weak	
	VII	Moderate	Moderate	Weak	
	VIII	Strong	Strong	Moderate	
Environment	VI	Strong	Strong	Strong	
	VII	Strong	Strong	Strong	
	VIII	Strong	Strong	Moderate	
Hazard	VI	Weak	Weak	Very weak	
	VII	Strong	Strong	Moderate	
	VIII	Strong	Strong	Moderate	
Frontiers of science and technology	VI	Very weak	Very weak	Very weak	
	VII	Moderate	Very weak	Very weak	
	VIII	Moderate	Weak	Very weak	

In contrast to the areas of "health" and "environment', the area of "natural resources" did not receive much attention, particularly in the Grades VI and VII textbooks. Content related to natural resources appeared in them very few times and none of these textbooks included an exclusive unit dealing with such content. The Grade VIII textbook, while including one exclusive unit on natural resources, did not indicate how the discussion on natural resources could help students make decisions about their everyday actions. For example, a discussion on renewable (e.g., solar cell) and non-renewable (e.g., coal and mineral oil) energy resources could contribute to students' awareness of the consumption and conservation of energy resources in a sustainable way. Since people often encounter issues related to consumption and conservation of the energy resources in personal, social and global life (OECD, 2006), excluding such discussion in the textbook may hinder students from responding effectively to related issues encountered in life.

Among the five areas, "frontiers of science and technology" received the least attention in the Grades VI and VII textbooks; none of them included discussion on scientific and technological applications in life, nor did they provide an exclusive unit dealing with such content. The Grade VIII textbook, while including an exclusive unit titled "science and technology in everyday life" with some content on the function and use of some technological applications (e.g., radio, TV, computer) in everyday life, has not represented many other aspects of this area, for example, music and personal technology, sports and leisure, genetic modification, weapon technology, extinction of species or exploration of space. As suggested in the OECD-PISA report (OECD, 2006), people encounter these aspects in contemporary personal, social and global life and therefore it would be desirable that students were familiar with these aspects if they are to deal with them in any capacity such as in decision-making. Therefore, it could be argued that in excluding such aspects, the analysed textbooks have failed to create a comprehensive idea about science and technology in contemporary life.

In a similar vein, the analysed textbooks have failed to create a comprehensive idea of science in terms of social ideology. The textbooks, in this analysis, only considered the positive social ideology of science through portraying the role of science to improve the quality of human life. This portrayal in the textbooks could help students think of science in a positive way. However, none of the textbooks, in this analysis, has presented how science can decrease the quality of life by leading to problems. As science has both positive and negative effects while interacting in society, exclusion of the negative effects and the limitations of science, and portrayal of only the positive aspects could represent an incomplete picture of science that may eventually lead to students developing unrealistic expectations of science.

3.5 Chapter Summary

This chapter presents an analysis of science textbooks used at the junior secondary education level in Bangladesh. The purpose of this textbook analysis was to set a curriculum context for exploring how scientific literacy is promoted through school science education in Bangladesh where textbooks are considered the “de-facto” curriculum, setting priorities for the classroom teachers and playing a vital role in developing students’ ideas of science. The analysis shows that textbooks mostly emphasise content that is academic in nature and not connected to students’ everyday lives. Moreover various application areas of science are not well-considered in presenting content in the textbooks. In a textbook-dependent education system, these results serve as a base to explore teachers’ perspectives of scientific literacy, their teaching approaches and the challenges they experience in their efforts to promote the curriculum aims. The methods used in this exploration are discussed in the following chapter.

CHAPTER 4
Research Methodology

4.1 Introduction

This chapter discusses the methodology used in this research, where "methodology" is defined as "the overall approach to research" (Mackenzie & Knipe, 2006, p. 198). As Mackenzie and Knipe have commented, the approach includes "systematic modes, procedures or tools used for collection and analysis of data" (p. 198). Thus the chapter describes how a number of data collection procedures and analytic techniques were used in different phases of this research. The chapter also explains how issues relating to credibility and ethics were addressed in the overall research process.

4.2 Research Questions

As expressed earlier, this research aims at exploring the major research question of how scientific literacy is promoted through junior secondary science education in Bangladesh. In order to do this, four subsidiary research questions have been framed:

RQ 1. How do teachers perceive scientific literacy?

RQ 2. How are teachers' perspectives of scientific literacy translated into classroom teaching?

RQ 3. What values do teachers consider in relation to scientific literacy and how are they considered in science classes?

RQ 4. What issues do teachers perceive as challenging in their teaching for scientific literacy?

4.3 Research Design

4.3.1 Philosophical worldview.

Research design is guided by the philosophical assumptions or beliefs the researchers hold about the world (Creswell, 2007), which guide them in thinking and in taking actions. Accordingly, this study will be guided by the set of beliefs that I have about the world indicating my philosophical worldview. I believe that realities are "socially constructed" (Mertens, 2005, p. 12). We construct our own understanding from an event. This understanding is subjective and hence varies from person to person (Creswell, 2009). Moreover, these constructions are alterable as they are open to new interpretations as information and sophistication of understanding improves (Guba & Lincoln, 2004). According to Guba and Lincoln, knowledge is created through interaction amongst the researcher and participants. The researcher's goal is to understand the multiple social constructions that the participants hold, thus research "must employ empathic understanding of those being studied" (Tashakkori & Teddlie, 2003, p. 705). I strongly espouse these views, which are also consistent with the views associated with the constructivist research paradigm. Thus my worldview for this research has been a constructivist one, aimed at building an understanding of teachers' perspectives of scientific literacy, translation of their perspectives into classroom teaching, the values they consider in their teaching for scientific literacy and the issues they perceive as challenging in their teaching. In order to do so, I listened carefully to and observed the practices of my research participants. In tune with my constructivist worldview, I developed a research approach that would permit exploration of teachers' perspectives, practices and challenges along with opportunities to consider how these have been shaped.

4.3.2 Research approach.

My constructivist worldview suggests I should consider either a qualitative approach or an approach combining qualitative and quantitative methods (see, Mackenzie & Knipe, 2006), since these approaches help researchers understand the multiple social constructions that the research participants hold. However, often a more complete picture of human behaviour and experience could be constructed by using a combination of qualitative and quantitative methods within a research study (Gay, Mills, & Airasian, 2006; Morse, 2003). It was therefore assumed that a mixed methods approach could give more complete and sophisticated understanding of the research problem.

In this research, a mixed methods approach has been adopted, where both quantitative and qualitative data were collected and used to shed light on the research problem and provide responses to the research questions in an appropriate manner. However, the demands of the research questions led this research to adopt a “dominant/less dominant status design” (Creswell, 2009; Creswell & Plano Clark, 2007; Tashakkori & Teddlie, 2003) with the domination of qualitative methods. Qualitative dominant mixed methods research has been defined as

> the type of mixed research in which one relies on a qualitative, constructivist-poststructuralist-critical view of the research process, while concurrently recognizing that the addition of quantitative data and approaches are likely to benefit most research projects (B. Johnson, Onwuegbuzie, & Turner, 2007, p. 124).

This research first employed a questionnaire to gather responses from a number of teachers teaching the General Science course at the junior secondary education level in Bangladesh. The questionnaire data (largely quantitative in nature) were used to gain an overview (I have termed this a "macro view") of teachers' perspectives, practices and challenges in their teaching for promoting scientific literacy. The questionnaire data were further used to select appropriate participants to invite to be involved in the detailed qualitative part of this research. In the process of this qualitative phase, six teachers' science classes were considered as six cases for gaining an in-depth understanding (I have termed this a "micro view") of the research problem, using qualitative methods, such as interviews with teachers, lesson observations and focus group interviews with students. The rationale for considering multiple cases is that individual cases would share some common and contrasting characteristics that would provide an in-depth understanding of the research problem (Stake, 2005, 2006; Yin, 2003).

In the case studies, I conducted a pre-lesson semi-structured interview with each participant to explore his/her perspectives of scientific literacy and the values he/she considered pertinent to scientific literacy. Then I acted as a passive observer of a series of classroom lessons (3 – 4 lessons for each teacher) to understand how they translated their perspectives into classroom teaching. These observations provided rich examples of these teachers' practice in action in the classroom and were an additional data source to their verbalised practices indicated in the initial interviews. Each teacher was interviewed again at the end of classroom observation to gain further explanation of what happened in the classroom. In addition, 6 – 8 students from each class were interviewed in focus groups to understand how they perceived what was taught in their science class. Focus group interviews were used as supporting data sources to understand teachers' practices in the science classes. Figure 4.1 illustrates an overview of how these data sources were used for the case studies.

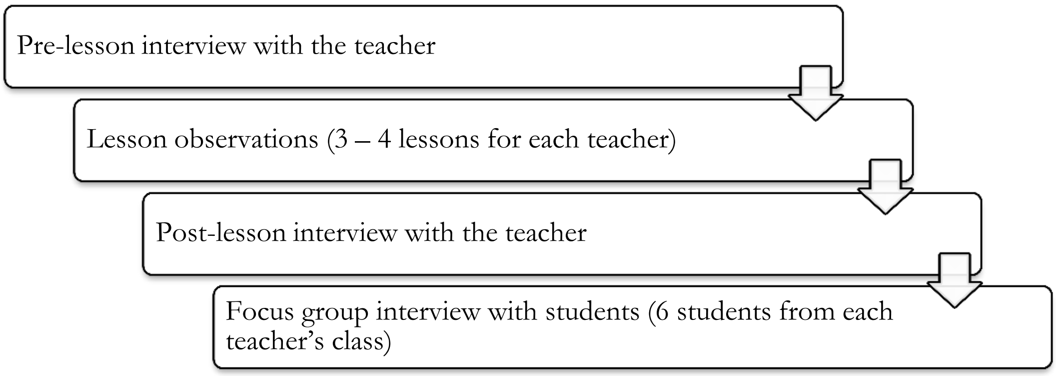

Figure 4.1. Data sources used for the case studies

A snapshot of the data sources used to address the four research questions in different phases is provided in Table 4.1 and explained below.

Table 4.1

Data Sources to Address Research Questions

Research question/ Data sources	Questionnaire	Pre-lesson interview	Lesson observation	Post-lesson interview	Focus group interview
RQ 1	√	√			
RQ 2	√	√	√	√	√
RQ 3	√	√	√	√	√
RQ 4	√			√	

4.4 Data Sources in Phase 1.

In the first phase, a questionnaire was administered among teachers teaching the General Science course at the junior secondary level. As noted previously, there are two main purposes of this questionnaire: firstly, the questionnaire data provided a macro view of teachers' perspectives of, and teaching approaches and challenges to, promote scientific literacy; secondly but most importantly, the questionnaire data were used to select the cases for the qualitative part of this study as discussed later in Section 4.5.1.

4.4.1 The questionnaire.

The questionnaire (Appendix 4) comprised five sections: Section A collected general information from teachers regarding their demographics and academic and professional qualifications; Section B sought information regarding work load and class size; Section C sought information regarding teachers' perspectives of scientific literacy including the purpose of science education, familiarity with the term of scientific literacy and their conceptions of scientific literacy; Section D asked for information regarding teachers' views on their teaching practice; and Section E gathered information regarding teachers' perceived challenges in teaching for promoting scientific literacy.

The questionnaire was structured so that in some items, respondents were asked to indicate their responses from the alternatives, while for others the respondents were asked to explain their choice. Some items were based on a rating scale indicating the extent of their use of teaching approaches mentioned in the statement. For some other items respondents were asked to rank statements on their level of importance. These ranking type questions were semi-closed to give respondents space to add additional items to rank. Other questions were open-ended in order to obtain responses in the participants' own words. Examples of each of the items are given below.

Example 1: Open-ended questions

What do you think scientific literacy would mean? Please <u>write</u> in your words.

Example 2: Alternative response type questions

Of the two alternatives, which do you believe should be the major purpose of the General Science course at the junior secondary level?

Please Tick one box only.

Make all students able to use their science learning in everyday life	
Build a solid foundation in science for the students who will study science in the next level	

Example 3: Ranking type questions

Please rank the following aspects as challenges to your teaching for scientific literacy. '1' indicates your first choice, '2' your second choice, and so on. You can give the same rank to more than one aspect.

Lack of scope in the curriculum	
School assessment system does not support	
Large class size	
Heavy workload	
Lack of resources	

Please write in if any issue you face is missing in the above and rank for that.

Example 4: Rating type questions

How often do you emphasize the following aspects in teaching science?

Please use one <u>Tick</u> for each row.

How often do you	Always	Often	Sometime	Rarely
explain the application of science in everyday life?				
encourage students to contribute personal stories into class discussion				

The questionnaire was first developed in English in consultation with my PhD supervisor and then was translated into Bangla as I anticipated that participants would feel more comfortable both in understanding questions and provide written responses in Bangla, their own language. In order to resolve any translation issue, I first translated the questionnaire myself, and then discussed this translation with Bangladeshi science educators pursuing higher degrees in educational research in Australian universities (e.g., at Monash University and the University of Melbourne). After a thorough discussion, we came to a consensus on my translation. The translated questionnaire was certified by a qualified NAATI (National Accreditation Authority for Translators and Interpreters) translator and was piloted with 10 science teachers to determine whether they understood the items. Any ambiguities found during this piloting were clarified for the respondents and recorded for further revision of the questionnaire. Finally a revised questionnaire was administered to the participants.

4.4.2 Respondents to the questionnaire.

Because of the time and cost-saving benefits of mailed questionnaires (Creswell, 2008, 2009), initially, I planned to mail the questionnaires to the respondents. In order to do this I collected the list of secondary schools from the Directorate of Secondary and Higher Education (DSHE), Bangladesh. From the list a total of 300 schools, equal numbers of schools from each of urban, semi-urban and rural areas were selected through a stratified random sampling procedure. As the notion of scientific literacy may depend on contexts as well as the challenges in the teaching of science, variation between different school contexts could be regarded as very likely. Thus considering schools from urban, semi-urban and rural areas in participant selection was perceived to be worthwhile; it would be helpful to increase the generalisability of the data as well. The teachers teaching the General Science course at junior secondary level in the selected schools were invited to respond to the questionnaire.

In order to test the applicability of the plan to use mailed questionnaires, I mailed the questionnaire to 15 schools with an explanatory statement, consent form and permission letter to collect data along with the postage-paid return envelope. However, I received only one questionnaire back after two weeks had elapsed. In order to increase the response rate, I sent follow-up mail invitations to the participants, but no improvement in response rate occurred. I discussed this issue with some experienced researchers in Bangladesh and my PhD supervisor in Australia. After reflecting on their expert suggestions, I changed my plan from using mailed questionnaires to arranging several seminars for in-service science teachers.

I organised five seminars in five districts with the help of the District Education Office of each district, with 35 – 40 teachers attending each of the seminars. The seminars were designed in two stages. In the first stage, I presented a worldwide scenario of school science education and discussed their experiences of science teaching in schools. The presentation followed a friendly conversation that helped build rapport with the attendees. This rapport was perceived to be important to get them involved in the research process. In the second stage, the teachers were introduced to my research and were invited to complete the questionnaire voluntarily. This procedure, which bore the characteristics of "convenience sampling", provided the benefit of easy recruitment of participants from the available respondents based on their willingness to participate in this research (Mertens, 2005). Altogether 159 teachers voluntarily completed the questionnaire in my presence. However, my physical presence while teachers filled in the questionnaires gave rise to an issue of reliability of data, since it appeared that the teachers tended to provide what they considered desirable answers.

Although the questionnaire clearly stated that teachers' own perspectives would be valued and that there were no right or wrong answers, I noticed that the participants still seemed to search for the "right"/"desirable"/"positively valued" answers rather than expressing their own views. For example, I found some participants asking others sitting nearby what the right answer would be to some questions. In order to respond to this issue, I probed the participants about my intentions of using the questionnaire and my expectations of them as participants. At this point, many of the teachers indicated that they had not noticed what the questionnaire expected from them as written in the beginning of the questionnaire or in the explanatory statement. This provided me with the understanding that a clearly written statement of the purpose of research may sometimes not be able to communicate to the research participants their role in the research process; rather a verbal communication may be necessary. Whilst I was not sure if my verbal communication with the participants was sufficient to address the issue, I felt that it would increase the possibility of getting their own authentic views rather than 'fabricated' views.

4.5 Data Sources in Phase 2

In the second phase, a small number of teachers, selected from the respondents of the questionnaire in Phase 1, were interviewed, a series of their lessons were observed and their students were interviewed in groups. It may be worth mentioning that I had also planned to analyse teachers' lesson plans/notes to see the intention or purpose of the lesson I would observe; however, none of my teacher participants could provide me with a lesson plan as it was not something they prepare regularly.

In the following sections, I describe the selection of participants for the second phase along with the data collection methods used.

4.5.1 Selection of participants for Phase 2.

4.5.1.1 Selection of teachers.

As noted previously, participants in the second phase were selected from the questionnaire sample based on the responses they provided. This purposeful sampling (Merriam, 1998, 2009) is regarded as useful for achieving an in-depth understanding of the research problem (Patton, 2002); indeed, adaptation of this sampling procedure helped me gain an in-depth understanding of teachers' perspectives, practices and challenges in relation to teaching for promoting scientific literacy.

In this sampling procedure, I followed three steps. In the first step, I looked at the responses given to question number 6 in the questionnaire and identified those respondents interested in participating further in the research process (i.e., interviews, lesson observations and focus group interviews with the students). In the second step, I categorised the interested participants based on their school location and school type. This was done to increase the representation of participants from different school contexts. In the final step, I identified the respondents expressing a range of perspectives of scientific literacy as reflected in their responses to the question about the meanings of scientific literacy. Inclusion of participants from different school contexts with a range of perspectives of scientific literacy for the detailed qualitative part of this research helped ensure the "maximal variation", which would provide a good qualitative data set (Creswell & Plano Clark, 2007, p. 112). In this manner, six teachers were selected as the participants for the second phase. The six teachers and their associated science classes (including students) were considered as six cases (a snapshot of the selected teachers' demographic information is illustrated in Table 4.2).

Table 4.2
Demographics of the Participant Teachers

Criteria	Sabina[1] (F)	Alam (M)	Ashim (M)	Morshed (M)	Rashid (M)	Jasmine (F)
School location	Semi-urban	Urban	Rural	Urban	Rural	Semi-urban
School type	Co-ed	Co-ed	Boys'	Boys'	Girls'	Girls'
Teaching experiences	12 years	13 years	10 years	18 years	16 years	9 years
Class size	53	50	100	65	85	70

[1] All the participants' names used in this thesis are pseudonyms to protect their identity.

With these six cases I explored the research questions as outlined in Section 4.2 to gain a micro view of how scientific literacy is promoted through junior secondary science education in Bangladesh. Selected teachers' demographic information illustrated in Table 4.2 reveals that the selected teachers represent a range of geographical locations (urban, semi-urban and rural), school types (co-ed, boys' and girls') with different class sizes (from 50 to 100 students) and lengths of teaching experience (from nine to 18 years).

4.5.1.2 Selection of students.

Six volunteer students from each of the cases were selected purposively for the focus group interviews. Whilst this research has no intention to compare the experiences of boys and girls, gender balance was taken into consideration in the case of co-education classes to ensure equal representation of boys and girls. As a result of including equal numbers of co-ed, boys' and girls' schools, there was equal representation of boys and girls in this research. Moreover, students from a range of levels of academic achievement were included.

I was aware that in the Bangladesh context, an unequal relationship may exist between a teacher and students in a school, especially between students and a teacher who directly teaches and assesses those students. As my student participants were directly taught and assessed by my teacher participants, I presumed that there might be an unequal relationship between my teacher participants and student participants. In order to minimise the unequal relationship, I nominated another teacher who does not teach in that particular class and was not participating in this research. This nominated teacher explained to students about the research project and distributed the consent forms and explanatory statement to interested student participants. Since this nominated teacher did not teach or assess these students, it was expected that students would think their participation was independent from the classroom assessment. It may be worth mentioning that the nominated teacher was briefed that his/her participation was completely voluntary, as was that of the students, and that s/he was not expected to force students to participate.

4.5.2 Methods of data collection.

As noted earlier, a number of methods, for example, interviews, lesson observations and focus group interviews were used to collect data for the qualitative case studies (Yin, 2009) in the second phase of this research. Rationales for using each of the methods along with brief descriptions of them are provided below.

4.5.2.1 Interview.

The purpose of interview, in general terms, is to find out what is in one's mind (Patton, 2002); specifically, an interviewee's "thoughts, values, prejudices, perceptions, views, feelings and perspectives" can be elicited through interview (Wellington, 2000, p. 71). Moreover, interview can capture the multitude of interviewees' views and negotiate meaning of a certain concept as perceived by the interviewer and the interviewees (Kvale, 1996). In an interview, both the interviewer and interviewees enjoy the scope of asking follow-up questions to clarify an issue. Thus interviews were perceived as appropriate for this research to understand how teachers perceive scientific literacy, what values they consider in teaching and the issues they perceive as challenging in their teaching.

Each of the selected teachers was interviewed twice, once before the first lesson observation (pre-lesson interview) and then at the end of the last observation (post-lesson interview). The purposes of the pre-lesson interview were primarily two-fold.

Firstly, this interview allowed me and the teacher participants to get to know each other, to develop a notion of mutual trust and build rapport (Babbie, 2011) and to make practical arrangements for observing their lessons. Secondly, in the pre-lesson interview, I asked the teacher participants questions to understand their perspectives of scientific literacy, the values underpinning their perspectives and the way they perceive they teach in relation to their perspectives. I prepared an interview schedule for the pre-lesson interview (Appendix 5); however, it may be worth noting that the schedule was kept flexible to allow scope for following up with further questions, prompts or comments if further information was required. In this manner, the pre-lesson interview was semi-structured in nature (Newing, Eagle, Puri, & Watson, 2011). Here are some examples of the pre-lesson interview questions.

Do you think all students should learn science in school? Why or why not?

What outcomes do you expect from your students when you teach science? How would the outcomes characterise scientific literacy?

The post-lesson interview focused on getting an explanation of what was happening in the classroom. Whilst there was a set of fixed questions that I asked in the post-lesson interview (for example, "what were the purposes of your teaching of the lessons I observed?"), the teaching episodes would necessarily be varied from teacher to teacher and as a result some questions in the post-lesson interview would vary from teacher to teacher. For example, as described in Chapter 6, it was observed in one of the teacher's class that in teaching about acids she discussed a global issue (acid rain) that was not intended in the curriculum for the Grade she taught. This observation persuaded me to seek the reason for this in the post-lesson interview. Her explanation in the interview helped me understand her intention to draw the links between school science learning and her students' lives. In this manner, the post-lesson interview process was flexible and loosely guided by a list of questions that allowed the flexibility to respond to a range of classroom episodes observed during the lesson observation. Appendix 6 presents a post-lesson interview schedule.

Interviews were conducted face to face with each teacher within their school premises. All interviews were conducted in Bangla, audio recorded, and field notes were taken to keep an account of any important data observed during the interview session.

4.5.2.2 Lesson observation.

The method of observation of case teachers' science lessons served two principal purposes in relation to the research questions. Firstly, this method was a major data source for the second research question (RQ 2), which intended to understand how teachers translate their perspectives into classroom teaching practice. In addition, this method was a major data source for a part of the third research question (RQ 3), which intended to understand how teachers consider the intended curriculum values in their classroom teaching. Secondly, observation of teachers' lessons helped me identify significant aspects of their teaching, which were worth further exploration during the post-lesson interview. Considering these two purposes, the observation of teachers' lessons was perceived to be an important method in this research.

As noted previously, a series of lessons (3 – 4) for each of the selected teachers was observed. In the pre-lesson interview, I made arrangements with teachers about observation of their lessons. In order to avoid any interruption to the usual school schedule I did not request that they teach any particular content/ unit, but I did observe all the lessons for the particular unit a teacher taught. A unit may have different emphases at different times in the progress of the topic, so observation of teaching the whole unit would help understand a teacher's overall teaching approach.

In observing the lessons, I followed the "passive participation" approach (Mertens, 1998, p. 318), where I sat in the back of the classroom and did not interact with the participants while observing. In this way I was able to follow the classroom events without interrupting the usual classroom situation.

I recorded observation data 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 losing integrity of this data, as soon as I completed an observation, I elaborated on the jotted notes by writing a brief report with the help of the audio recording. If a classroom lecture quote seemed to be worthwhile to me I transformed the audio-recorded piece into words and put it in the report. Analysis of observation data was conducted from the written report only. Whilst I was keen to record as much observation data as I could, I do acknowledge that I might not have been able to observe everything in a class, nor might I have recorded everything I had observed. In this sense, my observation report represented a sample of my observations as suggested by Babbie (2011).

4.5.2.3 Focus group interview.

As noted before, the second phase of this research adopted a case study approach where six teachers' science classes were considered as six cases. As students are an integral part of a class, their views about their class experiences are worthwhile in understanding how particular issues happened in a science class. Six students from each of the teachers' science classes comprised each of the six focus groups. The 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 class.

For this research, focus group interviews were perceived as appropriate to elicit a shared view from students about how science is taught in school for several reasons. For example, since within a group students were of similar age, they would feel more comfortable to talk among themselves than talking with the individual researcher only. This aspect may be seen as vital in Bangladesh; because of the assessment-oriented education and the lack of familiarity with research (Siddique, Begum, Roshid, Sarkar, & Majumder, 2011), students could perceive an individual interview as sort of an oral test with an external examiner (interviewer). Moreover, in a focus group interview, along with the interviewer, group members could stimulate each other (Frey & Fontana, 1993). Therefore, focus group interviews are largely used in educational research to explore participants' experiences about certain aspects in a shared environment. For instance, in the UK, Osborne and Collins (2001) used focus group interviews to explore students' views about school science.

In order to maintain the "quality control" (Krueger, 1993, p. 65) of the focus group interviews, I clarified the purpose of the interview to the students and my expectations from them. Whilst the explanatory statement prepared for the students clearly explained in writing that the focus group interview was not a sort of assessment but my purpose was to understand their perceived experience of school science, I also communicated the purpose to them orally at the beginning of the interviews. In an assessment-oriented education system, this was done to provide them with a notion of assurance that the interviews did not have any intention to assess them and therefore there were no correct or incorrect answers to the questions asked in the interviews. This verbal communication further helped to maintain a non-judgemental environment for the students during the interview sessions (Krueger & Casey, 2000).

At the beginning of the focus group interview, each student was given a name tag to wear. This gave me the advantage of being able to address them by their names so they could feel engaged in the interview. This seemed to be particularly helpful when there was the need to engage students who were less responsive in the group.

During the focus group interview, I played the role of moderator. I was aware of the need to keep the respondents focused on a particular topic and to "control the dynamic" within the group (Babbie, 2011, p. 344). This included providing equal opportunities to every respondent to participate fully. Most importantly, I listened carefully to each of the participants; I tried to be careful to not share my point of view to them, rather listening carefully to their points of view.

The focus group interviews were conducted using a flexible schedule (Appendix 7). Necessary probes and follow up questions were also used to elicit a range of views and experiences from the participants throughout the interviews. All of the interviews were audio recorded with the consent of the student participants.

4.6 Data Analysis

As Stake (1995) suggested, there is no common time frame to begin data analysis; rather, data analysis stages depend on several aspects, for example, the purpose of research, research design and types of data collected (Onwuegbuzie & Teddlie, 2003). Considering the aspects of this research, data were analysed in two stages described below.

4.6.1 Data analysis in Stage 1.

As noted previously, the collection of data in this research started with administering a questionnaire among teachers teaching the General Science course at the junior secondary level. One of the purposes of administering the questionnaire was to select the cases for the detailed qualitative part of this research. This purpose was served in the first stage of data analysis. In this stage, some of the questionnaire items (that were potentially important to help select a variety of cases) were taken into account for the analysis. A description of how the data in this stage were used to select the cases has already been presented in Section 4.5.1.1 and therefore will not be repeated here. However, what was not noted previously was that in order to select teachers with a range of perspectives, I analysed teachers' written responses to the questionnaire item that sought their conceptions of scientific literacy. Therefore, data for this item were necessarily qualitative and were analysed as described below.

In order to develop a deeper understanding of the responses being supplied by the teachers about their conceptions of scientific literacy, I read their written responses several times (Creswell, 2008), to which I then assigned codes. Similar codes were brought together to develop themes that represented teachers' conceptions of scientific literacy. Themes were counted according to their occurrence and were presented as percentages. Using this data transformation approach (Creswell, 2009), qualitative data were transformed into quantitative data and used to demonstrate teachers' macro views regarding their conceptions of scientific literacy as well as to select the participants with a range of perspectives of scientific literacy for further exploration. The other items in the questionnaire were analysed in the second stage as follows.

4.6.2 Data analysis in Stage 2.

In the second stage, the questionnaire data (largely quantitative in nature) were descriptively analysed using the Statistical Package for the Social Sciences (SPSS) software. The main purpose of this analysis was to construct, through descriptive statistics, a contextual background of the characteristics of participant teachers and their science classes and to sketch a macro view of how scientific literacy is considered in their science classes. It was expected that more meaningful interpretation of the macro view could take place against such background information.

As noted previously in Section 4.4.1, the questionnaire included several types of quantitatively-formulated items, for example, alternative response type, rating type and ranking type. Analysis procedures for different types of items are described below.

For alternative response type items, the frequencies of teachers' responses were counted against the alternatives and then presented in a pie-chart to provide a visual summary of the responses. For example, teachers were asked to indicate whether they had heard the term "scientific literacy" (Item 10a). The alternatives provided to them were "yes" and "no". Teachers' responses to these alternatives were summarised in a pie-chart to visually represent a macro view of their familiarity with the term of "scientific literacy" (see Section 5.3.2).

Rating type items sought teachers' views on the extent of their consideration of some aspects in their science teaching on a four point scale (Always, Often, Sometime, and Rarely). Teachers' responses to the rating type items were analysed using a similar scheme to that which Corrigan, Gunstone, Bishop, and Clarke (2004) used to determine how different values are emphasised in science and mathematics classes. According to this scheme, teachers' responses were scored as 4 (for "Always"), 3 (for "Often"), 2 (for

"Sometimes"), and 1 (for "Rarely"). Mean values of the scores were then calculated. As the mid-point of four point scale is 2.5, the mean value greater than 2.5 for a particular aspect indicates that this aspect is emphasised in the classroom. The closer the mean is to 4, the higher the extent of emphasis. Similarly, the mean value less than 2.5 for a particular aspect indicates that this aspect is either limited or not emphasised in the classroom. Whilst there may be some risk of "over-simplification" (Jenkins & Nelson, 2005, p. 47), this approach would facilitate the comparison of the extent of emphasis placed on different aspects in science classes.

For the ranking type items, the respondents were asked to rank various aspects based on their importance or priority. For example, they were asked to rank the issues that were challenging in their teaching for scientific literacy in a manner where "1" indicated their first choice of importance, "2", the second choice, and so on up to "5". In order to analyse the ranking type items, I put scores against the ranks that teachers made. For example, if a teacher put rank "1" for an issue, I considered this as the most important issue and therefore, scored this as "5". This was done to help calculate an average rating of the teachers' choice of importance. Average rating, as suggested by B. Johnson and Christensen (2008), was calculated to capture a relative picture of the issues the teachers rated in terms of importance. A higher average rating indicated that the issue was accorded a higher importance.

4.6.3 Data analysis in Stage 3.

In the third stage, case data that were qualitative in nature (interviews, lesson observations and focus group interviews) were analysed as described in the following paragraphs.

As noted previously, all the interviews (pre-lesson and post-lesson) with teachers and focus group interviews with students were conducted in Bangla – the official language of Bangladesh. This was done with the assumption that participants would feel more comfortable both in understanding the questions in the interviews and focus group interviews and in articulating their responses in their own language. All the interviews and focus group discussions were digitally recorded. The digital recordings were transcribed into written text in Bangla. The Bangla version transcripts were used for the purpose of analysis. Parts of the transcripts were translated into English for reporting in this thesis. Along with the transcripts of interviews and focus group interviews, analysis of observation data was conducted from the written observation reports. Appendices 8 – 11 each provide an example of pre and post-lesson interview transcripts, focus group interview transcript and lesson observation report (all in the English version).

The transcripts were prepared with as much detail as I could include after listening to the recordings. However, as the manners in oral language and written language are often different (Kvale, 1996), in preparing the transcripts I did not include every repetition or hesitation, nor did I include every laugh or pause. Rather I put into the transcripts only the level of details I thought might influence the interpretation. In order to enhance the credibility of the transcribed data (Creswell, 2007), the transcripts (Bangla version) were sent back to the participant teachers who confirmed the accuracy of the transcripts.

As reading qualitative data several times gives deeper understanding about the data (Creswell, 2008), the qualitative databases (interview transcripts, lesson observation reports and focus group interview transcripts) were read several times before assigning codes[2] to them. In following Miles and Huberman (1994), a list of codes or categories were identified in the transcripts as they emerged from the data. 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 to not impose a preconceived framework, which could impose excessive rigidity to the research. However, it may be worth noting that the analysis approach adopted in this stage could introduce a degree of subjectivity due to the fact that judgements were made by me (as a researcher) as to the meanings contained within the data. As a researcher with a constructivist worldview I acknowledge the subjectivity that allowed me to construct my understanding from the multiple social constructions that the participants hold.

Based on the analysis procedure as described above, detailed case reports for the participant teachers were then produced which are presented in Chapter 6. These case reports were finally analysed applying a cross-case data analysis procedure (Stake, 2006) to understand the pattern of the themes that emerged from the cases. Whilst the case analysis did not aim at generalising, a cross case analysis would help understand the relevance or applicability of the findings of this research to other similar settings (Miles & Huberman, 1994). Also, cross case analysis was undertaken to gain a deeper understanding and explanation of the research problem (Eisenhardt, 2002; Miles & Huberman, 1994). It was therefore perceived that cross-case analysis in this data analysis stage helped achieve a deeper understanding of teacher's perspectives of scientific literacy, the translation of their perspectives into classroom teaching, the values they

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[2] The software NVivo was used for coding.

consider in their teaching for scientific literacy and the issues they perceive as challenging in their teaching.

4.7 Issues of Credibility

This section discusses how the issues relating to ensuring the credibility of this research were considered. As noted in the previous sections, this research followed a mixed methods design where qualitative approaches dominated the overall research process. In the literature on mixed methods research, credibility issues are often termed legitimation issues (B. Johnson & Christensen, 2008). The type of legitimation I considered for this research is that of establishing "multiple validities" according to B. Johnson and Christensen (2008, p. 284). According to them, a notion of multiple validities refers to addressing the validity issues attached to the respective quantitative and qualitative methods used in a mixed-methods research. Considering this legitimation type, in order to ensure the credibility of this research, the validity issues were addressed in different quantitative and qualitative methods as explained below.

In a preliminary effort to enhance the credibility of the questionnaire, as noted previously, at the stage of its development, I discussed the questionnaire content, presentation of the questions and associated language issues with my peer group in Monash University and the University of Melbourne, who were science educators in Bangladesh. Being experienced and knowledgeable about the science education contexts in Bangladesh they provided insights about the questionnaire. Moreover, before administering, the questionnaire was piloted with 10 science teachers to examine whether they understood the items. Any ambiguities found during this piloting were clarified for the respondents and recorded for further revision of the questionnaire.

The issues regarding the credibility of the qualitative methods were addressed through several procedures. In order to ensure the accuracy of the interview transcripts, they were member checked with the respective participants (Creswell, 2007; Stake, 2010). In the process of member checking, each of the research participants reviewed the interview transcripts to establish whether they had been transcribed accurately. In developing the qualitative research methods (interviews, focus group interviews, and lesson observation schedule), I consulted with my fellow Bangladeshi colleagues as noted in the previous paragraph. Their suggestions were also sought when issues arose in translating and interpreting the data. Such discussion with peers (B. Johnson & Christensen, 2008) helped me address several translation and interpretation issues. Moreover, having various data sources allowed triangulation in this study as they enabled the consistency of the data from the multiple sources to be evaluated.

Whilst the credibility issues have been considered to enhance the validity of the knowledge produced in this research as noted above, I do acknowledge the limitation of a research process to make absolute claims about the validity of knowledge produced. Moreover, I acknowledge the theory-laden characteristic of any research process. For example, I believe that interpretations made in the interviews and observations are functions of my theoretical knowledge, personal experiences and sensitivity to the research setting. Thus subjectivity in interpretation may be inevitable. In this sense, in this research, I do not intend to make absolute claims about the validity of knowledge produced; rather I intended to be transparent in addressing the credibility issues in different research methods as described previously. Such transparency may help readers see the thoroughness of the research process by which data were collected, analysed and interpreted in making the subjective knowledge claims (Rubin & Rubin, 2005).

4.8 Ethical Issues

Ethical issues are codes of professional conduct for researchers (Creswell, 2009). Concurring with Mertens' (1998) view that ethical issues are an integral part of the research planning and implementation process, in this research I considered several ethical issues in designing and reporting the research findings. The issues also addressed the code of ethics embodied within the Monash University Human Research Ethics Committee. In this section, I will shed light on some of the issues.

I sought a permission letter (see Appendix 2) from the Directorate of Secondary and Higher Education (DSHE), Ministry of Education, Bangladesh. The DSHE serves as a gatekeeper to accessing secondary schools in Bangladesh. Thus the permission letter accompanied my letter for inviting teachers and students to participate voluntarily along with explanatory statements and consent forms. The explanatory statements explained the purpose of this research and the participants' role and associated risks along with participants' rights to withdraw themselves from this study at any stage. The explanatory statements clearly demonstrated that the purpose of this research was not to assess teachers' teaching performance or students' knowledge and skills; rather the purpose was to understand how scientific literacy is promoted in science classes. The participants' rights were preserved so that they could avoid answering questions in the questionnaire, interviews and focus group interviews if they seemed too personal, sensitive or uncomfortable to them. Participants were informed how they could access appropriate counselling services if they encountered any inconvenience and discomfort and report such to the Monash University Human Research Ethics Committee. The participant teachers were requested to provide their consent after carefully reading the explanatory statements in Bangla. As the student participants were under 18 years, written consent was sought from them as well as their parents/guardians. Parents/ guardians therefore were provided with the explanatory statement so that they could understand the purpose of this research and their child's role.

Minimising power relations is a part of the complexity in working with humans in social settings (Mertens, 2005). Whilst as a researcher I did not have a power relationship with the participant teachers and students, I was aware that the students might have such a relationship with their teacher who directly taught or assessed them. As described in Section 4.5.1.2, I negotiated this issue so that students' participation or non-participation in this research would not affect them in any way.

Ensuring anonymity and confidentiality of the participants is another code of practice in research (Babbie, 2011). However, as this research employed audio recording, it could not be totally anonymous. In order to ensure the confidentiality of the participants, I used pseudonyms for reporting. During data collection, I kept data confidential and did not share them with other participants or people outside of this research.

As Babbie (2011) commented, developing a notion of mutual trust and building rapport are an important code of practice in research. All the participants were treated with respect and courtesy. During the lesson observation as a passive observer, I tried my best to not make any interruption to usual classroom settings. I was aware that my presence as an outsider might, however, be an interruption. According to the suggestion of Creswell (2008), I tried to minimise this interruption by clearly communicating the purpose of my presence and making a friendly relationship with the participants.

4.9 Chapter Summary

This chapter has discussed the methodology adopted to explore the major research question of how scientific literacy is promoted through junior secondary science education in Bangladesh. In order to explore this question, this research followed a mixed methods design where qualitative approaches dominated the overall research process. In addition, some quantitative data, as collected through a questionnaire also helped build a macro view of how scientific literacy is considered in science classes and assisted in the selection of appropriate participants for the detailed qualitative part of this research. The qualitative data were used to illustrate a micro view of how scientific literacy is considered in science classes. The following two chapters present these two views.

CHAPTER 5

A Macro View of Scientific Literacy in Science Classes: The Questionnaire Data

5.1 Introduction

This chapter presents an overview of teachers' perspectives of scientific literacy and their teaching approaches to promote it in Bangladesh based on the results from a questionnaire among General Science teachers (N = 159) teaching at the junior secondary level. Background information regarding the participant teachers and their science classes is articulated in Section 5.2. The following sections present an analysis of data relating to teachers' perspectives of scientific literacy, teachers' views on their teaching practice, and teachers' responses to the perceived challenges in their teaching for scientific literacy. These data provide an important basis for a macro view of how scientific literacy is considered in science classes in Bangladesh. Moreover, some of these data were used in selecting a sample of participants for the detailed qualitative part of this research presented in Chapter 6.

5.2 Background Information

This section presents background information on the participant teachers and their science classes. Background information includes the teachers' educational qualifications, teaching experience, involvement in professional development activities, workload and class size.

5.2.1 Educational qualification.

Science content knowledge is argued to be one of the important facets for good science teaching (Osborne & Simon, 1996). It is, therefore, important to know the educational qualifications of the participant teachers in this study. As is seen in Figure 5.1, the majority of participant teachers hold a degree in Science (77%), with the remaining 23% of the participants either with a non-Science degree or no degree at all. This result indicates that the majority of the participant teachers had the opportunity to develop science content knowledge from their academic studies. The result, however, also indicates that almost one-quarter of them may lack in science content knowledge, which in turn might have implications for their teaching of the content-dominated General Science course.

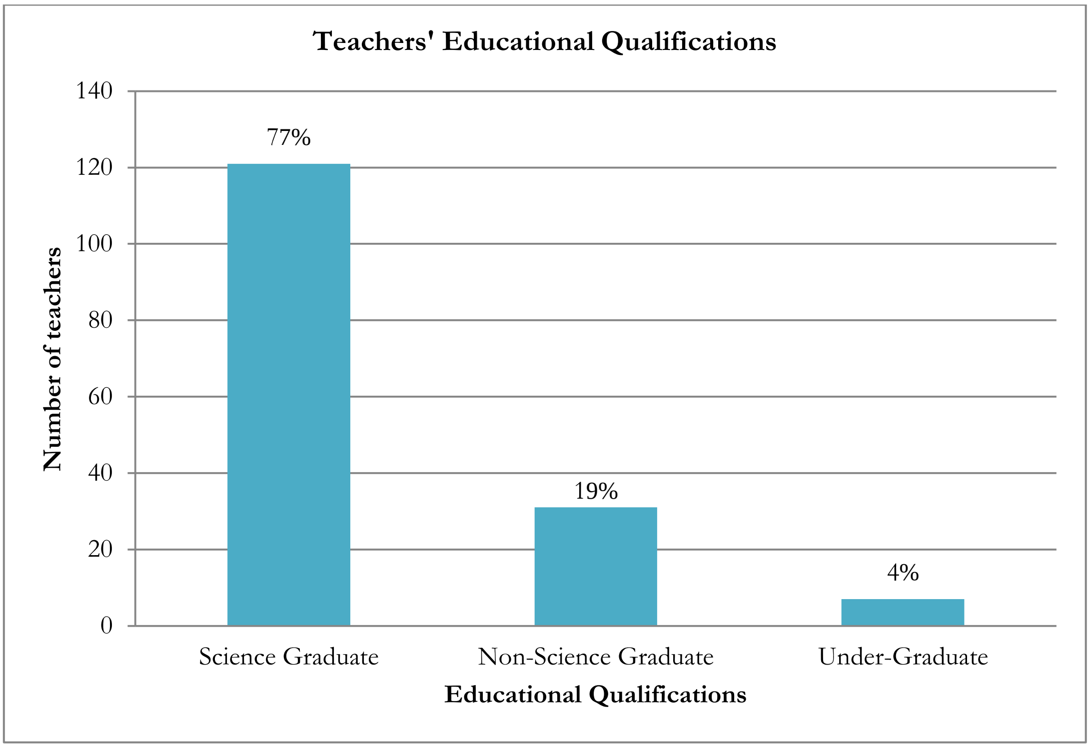

Figure 5.1. Educational qualifications of the participant teachers

5.2.2 Teaching experience.

Goodrum et al. (2001) pointed to the importance of teaching experience for effective science teaching. As is seen in Figure 5.2, more than 90% of the participant teachers have teaching experience of longer than five years and a large majority (54%) have been teaching for more than 10 years. This result suggests considering the majority of participant teachers in this study as experienced in terms of the length of their teaching career.

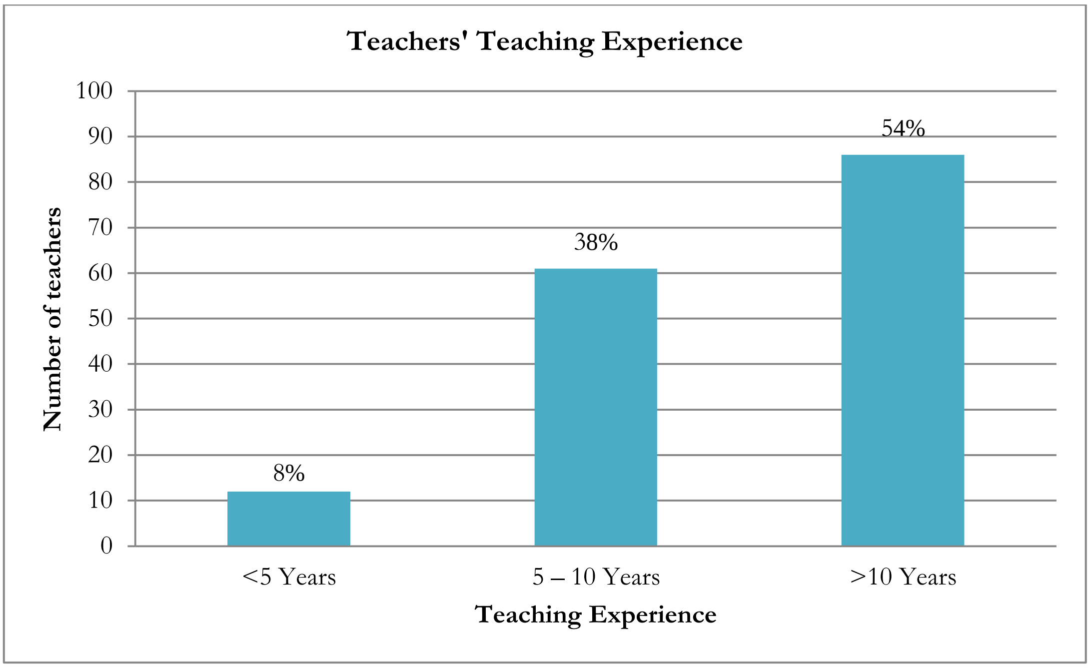

Figure 5.2. Teaching experience of the participant teachers

5.2.3 Involvement in professional development activities.

Professional development activities such as training may be seen as important to develop teachers' pedagogical knowledge because they can provide opportunities to teachers to update their teaching skills and knowledge (Goodrum, et al., 2001). Considering this, teachers in this research were asked about their involvement in professional development activities in recent years. As is seen in Figure 5.3, most of the teachers (93%) had attended some professional development activities to upgrade their knowledge and skills for teaching science in recent years.

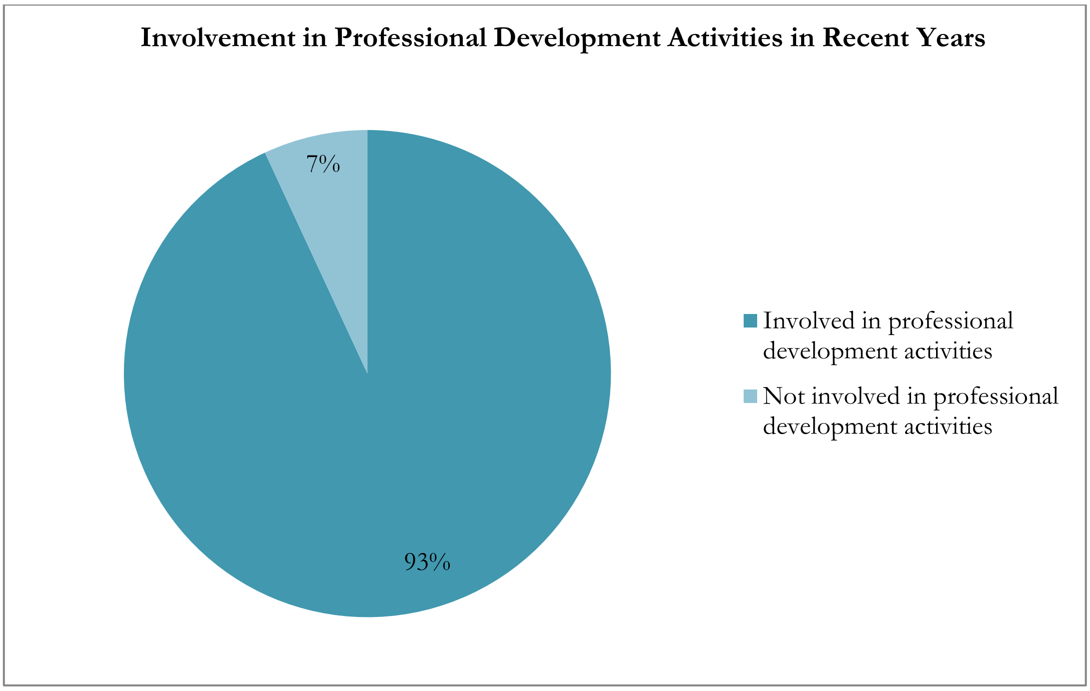

Figure 5.3. Teachers' involvement in professional development activities

5.2.4 Workload.

As Figure 5.4 illustrates, 61% of the participant teachers in this research were committed to conducting at least 28 classes per week, with 16% of the total participants having to conduct more than 33 classes per week. Moreover, a calculation of the average class loads in this regard shows that teachers, on average, conduct 30 classes per week with six classes per day and would need to spend time in addition to this, preparing for these classes. In Bangladesh seven classes (35 – 40 minutes each) are generally scheduled in a typical weekday. There is no break in between classes except one meal break (called "Tiffin" break). Thus it may be a challenge for teachers to find preparation time for the next class. Considering the preparation time, the workload of most of the participant teachers could be seen as extremely heavy.

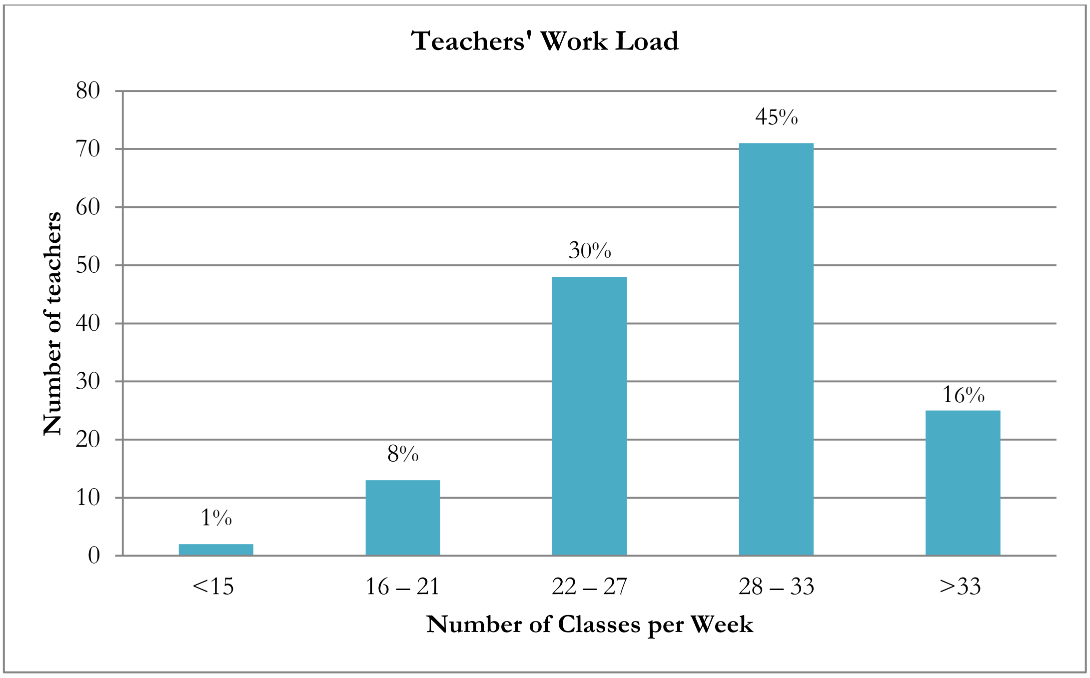

Figure 5.4. Workload of the participant teachers

5.2.5 Class size.

Class size is an important factor in quality teaching of science, particularly if it is aimed to involve students in science activities and focus on individual learning opportunities for every student (Goodrum, et al., 2001). Whilst there is no universal standard for class size, in Bangladesh, it is recommended in the National Education Policy 2000 (Ministry of Education, 2000) that a standard class would accommodate a maximum of 40 students. However, Figure 5.5 illustrates that only 4% of the science classes in this study have a maximum of 40 students. Almost half of the participant teachers reported that their science classes accommodate more than 80 students, which is twice the recommended class size and this is quite common in practice in Bangladesh.

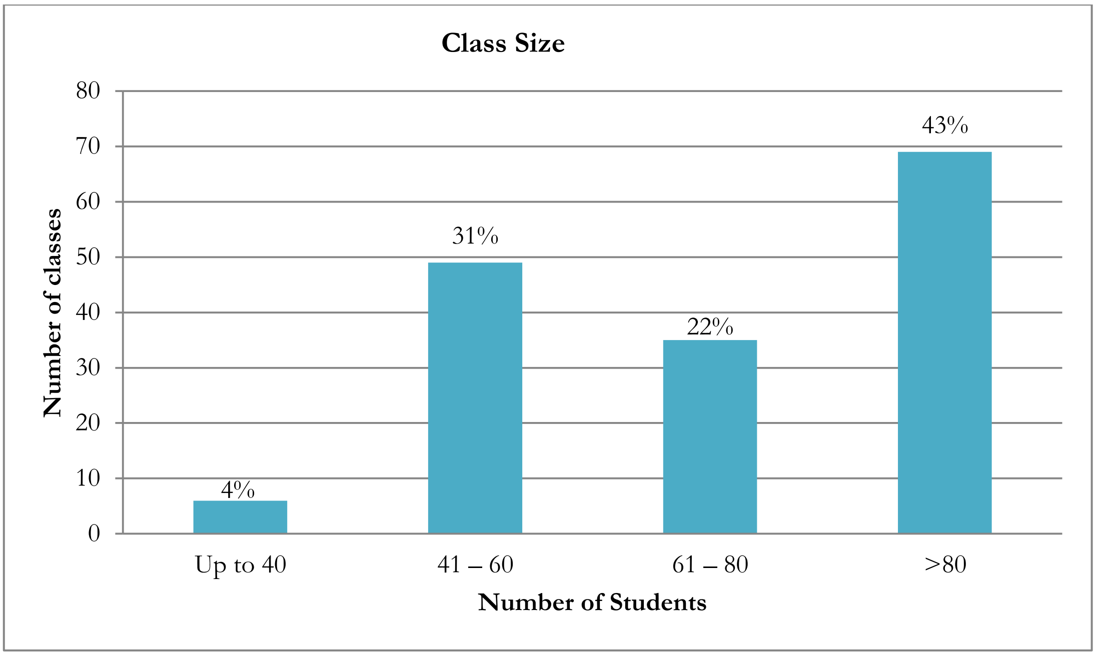

Figure 5.5. Average size of the participant teachers' science class

5.3 Teachers' Perspectives of Scientific Literacy

Teachers' perspectives of scientific literacy are represented in the responses to three questions: the first asks for teachers' views about the purpose of school science education; the second asks about their familiarity with the term "scientific literacy", and the third question (open-ended in nature) asks them to describe what the term "scientific literacy" means for them.

5.3.1 Purposes of school science education.

As discussed in Chapter 2, different purposes for giving priority in different emphases by different stakeholders can result in two major purposes of school science education – providing future scientists and providing a scientifically literate citizenry. Participant teachers in this research were given two alternatives reflecting these two purposes and asked to mention which purpose they consider to be the primary purpose of school science education. This has been set up in an either/or manner, as in

Bangladesh students are streamed to Science or non-Science groups after the junior secondary level. Judgments are thus routinely made about who has a future in science. Moreover, it may be worth mentioning that the term "scientific literacy" was not used in this question in the questionnaire with anticipation that this term could be unfamiliar to many of them. Rather a notion of scientific literacy was provided which could be seen as accessible to the teachers. As Figure 5.6 shows, most of the participant teachers (93%) in this study acknowledged the notion of scientific literacy as the primary purpose of school science education, while a few of them (7%) considered preparing future science professionals as the primary purpose of school science education.

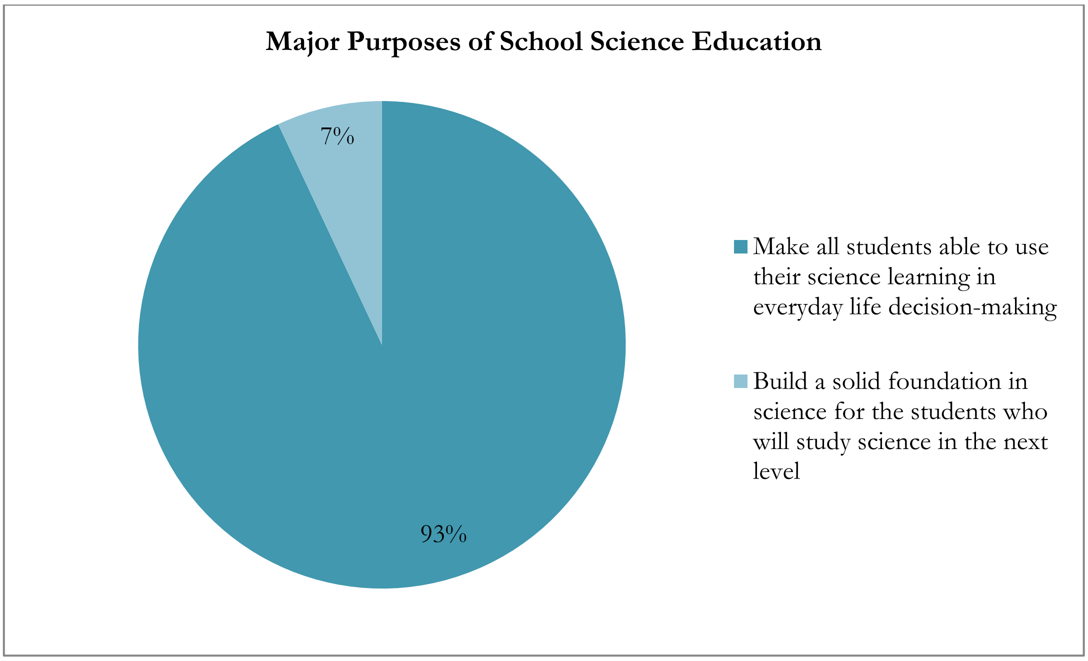

Figure 5.6. Teachers' views on the major purposes of school science education

5.3.2 Familiarity with "scientific literacy".

Whilst most of the teachers acknowledged the notion of scientific literacy as the primary purpose of school science education (see Figure 5.6), Figure 5.7 illustrates that the majority of them (67%) were not familiar with the term "scientific literacy". This may be because neither the official curriculum report nor the textbooks (on which teachers rely heavily to get information about science education) have included this term in representing the purpose of science education.

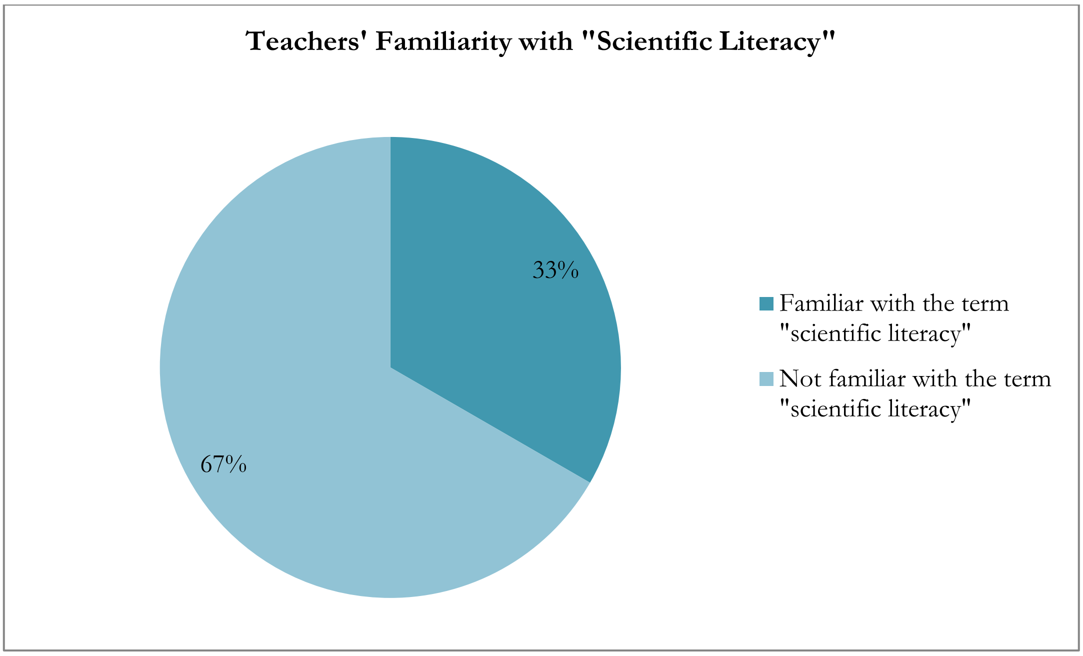

Figure 5.7. Teachers' familiarity with scientific literacy

5.3.3 Conceptions of scientific literacy.

Teachers were given a space to describe their conception of scientific literacy in their own words. Themes that have emerged from their written responses are presented in Table 5.1 along with the frequency of their representation. This frequency has also been represented as a percentage of the total number of representations across the themes that emerged.

Table 5.1

Themes That Emerged from Teachers' Written Response about their Conceptions of Scientific Literacy

Themes	Frequency of appearance (*f*)	Percentage
Use of science in everyday life	102	50.75%
Developing values/ attitudes/ scientific temper	59	29.35%
Having basic science knowledge	26	12.93%
Reading and writing	14	6.97%
Total	201	

Table 5.1 illustrates that a total of four themes have emerged from teachers' written responses with 201 instances of their representation. The theme "use of science in everyday life" appeared in 102 written responses (50.75%), suggesting that the highest portion of teachers in this research perceive scientific literacy as an ability to use science in real life. Two typical examples of written responses reflecting this theme are as follows:

> *I would consider my students as scientifically literate if they have the ability to use their science learning in real life. It is not like just knowing something about science, rather it is something related to use of science in real life. For example, a scientifically literate student not only just knows about nutrition, s/he is able to identify vitamins and minerals in food, recognise the balanced diet, and help his/her family to prepare a food chart.*

> *I know about the food elements of an orange and their importance for my health. If I use this knowledge to mitigate the [health] problems that occurred due to the deficiency of the particular food elements, I am scientifically literate.*

The first comment above indicates the teacher's valuing of functional knowledge about everyday issues, such as nutrition. As he expected, students would use this functional knowledge in preparing a balanced diet chart for their family. In a similar vein, the second comment also indicates the teacher's valuing of functional knowledge that can be used in health related issues. It seems that both of the teachers valued the utilitarian aspect of science (Millar, 1996) through its use in everyday coping (Roberts, 1982). This utilitarian science, further, would help to enhance the standard of life that is reflected in a teacher's comment below.

> *Scientific literacy is acquiring the science knowledge that is needed to lead a civilised life in the modern society. This knowledge must not be something just bookish; rather they have the usefulness to enhance the life standard. For example, if an individual knows which fertilisers are good for his field, he may get a good harvest and his quality of life would be increased. If he just knows about the formula and atomic structure of different fertilisers it would not mean anything to his life.*

It appears from the above comment that the teacher did not consider having the academic science knowledge (e.g., formula and atomic structure of fertilisers) important for scientific literacy; rather he placed emphasis on acquiring the functional knowledge that has use in real life (e.g., knowing about suitable fertilisers for the particular field). Use of this functional knowledge might help people get a good harvest that would give them economic benefit; this eventually, would help them increase their standard of living.

Whilst the majority of the teachers' notions of scientific literacy addressed the functional science knowledge to be used in everyday life, data in Table 5.1 also show that a number of teachers' notions (*f* = 26, 12.93%) addressed another aspect of science knowledge, basic science knowledge. Whilst it may not be clear what they meant by the word "basic" in their responses, the following teacher's comment could give an idea of the teacher's notion of basic knowledge.

> *At Grade Six students are getting the basic knowledge that will help them understand science at Grade Seven. At Grade Seven they are also getting the basic knowledge that will help them at Grade Eight. So, if students don't have the basic knowledge, they will not become scientifically literate.*

It seems from the above comment that the teacher perceived the basic knowledge as one that is needed to study science at the next year. Eventually, his notion of scientific literacy involved preparing students for higher studies in science. This notion, further, may persuade him to take more care of the minority of students who wish to pursue further studies in science, and take less care of helping the large majority become scientifically literate. This notion, therefore, could be seen to be contradicting the aim of preparing scientific literate citizenry through school science education.

As illustrated in Table 5.1, another major theme appearing in the teachers' written responses is "developing values/ attitudes/ scientific temper" (*f* = 59, 29.35%). Whilst there may be differences in the meaning of the terms "values", "attitudes" and "scientific temper" (Koballa & Glynn, 2007), none of the responses attempted to make a distinction among the terms; rather these three terms have been used interchangeably in teachers' written responses. For example, "rational thinking" has been termed as both "values", "attitudes" and "scientific temper" in teachers' responses. However, since the focus of this research is not on discussing the differentiation among these terms intensively, teachers' responses addressing attitudinal aspects like "rational thinking" have been considered under the theme "developing values/ attitudes/ scientific temper". Most of the responses under this theme addressed teachers' consideration of values and scientific temper as a way to overcome superstition. Here is an example.

> *Scientific literate people are scientifically tempered. If people possess scientific temper, they would value rational thinking in every step of their life; they would not accept anything irrational. This rational thinking would keep them away from superstition.*

As is seen in the quote above, the teacher perceived scientific literacy involves a scientific temper or rational way of thinking that would help people to decide about the more plausible and fruitful explanation (i.e., rational explanation) than that provided by superstition. One teacher acknowledges the importance of values in how people use science in real life in the following way:

> *The use of science depends on the values people hold. Scientifically literate people value mankind and use science accordingly.*

This comment indicates that the teacher likes to see science impact positively on society and her perception of scientific literacy is shaped with this view. Also, it seems from the comment that in talking about values this teacher may mean general education values, for example, morality and humankind, which she claims would influence people in how they would use science for the good of humankind.

Table 5.1 also illustrates teachers' responses (*f* = 14, 6.97%) that viewed scientific literacy as the ability to communicate via reading and writing.

> *Scientific literacy is the ability to communicate with others. For example, one of my friends wrote me a letter. If I can understand the meaning of the letter after reading and then write him a response back, this is scientific literacy, I think.*

The comment above does not address anything about science; rather the teacher viewed scientific literacy as an ability to communicate with one's counterpart. It seems that this view of scientific literacy did not go beyond the language perspectives, which could be construed as naive, as this view is not supported by the contemporary literature on scientific literacy (Roberts, 2007).

5.4 Teachers' Views on their Teaching Practice

This section presents teachers' views on their teaching practice and focuses on: the extent to which teachers consider drawing links between school science and students' everyday life; the emphases teachers place on the selected values; the focus of teachers' assessment practice; the extent of using typical methods/ techniques in science classes; and the extent of using teaching-learning materials in science classes. Teachers were asked to indicate, on a four point scale (*Always, Often, Sometimes, Rarely*), their views on the extent of their consideration of some aspects in their science teaching. As noted previously in Section 4.6.2, for the items of this question, I have scored responses as 4 (for *Always*), 3 (for *Often*), 2 (for *Sometimes*), 1 (for *Rarely*), and calculated means to determine the emphasis placed on a particular practice according to previous research (Corrigan, et al., 2004).

5.4.1 Teachers' views on drawing links between school science and students' everyday life.

Teachers' views on the extent to which they consider drawing links between school science and students' everyday life were explored through analysing their responses to a number of statements about possible practices, for example, explaining the application of science in everyday life, providing real life examples of science, bringing students' personal stories into the science classes, linking science with students' interests and hobbies and learning science from multiple resources. These practices, as suggested by Goodrum (2004), generally reflect the emphases required in teaching for promoting scientific literacy. Table 5.2 presents teachers' views on the extent to which they consider the practices in their science teaching.

Table 5.2

Teachers' Views on the Extent of Draw Links between School Science and Students' Everyday Life (Scores: 4 – Always, 3 – Often, 2 – Sometime, 1 – Rarely)

Aspects considered in teaching practice	Mean score
Teacher provides students with everyday life examples in teaching particular science content	3.32
Teacher explains the application of science in everyday life	3.31
Teacher encourages students to contribute personal stories into class discussion	2.95
Teacher encourages students to learn science from various sources, such as newspapers, books other than textbooks, science fiction, TV, radio, internet etc.	2.77
Teacher exemplifies science from the students' interests and hobbies	2.69

An overview of Table 5.2 shows that all of the items achieved mean scores higher than 2.5, indicating that these aspects are emphasised in science classrooms. In particular, it seems that in teaching science teachers place a higher emphasis on providing students with everyday life examples and explaining the applications of science in everyday life. Even though the mean of 2.95 is slightly less than the two previous aspects, teachers also emphasise encouraging students to contribute personal stories to class discussion. Data in Table 5.2 also indicate teachers' emphasis (though to a lesser extent compared to the previous aspects) placed on exemplifying science in relation to students' interests and hobbies (e.g., giving examples regarding musical instruments while teaching about sound) and encouraging them learn science from various resources beyond classroom resources (e.g., mass media). Therefore, it seems that teachers' verbalised practices in relation to their emphases in linking school science with students' everyday life follows the emphases suggested by Goodrum (2004) as required in teaching for promoting scientific literacy.

5.4.2 Teacher's views on their emphasis on the selected values.

This section presents an overview of the emphases teachers felt they placed on the selected values (e.g., curiosity, rational thinking, open-mindedness, respect for others' opinions, and intellectual honesty) in their teaching. Two items were designed to achieve an overview of how each of these values are perceived to be emphasised in science classes. For instance, the items "How often do you encourage students raising questions from their experiences?" and "How often do you encourage students to seek information to explain new phenomena or solve problems?" relate to the value of "curiosity". In the data reported in Table 5.3, for example, teachers' views on the extent of emphasis on these two overview items are represented by the mean scores. Based on the mean scores for the two items, the average mean score was calculated, indicating the extent of emphasis on "curiosity" and so on for the other values. Analyses of data presented in Table 5.3 have been explained in the following under the respective values considered in this research.

Curiosity

Curiosity in this research has been referred to as people's willingness to engage in "wondering how things work" (Hildebrand, 2007, p. 53) and seeking information to explain new phenomena or solve problems. Teachers were asked two questions reflecting possible classroom manifestations of the value of curiosity in science class as exemplified above. As seen in Table 5.3, the average mean score produced for these two items representing the value of curiosity ($\overline{M}$ = 2.91) is higher than 2.5, suggesting that teachers placed a general emphasis on promoting students' curiosity in science class.

Table 5.3

Teachers' Views on their Emphases on the selected Values in Teaching Science (Scores: 4 – Always, 3 – Often, 2 – Sometime, 1 – Rarely)

Value	Aspects considered in teaching practice	M	$\overline{M}$
Curiosity	Teacher encourages students to raise questions from their experiences	3.08	2.91
	Teacher encourages students to seek information to explain new phenomena or solve problems	2.75	
Rational thinking	Teacher encourages students to debate/ argue with each other in science class	2.69	2.69
	Teacher encourages students to provide justification on their ideas in science class	2.69	
Open-mindedness	Teacher gives students examples of how scientific ideas can be revised	2.64	2.64
	Teacher encourages students to revise their ideas if any new idea evolves	2.63	
Respect for others' opinions	Teacher encourages students to present their views and ideas in science class	2.27	2.76
	Teacher encourages students to respect others' views and beliefs that differ from theirs	3.26	
Intellectual honesty	Teacher encourages students to perform an activity (e.g., an experiment) honestly in science classes	2.70	2.78
	Teacher encourages students to report results from an activity honestly rather than report the correct result by manipulation	2.86	

Note. M = Mean score, $\overline{M}$ = Average mean score

Rational thinking

Valuing rational thinking in this research has been referred to as "emphasising argument, reasoning, logical analysis and explanations" (Corrigan & Gunstone, 2007, p. 145). Teachers were asked two questions representing possible manifestations of an emphasis on rational thinking in science classes: "How often do you encourage students to debate/ argue with each other in science class?" and "How often do you encourage students to provide justification on their ideas in science class?". The average mean score produced for these two items representing the value of rational thinking ($\overline{M}$ = 2.69) is higher than 2.5, suggesting that a general emphasis was placed on promoting rational thinking in their science classes.

Open-mindedness

Open-mindedness in this research has been defined as the willingness to change one's mind in the light of new evidence or reinterpretations of old evidence (Hodson & Reid, 1988a). Teachers were asked two questions reflecting possible classroom manifestations of open-mindedness in science classes: "How often do you give students examples of how scientific ideas can be revised?" and "How often do you encourage students to revise their ideas if any new idea evolves?". The average mean score produced for these two items representing the value of open-mindedness ($\overline{M}$ = 2.64) was higher than 2.5, suggesting that teachers placed a general emphasis on open-mindedness in science class.

Respect for others' opinions

Respect for others' opinions in this research has been considered as a supporting value associated with open-mindedness and referred to as people's admiration for others' right to hold and express their opinion. Reflecting on this perception teachers were asked to respond to two questions "How often do you show students that scientists can come to different conclusions using the same data?" and "How often do you encourage students to respect others' views and beliefs that differ from theirs?" As results show, the average mean score produced for these two items representing the value of respect for others' opinions ($\overline{M}$ = 2.76) is higher than 2.5, indicating a general emphasis placed for promoting respect for others' opinion in science classes.

Intellectual honesty

Intellectual honesty in this research has been defined as one's integrity in performing and communicating intellectual activities such as an experiment. Reflecting on this definition, teachers were asked to respond to two questions "How often do you encourage students to perform an activity (e.g., an experiment) honestly in science classes?" and "How often do you encourage students to report results from an activity (e.g., an experiment) honestly rather than report the correct result by manipulation?". As shown in Table 5.3, the average mean score produced for these two items representing the value of intellectual honesty ($\overline{M}$ = 2.78) is higher than 2.5, suggesting that teachers placed a general emphasis on promoting students' intellectual honesty in science classes.

5.4.3 Teachers' views on their assessment practice.

Considering assessment as an integral part of teaching and learning, teachers were asked to express their views on the extent to which they consider some assessment-related aspects, such as the extent of assessing students' understanding of science concepts and their application to new situations, the extent of providing students with feedback after the assessment, and so on. These aspects (see Table 5.4) were considered by Goodrum (2004) to be teaching emphases required for promoting scientific literacy.

Table 5.4

Teachers' Views on their Assessment Practices (Scores: 4 – Always, 3 – Often, 2 – Sometime, 1 – Rarely)

Aspects of assessment practice	Mean score
Teacher assesses students' ability to recall scientific terms and facts	3.01
Teacher assesses students' understanding of science concepts and its application to new situations	2.44
Teacher gives students feedback after the assessment	2.79
Teacher uses a variety of methods to assess students' understanding, including open-ended questions, checklists, project work, practical reports etc.	2.44

Data in Table 5.4 show that teachers place more emphasis on assessing students' memorisation ability ($M > 2.5$) than their understanding of science concepts and the application of these in new situations ($M < 2.5$). In an examination-driven education context like in Bangladesh, this assessment practice may encourage students to rely on rote memorisation of content and may discourage them from learning the application of content in different situations. Data in Table 5.4 also show that whilst teachers are more likely to assess students in a formative manner through providing students with feedback after assessment, they are most likely to adopt an assessment practice that does not include a variety of assessment methods but rather focuses on the traditional paper-pencil test. Therefore, with the exception of the professed emphasis on formative assessment practice, it seems that teachers' emphasis in assessment of students mostly contradicts Goodrum's (2004) suggestions about the emphases necessary to promote scientific literacy.

5.4.4 Teachers' views on the use of teaching methods/ techniques.

Goodrum et al. (2001) argued that no single teaching method/ technique can be regarded as the best for teaching science; rather teachers are suggested to consider a variety of methods/techniques in teaching for promoting scientific literacy (Millar & Osborne, 1998). Considering this, teachers in this research were asked to describe the extent of their use of typical methods/ techniques in teaching science. According to the scheme described previously, mean scores indicating the extent of using a particular method/ technique were calculated and represented in Figure 5.8.

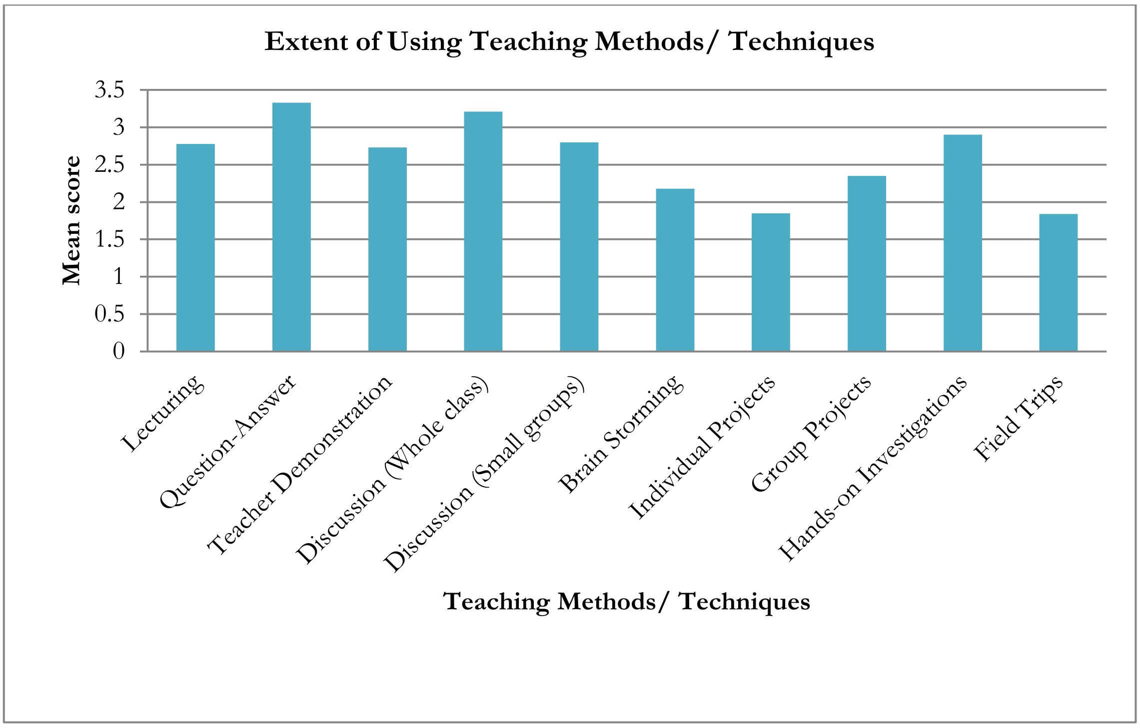

Figure 5.8. Teachers' use of teaching methods/techniques

It would be reasonable to infer from the data in Figure 5.8 that science teaching is based around lecturing, question-answer, teacher demonstration, discussion (whole class and small group), and hands-on investigations (*M* > 2.5 for all of these methods/ techniques). On the other hand, brain storming, projects and field trips are not frequently used in teaching science (*M* < 2.5 for all of these methods/ techniques). The reportedly infrequent use of field trips might restrict the scope for students making connections between school science and the world outside of the classroom.

5.4.5 Teachers' views on the use of teaching-learning materials.

Teachers in this research were asked to describe the extent to which they use teaching-learning materials in teaching science. Teachers' data in this regard are represented in Figure 5.9.

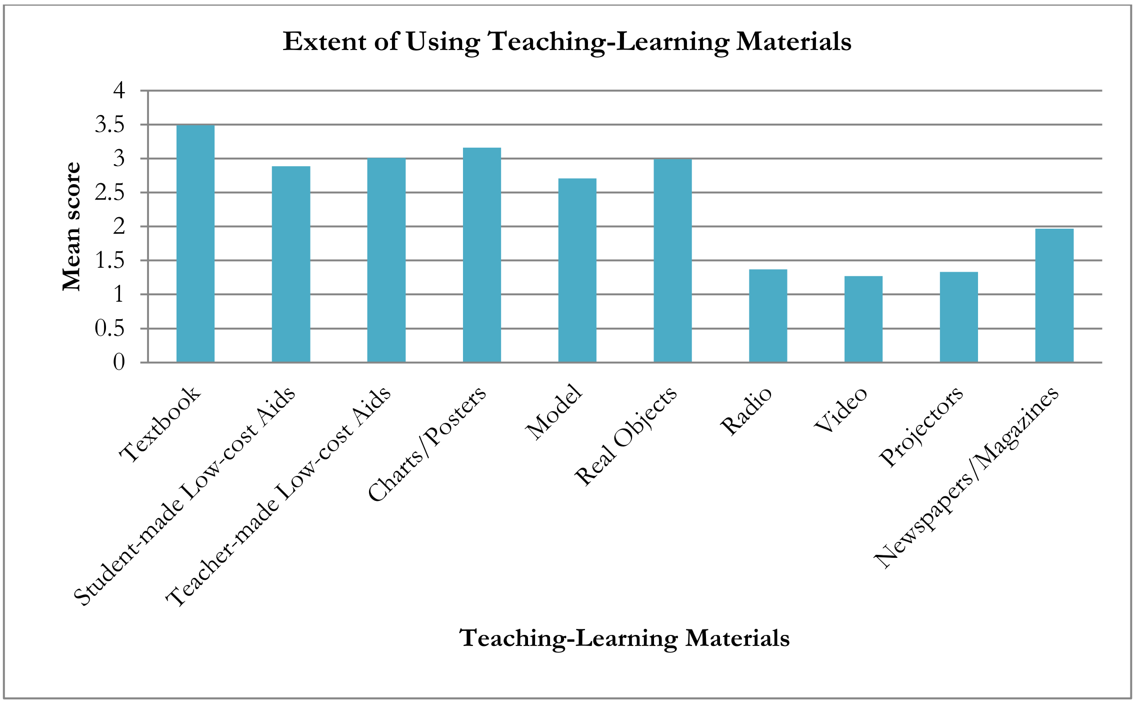

Figure 5.9. Teachers' use of teaching-learning materials

It would be reasonable to infer from the data in Figure 5.9 that teachers mostly use textbooks followed by charts/ posters, low-cost aids made by them, real objects (e.g., leaves, flowers, insects and rocks) and models ($M > 2.5$ for all of these materials). It is important to note less frequent use of different media, for example, radio, video and newspapers/ magazines ($M < 2.5$ for all of these materials) though these could help draw links between school science and the everyday world.

5.5 Challenges in Teaching for Scientific Literacy

This section presents teachers' views on the extent of challenges encountered in teaching to promote scientific literacy. Five challenges for teaching science as reported in previous research and as described earlier, were presented to teachers to rank with "1" representing their first choice of dominance, "2", the second choice, and so on (Table 5.5) with an open space to add other challenges they encounter in their teaching for scientific literacy (Table 5.6). It should be noted that teachers' given ranks were reversed in order to calculate the average rating in the same way as for the other aspects. For example, if a teacher put rank "1" for the challenge "large class size", I have considered this as the most dominant challenge and therefore, have scored this as "5".

Table 5.5

Teachers' Views on the Rank for the Perceived Challenges

Challenge	Rank (Average rating)
Large class size	1 (4.23)
Lack of scope in the curriculum	2 (3.90)
Heavy workload	2 (3.90)
Lack of resources	4 (3.87)
Assessment system does not support	5 (3.54)

As Table 5.5 indicates, teachers in this research viewed the large number of students as the leading challenge to their teaching for scientific literacy. This finding was not unexpected as almost half of the participant teachers' science classes accommodate more than 80 students (see Section 5.2.5). Teachers ranked "lack of scope in the curriculum" and "heavy workload" as the second dominating challenge to promote scientific literacy. Teachers' class teaching commitments (averaging 30 classes per week) as elicited in this research (see Section 5.2.4) may have persuaded them to consider their workload as a major challenge to their teaching to promote scientific literacy. Table 5.5 also shows that lack of resources ranked as fourth in the challenge list followed by the school assessment system.

In addition to this challenge list, three more challenges were added by a number of teachers as illustrated in Table 5.6.

Table 5.6
Additional Challenges Added by Teachers

Additional challenge	Number of teachers
Teachers' poor content knowledge	17
Students' poor merit	12
Lack of training opportunities for the teachers	6

Teachers' additional data in respect to their perceived challenges show that some teachers (n = 17) viewed their content knowledge in science as "poor" and perceived this as a challenge to their teaching for scientific literacy. Teachers' background information as depicted previously in Figure 5.1 indicates that one-quarter of the participant teachers in this research do not hold a degree in Science, which might have caused them to consider their content knowledge in science as "poor". Also "students' poor merit" was reported by some teachers (n = 12) as a challenge in their teaching for promoting scientific literacy. Whilst it was not explicit what they meant by "students' poor merit", it might mean students' academic ability. A small number of teachers (n = 6) reported "lack of training opportunities for the teachers" as a challenge in their teaching for scientific literacy.

5.6 Chapter Summary

This chapter illustrates a macro view (an overview) of the teachers' perspectives of scientific literacy and their teaching approaches to promote it at the junior secondary education level in Bangladesh. Background information of the participant teachers and their science class revealed that the majority of the teachers hold a science degree; most of them are professionally trained and have been teaching for a number of years; they have an extremely heavy workload and large classes. Data relating to teachers' perspectives of scientific literacy show that while the majority of the teachers in this research were not familiar with the term "scientific literacy", most of them acknowledged aims consistent with the concept of scientific literacy as the primary purpose of school science education. Also, these teachers held a range of interpretations of scientific literacy; two main interpretations elicited in this research involved the use of science in everyday life and the development of values/ attitudes/ scientific temper. A number of teachers also interpreted scientific literacy as related to language literacy. An overview of the teaching approach revealed that teachers generally considered it important to draw links between school science and students' everyday life and placed a general emphasis on selected values considered in this research. Their professed teaching approaches also included emphasis on lecturing, question-answer, teacher demonstration, discussion (whole class and small group), and hands-on investigations, which were mostly conducted following the prescribed procedures in the textbooks. Data relating to teachers' perceived challenges to their teaching for scientific literacy elicited "large class size" as the most dominant challenge followed by "lack of scope in the curriculum" and "heavy workload".

With this macro view of the Bangladeshi teachers' perspectives of scientific literacy and their teaching approaches to promote it, let us now focus on a micro view (in-depth understanding) of scientific literacy as represented in six of these participant teachers' science classes.

CHAPTER 6

A Micro View of Scientific Literacy in Science Classes: Individual Teachers' Cases

6.1 Introduction

In the previous chapter, I have presented a macro view of 159 participant teachers' perspectives of and teaching approaches and associated challenges to promote scientific literacy. This chapter focuses on six of these participant teachers' science classes as six cases so as to present a micro view of how scientific literacy is considered in these classes. With these six cases I explored the teachers' perspectives of scientific literacy, the translation of these perspectives into classroom teaching, the values they considered in their teaching for scientific literacy and the issues they perceived as challenging in their teaching.

6.2 Data Sources and Data Analysis

As explained in detail in Chapter 4, the initial exploration of teachers' perspectives of scientific literacy and the values underpinning their perspectives was conducted through a pre-lesson semi-structured interview. A series of their classroom lessons (3 – 4 lessons for each teacher) was then observed, with the researcher as a passive observer, to understand how the teachers translate their perspectives into classroom teaching. These observations provided rich examples of these teachers' practice in action in the classroom and were an additional data source to the perceptions of their practices expressed in the initial interviews. Each teacher was interviewed again at the end of the classroom observation to obtain further explanation of what had happened in the classroom. In addition, 6 – 8 students from each class were interviewed in focus groups to understand how they perceived what was taught in their science classes.

Digitally recorded interviews and focus groups were transcribed and then member checked to enhance the credibility of data. The initial interview transcripts were coded and analysed thematically to identify teachers' perspectives of scientific literacy and the values underpinning their perspectives. Observation notes and post-lesson interviews were analysed to understand how teachers translated their perspectives into their teaching practice. Subsequent analysis compared the values identified from the interviews with those that observed in the teaching practice. Students' focus groups were also analysed to understand how they perceived the values teachers considered in teaching practice. Data from interviews, observations and focus groups were used in triangulation for the validity of the findings (Creswell, 2007). Detailed case reports for the participant teachers were then produced. These case reports are presented in Sections 6.4 to 6.9.

6.3 Formatting Used in this Chapter

In order to present the case reports, I have used particular formatting that may require explanation and is discussed here. Long quotes from the participants' interviews and classroom observations are presented as italicised and indented; any modification made by me to ensure comprehensibility in such quotes is presented in [ ]. In some cases, observed classroom situations are presented within ( ). In addition, " " are used for the words or statements taken directly from the interview transcripts.

6.4 Case 1 – Sabina

6.4.1 Introducing Sabina.

Sabina is a female science teacher teaching in a semi-urban coeducational secondary school where she started her teaching career and has been teaching for 12 years. She holds a degree in science with biology as a major. At the time of participating in this research, she was undertaking a Bachelor in Education from the National University, Bangladesh. In her in-service teaching career, she completed two short-term professional development courses organised by the Teachers Quality Improvement in Secondary Education Project (TQI–SEP), an education development project in Bangladesh. Her work load includes conducting about 29 classes per week. Her teaching of science at Grade VIII level (three lessons on the textbook unit "acids, alkalis and salts") was observed. She had 53 students in her Grade VIII science class.

6.4.2 Sabina's perspectives of scientific literacy and teaching approaches.

Sabina perceived science as worth knowing "to become a competent citizen for the current age". For her, a competent citizen is one who is able to use science knowledge in life and follow media reports about science related issues. In her words,

> *Scientific literacy is something like using science in your life. … Science can provide students with the knowledge about their health and environment. They often make decisions about food, nutrition, environmental pollution and so on. This knowledge can help them to make a decision about these everyday issues. ... Scientifically literate people need to understand science related reports in the media. ... Acid rain related news is common in media like TV and newspapers. Now [my] students can follow such kinds of media reporting.*

As is seen in the above comment, Sabina perceived scientific literacy as an ability to use science knowledge in making decisions in everyday issues, such as food, nutrition and environmental pollution. Sabina also perceived that scientific literacy comprises an understanding of media reports on contemporary science related issues such as acid rain, and expected that science learning in school would help her students in this regard. She expressed the view that "school science should emphasise the science knowledge that is relevant to students' everyday life". Observation of her classroom lessons, however, suggested that this view was not translated into her teaching practice.

In her teaching of acids, Sabina discussed at length the properties of acids, the chemical reactions of acids with alkalis and respective chemical equations. In addition to such exposition of theoretical aspects, she provided examples on the use of acids in personal life. For instance, she exemplified Vitamin C as a kind of acid and explained its importance in maintaining personal health, particularly for "healing wounds and preventing deformed bones and teeth". Indeed, she illustrated the use of acids more broadly, in fertilisers, jewellery making, cosmetics and photographic industries. In her teaching of acids, she brought up a global issue, acid rain, which was not intended in the curriculum for this grade level, as she indicated in the post-lesson interview:

> *Acid rain is a global issue and one that everyone needs to know. I tried to inform my students about the issue and its importance in our life. This content is not in the textbook, but I think they should know about this. I have informed students about how acid rain occurs [and] why it occurs. ... Also, I have explained that many of our activities are responsible for the acid rain. ... You see, we use coals as fuel in the brick fields. It releases sulphur and nitrogen in the air. These elements react with the water molecules in the atmosphere to produce acids, and acid rain occurs. Now my students will be aware about the occurrence and consequences of such an environmental issue.*

As acid rain is an important environmental issue in many countries including Bangladesh, Sabina expected that her presentation of information about acid rain would help students be aware about the human responsibilities for, and the consequences of, acid rain. In the focus group interview, her students, in general, expressed the importance of learning about acid rain.

> *Sagar: I have learned that human activity is responsible for acid rain. We are burning plenty of coals in brick fields. It is producing different chemicals like sulphur, nitrogen, and releases them into the air and causes acid rain. So, we need to be careful in using coal in brick fields.*

> *Benu: You see [the reports on] acid rain in newspapers and TV. What I learned in the last few lessons will help me to understand the reports.*

In the first comment, Sagar illustrates how human actions can cause acid rain and that he learned this in his science classes, while Benu made the point how her learning about acid rain would help her understand the media reports on acid rain. Despite seeing the importance of learning about acid rain in science classes, the majority of students stated in the focus group interview that many aspects they learn in science classes remain unconnected to its use. The aspects included the description of the properties of acids, and information about the chemical reactions of acids with alkalis and respective chemical equations. Here is a student comment:

> *Abu: Madam [Sabina] taught us about the chemical reactions between acid and alkali. She wrote down some equations on the board. I am not sure what to do with this.*

It seems from Abu's above comment that the way in which students were taught about chemical reactions and equations was not useful to provide a notion of a connection of the content to their lives. Rather, students considered that the point of learning about chemical reactions and equations was simply to prepare for the exams.

And it appears from the following student comment that because of the rote memorisation of such knowledge, it would be forgotten after the exam:

> *Jalal: I will memorise some equations important in the exams. It is enough for me if I can just write [them] down in the exam and then lose them. I don't see any other use of this knowledge.*

In response to Jalal's comment above, students wishing to study science at the upper level, argued that this science knowledge would be useful in future science study. For example,

> *Sagar: If I don't know the symbol, I can't write the formula and can't write a chemical equation. If I don't learn the symbols, formulas and equations, how will I study chemistry?*

However, Abu challenged Sagar's argument,

> *Abu: I am not going to study chemistry after [secondary] school. Perhaps I am not going to study any science at all. It [learning about writing chemical equations] doesn't have any use in my life.*

It seems from the above discussion that whilst Sabina believed that school science should emphasise the science knowledge relevant to students' everyday life, in practice she emphasised academic science knowledge (e.g., chemical reactions and equations). Such knowledge was not perceived as important to many of the students, particularly to those who do not wish to study science at the upper level. However, Sabina's somewhat limited attempts to make the links between science and students' life (for example, the account of acid rain) were perceived as of worth to students.

6.4.3 Values considered in relation to scientific literacy.

As discussed previously, this research sought evidence of how five values (rational thinking, curiosity, open-mindedness, respect for others' opinions, and intellectual honesty) intended in the junior secondary General Science curriculum in Bangladesh were addressed science classes. Among these five values, four were considered in Sabina's science class: curiosity, rational thinking, respect for others' opinions and open-mindedness. It should be noted that there was no evidence of how the value of intellectual honesty was considered in her class.

6.4.3.1 Curiosity.

Sabina was explicit in recognising the value of curiosity as important for her students' scientific literacy:

> *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 use this [knowledge] in their everyday life as well. So, you see, curiosity is important for scientific literacy.*

As is evident in the comment above, Sabina valued curiosity in her teaching because it prompts students to ask questions which in turn, may lead them to explore different resources to extend their science knowledge. Sabina expected that the knowledge they get from these resources could help them answer their questions as well as potentially being useful in their everyday lives.

Sabina felt that she could promote students' curiosity through constantly asking questions of students and encouraging them to ask questions as well. It was observed in her teaching of acids that she asked students questions, examples of which follow:

> *Have you heard about acid or alkali?*
>
> *Do you know you take acids as food?*
>
> *What is the chemical name of edible soda?*

It seemed that the questions above, prompted students to answer the questions rather than encouraging them to identify and explore their experiences of acids in everyday life. Moreover, as observed, she did not encourage students to ask questions themselves. Rather she took the view that if she "ask[s] students questions, they will in turn learn to ask questions themselves" and this could promote curiosity. This view could be reasonably considered her attempt to role model asking questions so that this may be seen by students as a good thing to do. However, as such questions seemed to have simply prompted students to answer the questions rather than stimulating further inquiry, they seemed unhelpful in promoting students' curiosity.

Whilst most of the 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 is seen in Sagar's comment below, curiosity led him to seek the reason for the change in colour of litmus in acidic conditions.

> *Sagar: 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 of the students to generate questions as a result of their curiosity may question Sabina's views and teaching practice for promoting students' curiosity.

6.4.3.2 Rational thinking.

Considering the interviews with Sabina and after observing her teaching, it appears that she valued rational thinking as an important aspect of scientific literacy because she believed this value could help students "make justifications", which could in turn help them make a well-informed decision. Moreover, she advocated the importance of rational thinking for eradicating the superstitions that are embedded in Bangladeshi society:

> *Scientifically literate students will value being rational in every step in their lives. In villages, people believe in many irrational things that we may call superstitions. Students can analyse them [superstitions] rationally and can prove them false. Most of my students come from remote villages. Many of their family members are not formally educated, so they often have beliefs in superstitious things. My students can make their family members and others aware about these superstitions. I can give you an example of such superstition. Last year, one of my students told me that she heard [from someone] that if one does not say Bismillah*[3] *before eating something, 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.*

The above comment illustrates how the reason for an acidity problem was explained in scientific ways that Sabina considered challenged the superstition about stomach acids. Sabina expected that rational thinking would help her students decide which explanation (scientific explanations or the superstition) is more plausible and fruitful to adopt. Moreover, observation of her classroom teaching showed how Sabina intended to promote rational thinking among her students.

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[3] "Bismillah" is an Arabic word and the meaning is "In the name of the Allah (God)". As a religious convention of Islam, Bismillah is said as a blessing before eating food and other actions that are worthy of giving thanks to God or asking of His support.

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 appeared in the above classroom conversation, Sabina asked Benu to present her "justification" for considering acid as sour. Benu described the way of thinking that she had followed in deciding about the taste of acid, and this was acknowledged as "good justification" by Sabina. This notion of valuing justification was also reflected among her students. Here are two students' comments from the focus group interview as follows.

Benu: Madam (Sabina) always encourages us to talk rationally. When I go to say something, she will ask me to justify it.

Abu: There is a superstition that if you eat pineapple after taking milk, you may die from the 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 more 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.

Benu's comment above, reflected 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 helped him to explain a superstitious belief regarding acidity. It seems from this comment that he was more convinced with the scientific explanation that he got from his science learning. This could be seen as an indication of the valuing of rational thinking as perceived by Abu.

6.4.3.3 Respect for others' opinions and Open-mindedness.

Sabina was explicit in recognising the value of respect for others' opinions in her pre-lesson interview:

> *In group work, they [students] will listen to others and practice respecting others' views. This is very important, you see, people in my country often don't respect others' views. If one's view is different to them, they often attack one personally. But everyone has the right to express views. If my students learn valuing respect for others' views in science class, they will not attack anyone personally for holding a different view.*

As is evident in the comment above, Sabina perceived the value of respect for others' opinions as "very important" for Bangladeshi society, as she thought it was not common in Bangladesh. She expected that in the long run her students would respect their counterparts' right to express views in group activities.

Whilst Sabina did not make any explicit comment about open-mindedness in her interviews, observation of her teaching lessons suggested that she valued open-mindedness in the science class. Observation indicated that her approach to engaging students in group discussion included explicit encouragement of students to express alternative views to an idea. In addition, she encouraged others to think about the alternatives. This encouragement was also evident in the students' focus group interview as follows.

> *Arun: I would oppose their [other students'] ideas and present mine. You know, every person is different; they have different ideas and they can see a thing differently. So I don't think I would go to hurt them. But I must present what I know and will rethink about this [his idea].*

In responding to the probe "what would you do if your classmate gives an idea that you think is incorrect", Arun suggested that he would present his view and oppose his classmate's idea. In addition, acknowledging the diversity in people's ideas, he was open to revising his existing idea. This acknowledgment of diversity in people's ideas and the openness to revise an existing idea may be seen as a notion of open-mindedness that also led him to respect his colleagues' right to express ideas that were different from his. It also implies that the classroom atmosphere would permit such exploration.

6.4.3.4 Intellectual honesty.

In the interviews, Sabina could not articulate her notion of intellectual honesty in science education, nor did observation of a series of her classroom lessons provide any instance of her consideration of intellectual honesty. For example, she did not explicitly (or even implicitly) encourage students to report an experiment honestly or to communicate a conclusion consistent with the data. Therefore, it would be reasonable to argue that there had been no consideration of intellectual honesty in Sabina's science classes.

6.4.4 Challenges encountered.

The post-lesson interview with Sabina elicited the challenges she felt she encountered in her teaching for scientific literacy. One such challenge was content knowledge in science:

> *My academic background is biology, so I feel more interested and confident in teaching biological content. I am not confident about my theoretical understanding about some physics and chemistry topics. … Sometimes, I am not sure about the possible applications of many physics and chemistry topics in everyday life that I could present to students. [In such cases], I just follow the textbook.*

As noted previously, the General Science course includes content from physical sciences, biological sciences and earth sciences. Sabina was not confident with her content knowledge in physical sciences since this was not her academic background. It is therefore not surprising that she would be less interested in teaching the physical science content. Moreover, she struggled with finding possible applications or uses of physical sciences content that she could present to students. In such cases, due to her lack of confidence, she presented science to students as it was represented in the textbook. This practice may have reinforced Sabina's reliance on the textbook.

Moreover, the "overloaded" General Science syllabus, coupled with the exigencies of limited time, forced Sabina to rush through the syllabus and left little time for reflecting on her teaching. This, she maintains, results in failure to monitor students' learning adequately:

> *I cannot assess my students to see how they are learning. You know, our syllabus is overloaded. I have to complete this within a very limited time as school contact hours are short. [Moreover,] schools remain closed due to various unavoidable and unwanted circumstances. This time constraint hampers my teaching. I often cannot give them feedback after assessment. On one side, I cannot monitor their learning, and on the other side, they cannot monitor their learning either.*

Sabina also believed that examination practices in her school were a challenge to her teaching. Like in many rural schools in Bangladesh, examinations to assess Sabina's students are developed by an external local board. These exams conventionally measure students' ability to recall science knowledge rather than their ability to apply science knowledge in everyday situations. As the test scores are used to measure the quality of her teaching and the achievements of the school, she is often driven to prepare her students for this traditional type of exam:

> *I have no right to make students' exams, you see. Exams are made by a board that prepares the traditional exams. No application, just memorisation of a large amount of factual content. … But the students' results are important. The school and parents want them [students] to do well. It is important to me as their teacher as well.*

Moreover, there is no practical exam in junior secondary level and therefore, Sabina's students did not have access to the school science lab, which was also limited ("poor", according to her) in its facilities. Whilst Sabina involved students in testing acidity using different household items, she was afraid that this limited lab access might hamper student learning and decrease their interest in science:

> *No practical exam, so no lab work. … You see, today I taught about the properties of acid. The syllabus suggests students will do some experiments on this. I used some household items to do some experiments but I could not give them the lab access where it was necessary. I just recited the procedures and findings from the textbook, for example, if acid reacts with a metal, salt and water is produced. They could not do the experiment and I could not even show them [the experiment]. Perhaps, they would just memorise this. This learning may not last long. Also their interest in science may be decreased.*

Sabina also saw her students' intellectual ability as a challenge in her teaching:

> *Some are very weak. They just want to pass. Some are good. They want to learn. It is very difficult for me to balance the needs for these two groups.*

However, there was no evidence on how Sabina responded to this issue; rather, she pointed out in the interview that responding to this problem is beyond her capacity.

Therefore, it would be reasonable to assume that this issue would remain in her teaching and impede her efforts to promote scientific literacy.

6.5 Case 2 – Alam

6.5.1 Introducing Alam.

Alam, a male, teaches in a renowned coeducational secondary school in the capital city in Bangladesh. He started his teaching career in this school and has been teaching for 13 years. He holds a master degree in science with chemistry as a major. He also holds a Bachelor in Education that he pursued in his in-service teaching career. In his in-service teaching career, he also completed two short-term professional development courses organised by the TQI–SEP Project. One of these courses was on teaching science, while the other focussed on teaching mathematics. His workload includes conducting about 20 classes per week. His teaching of science in Grade VIII (three lessons on the textbook unit "gravitation and gravity") was observed. He had 50 students in his Grade VIII science class.

6.5.2 Alam's perspectives of scientific literacy and teaching approaches.

Alam perceived that the purpose of science education is to build a nation with skilled manpower for working in science-related professions in the modern age:

> *Science is controlling the modern world. You cannot cope with this world without the knowledge of science. Can you imagine a country with no doctors or engineers? It is science that makes sure [of] the supply of these kinds of professionals. So, students need to study science very well so that they can become science professionals. When a student is able to work as a science professional, I'll call him/ her a scientifically literate person.*

It seems from the above comment that for Alam, the goal of science education is developing scientific literacy; however, he perceived scientific literacy to be equated with being able to work as science professionals. This perception of scientific literacy is somewhat at odds with the currently accepted notion throughout the science education community. Such a perception may persuade Alam to take care of the future science career group more than providing a good foundation in science for all students so they may become effective citizens. As he saw it, his students need to be actively encouraged to consider science related professions for their career purposes. In the pre-lesson interview, he explained,

> *If we don't educate students in science, the country will suffer from inadequate science professionals. If you don't have enough doctors, your health sector will be in trouble; if you don't have enough engineers and technicians, your industry sectors will be in trouble. I don't think it is possible to maintain your country's development without the knowledge of science. So, as a teacher, my duty is to encourage my students in this concern.*

The translation of this view into practice was observed in Alam's teaching, in which on a number of occasions he attempted to encourage his students to consider science-related professions. Here is an illustrative quote from Alam's classroom lecture.

> *Studying science will expand your career opportunity. You have lots of things to do. Look, you are learning about gravitational force. This learning will help you if you want to study space science. Being a space scientist is very prestigious, isn't it?*

Moreover, as was observed, most of Alam's classroom discussion was devoted to explaining Newton's laws of gravitational force, Galileo's experiment of falling bodies and distinctions between mass and weight. His students revealed in the focus group interview, that they had difficulty in articulating how learning such things could be useful in everyday life. Rather, they expressed the value of learning science in relation to their future career purposes. Here are two such examples.

> *Atif: You are studying science and you have lots of things to do. You can be a doctor, you can be an agriculturist, you can be a computer engineer, and many more. When you have these prestigious occupations, then people will say you have done very well.*

> *Mita: I want to be a space scientist and work at NASA. So, it [learning about gravitation and gravity] is important for me.*

As Atif's comment above shows, learning science opens a range of occupations that are regarded as "prestigious" in society. It is interesting to note that the teacher, Alam, had encouraged students to consider science related occupations after labelling them as "prestigious" during his teaching of science, which was echoed in his student Atif's comment. In a similar vein, Mita reiterated the importance of learning about gravitation and gravity for her career aspiration that was first expressed by her teacher, Alam.

As an exception, Nabila, in the students' focus group interview, articulated how science learning in school could be useful in everyday matters, for example, in making decisions about health matters and using simple machines to make everyday work easier.

> *Nabila: Science is all around us. Wherever we go, whatever we do, there is some science. Science gives us better life and comfort. If we know about health science, it will help make decisions about health matters and can keep our body well. If we know about simple machines, it will make our work easier. I saw people using an iron rod to lift heavy stuff up from the ground. But I didn't know why people use an iron rod for this. In the "simple machines" chapter, I have learnt that the iron rod is used as a lever and the working principles of a lever. Now I know how an iron rod makes work done easier by increasing the force.*

Nabila, however, as with other students, could not articulate how her learning about gravitation and gravity could be useful in everyday matters.

From the above discussion, it appears that both Alam and his students perceived the importance of learning science in school for career purposes. Whilst one of the students added the importance of learning science in everyday matters, students mostly found difficulty in articulating how their science learning could be useful in their everyday lives. This could be viewed as an indication of the limited effort that had been paid to making links between school science learning and students' everyday life in Alam's science class.

6.5.3 Values considered in relation to scientific literacy.

Among the five values intended in the junior secondary General Science curriculum and focussed on in this research, four values were considered in Alam's science class: curiosity, rational thinking, open-mindedness, and respect for others opinions. It is interesting to note that, as for Sabina, the value of intellectual honesty was also missing in Alam's science teaching. In the interviews, Alam could not articulate his notion of intellectual honesty. Observation of a series of his classroom lessons also failed to provide any instance of his consideration of intellectual honesty. Therefore, it seems that Alam did not pay importance to the value of intellectual honesty in his science teaching.

6.5.3.1 Curiosity.

Alam was explicit in recognising the value of curiosity as important in his teaching of science:

> *I see my students are very curious. Many of them spontaneously ask questions like "why" and "how" when I teach them. When students come with questions like "why" and "how", it seems they have the spirit to learn. So, I use curiosity as a motivator to leaning science. I think, if I can sustain their curiosity in science class, this will help them to learn science very well and that will make them able to become science professionals.*

In the comment above, Alam articulated how sustaining students' curiosity could motivate students to learn science and become science professionals. Since Alam's perspective of scientific literacy, as noted in the previous section, is associated with taking up a science related profession, it seems that he perceived the importance of curiosity for his perspective of scientific literacy. The above comment also illustrates his recognition of his students' curious nature, which was also elicited from the students' focus group interview, where a student commented that

> *Meem: I come up with questions like, what is happening? How? Why?*

Alam articulated his approach to promoting students' curiosity by provoking their thoughts and exemplifying scientists' curious nature found in the stories of scientific discoveries:

> *I try to begin a [science] lesson with a question or statement that can stimulate their thinking. Sometimes, I also try to tell them story of a scientific discovery that includes the scientist's curiosity.*

Observation of Alam's science lessons elicited an example of how he provided students with a story of a scientific discovery. Here is the example,

> *When you throw something up, what happens? It falls to the ground, doesn't it? Do you know why it 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.*

Whilst the veracity of this story is not beyond debate (Keesing, 1998; Patricia, 1999), this could be seen as an example of how an incident can cause people to wonder about the reason behind the incident. In presenting this story to students, there might have been opportunities that could be considered to promote curiosity. For example, as is seen in the above, Alam asked students what happens if something is thrown up and the reason for it. However, he did not leave any time for students to think about the matter, nor did he give any space to them to present their thoughts. Rather he took the view that his own asking of such questions would stimulate students' curiosity. This view could be considered as naive as it does not encourage students to raise their own questions from their experiences. This naive view may be seen as failing to promote students' curiosity.

6.5.3.2 Rational thinking.

Alam considered rational thinking as an important value of science education. In the pre-lesson interview, he recognised the importance of rational thinking in the following way.

> *Why do people believe in irrational things? Why do people believe that some sort of hair oil sold on the footpath will help grow hair on a bald head? It is because some people cannot think rationally. Look at science and scientists. Scientists follow systematic steps for scientific investigations. You can't change the steps. There is nothing you can say that is irrational. A person who learns science will think in such a rational way. So students need to perform experiments.*

As the above comment illustrates, Alam perceived that rational thinking would help prevent people accepting irrational things and he expected that science learning would help people develop rational thinking. In particular, he asserted that performing experiments by themselves would help students develop rational thinking. However, the comment also illustrates his belief in a universal scientific method that he thought is rational and is followed by all scientists in their investigations. It seems that Alam had a naive perception about scientific practice in which there is a recipe-like stepwise procedure typifying all scientific investigations. This perception could also lead Alam to adopt a teaching approach comprising cookbook or recipe-like experiments. However, there was no evidence of involving students in performing experiments found in his teaching practice as observed, and certainly none where they developed their own experiments. Students, in the focus group interview, also confirmed that they were not involved in performing experiments in their science classes. For example,

> *Atanu: We want to do experiments ourselves. There are many experiments in the science textbook. If we do not do the experiments and see the results, how will we learn those? But we do not do the experiments in class.*

It seems from the above discussion that Alam neither practised in his teaching his own perceptions of the way to promote rational thinking in science classes, nor had a full understanding of the range of ways scientists practise scientific inquiry.

6.5.3.3 Open-mindedness and Respect for others' opinions.

Alam recognised open-mindedness and respect for others' opinions as important values in his science classes. Here is an illustrative quote from his interview.

> *Sometimes I had noticed tension among the group members. This usually happens when group members cannot come to consensus on an issue. I try to maintain a group environment where everyone has the chance to speak out and all must have to listen to what others are saying. Different individuals may see a thing differently. You may get a different view from others that you might not have thought about before.*

In the above quote, Alam articulated how he encouraged students to share their views and consider others' views in group activities. This encouragement may help students appreciate everyone's right to express their views and eventually promote the value of respect for others' opinions. In the above quote, Alam also recognised the diversity in peoples' views. This recognition is reflected in his encouragement of students to listen to other group members' views. In listening to others' views, they might identify possible alternatives for looking at an issue and be encouraged to consider these alternatives. This encouragement may help students become more open to alternative views and thus may promote open-mindedness.

However, observation of a series of his classroom teaching sessions did not provide any instance of how Alam incorporated his abovementioned notions of open-mindedness and respect for others' opinions into his teaching practice. Moreover, conversation with students in the focus group interview elicited the view that their teacher, Alam, was not respectful towards students' ideas. Here is a student's comment:

> *Asad: If the sun is the source of energy, then everyday sunlight is coming and it is adding to the existing energy. So, there should be an increase of energy. But the law of conservation of energy states that the amount of energy is fixed. How is it possible? I asked Sir [Alam] about this. He was very disturbed and asked me to not to be asking him such a "stupid" question.*

As is seen in the comment above, Asad showed a sceptical view about the law of conservation of energy. The view, perhaps, may represent an alternative view about this law. His teacher, Alam, however, did not take into account this alternative view and considered this view as a "stupid" one. Such an explicit disregard of students' alternative views may inhibit students from presenting their alternative views in the classroom, or from trying to make sense of scientific ideas. This may also build confusion among students about whether they should show respect for the right of younger and less experienced people to hold and express their views (as they are younger and less experienced than their teacher).

6.5.4 Challenges encountered.

The post-lesson interview with Alam elicited the challenges he perceived he faced in his teaching for scientific literacy. These challenges included the overloaded curriculum, limited time, insufficient laboratory facilities and mixed-ability student groups.

Alam considered as a challenge the General Science course to have "a huge syllabus" that could not be completed in the allocated time. But he did not articulate any strategy to overcome this challenge. He also considered the allocated time for the General Science course as insufficient and perceived this as a challenge in his teaching.

> *My science class is just 35 minutes. I have to do all the things in this time. Sometimes, I do hurry to finish a topic anyway; I also skip some. The thing becomes worse when I try to involve students in group discussion. I feel, I don't give them enough time for a good discussion. I have to force them to finish as the clock is banging in my mind.*

As apparent in the above comment, the limited time allocated to the General Science course led Alam to rush though the topics. Also, whilst an attempt to involve students in group discussions could be useful in promoting open-mindedness and respect for others' opinions, he felt that limited class time necessitated restricting his students from conducting a "good discussion". However, whilst Alam recognised the overloaded General Science course and limited time allocation for this course as challenges in his teaching, he was not able to exemplify how he responded to the issues. Rather, his comment in this respect, "what can I do?", seems to reflect his notion of seeing himself as subject to external forces such as the course curriculum and time allocation.

Alam also remarked that failure to provide lab access to students was a challenge in his teaching science:

> *When you are learning science, it is obvious you are doing some experiments in the lab. You will then learn how a scientist works in a lab. School lab is not for the students below the secondary level. How will they learn science properly?*

It seems that Alam appears to have the notion that science work only happens in laboratories. This notion may be seen as his naive view of the way scientists work and may restrict him from involving students in hands-on activities that can be organised without laboratory support. Moreover, in the interviews, he could not articulate his strategies to address this challenge.

Alam identified the mixed ability class as a challenge in his teaching, as he perceived difficulty in attempting to meet the needs of all students in his class. In his words,

> *Some students have learned the earlier content very well, some haven't. If I move forward, some can't keep track with this. They need repetition of the earlier content and mostly I do so. But some get bored with this and they are not willing to go through this again and there is a tension regarding this.*

As the comment above shows, Alam perceived that in his class some students need to go through a repetition of earlier content, but some students do not need such repetition and thus they show reluctance to engage in the repetition. In order to respond to this issue, Alam took a small group approach and made student groups with students from different academic abilities:

> *I had carefully placed the students into groups according to their merit. For example, I had made a group with students whose class roll numbers[4] were 1, 11, 21, 31 and 41.*

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[4] In Bangladesh, every student in a Grade has a roll number that is based on his academic result in the earlier Grade. For example, a student who gets the highest marks in Grade Seven examinations is allocated roll number "1" in Grade Eight. In this manner, in Bangladesh, class roll numbers often are considered as an indicator of students' academic ability.

> *In this way, brighter students could get the chance to work with less able ones and help them to understand earlier content.*

Based on the academic results Alam categorised his students into five groups (for example, students with class roll numbers 1 to 10 in one group, roll numbers 11 to 20 in another group, and so on) and made up student groups with one student from each of these groups. If the class roll number is considered as an indicator of a student's academic ability, it is reasonable to consider that in this manner, Alam made mixed ability student groups where the "brighter students" could be involved in helping the "less able" ones. Also, Alam believed that in mixed ability groups "the weaker student may also have some distinctive things that others can learn, such as leadership or creativity". It would seem, therefore, that Alam's perspectives and strategies regarding mixed ability student groups were focussed on developing support, mutual respect, understanding and tolerance among students and thus were likely to help promote the value of respect for others' opinions.

An overview of the above discussion related to Alam's perceived challenges encountered in his teaching science indicates that whilst he responded to some challenging issues, there were a number of issues that he felt he could not respond to. It is reasonable to conclude that if he is not able to address the issues, they would remain as a problem in his teaching.

6.6 Case 3 – Ashim

6.6.1 Introducing Ashim.

Ashim is a male who has been teaching science in a rural secondary boys' school in Bangladesh for 10 years. He holds a degree in science. In his in-service teaching career, he completed a short-term (40 days) professional development course organised by a non-government organisation, Bangladesh Rehabilitation Assistance Committee's (BRAC) Post-primary Basic and Continuing Education programme. This course sought to develop a community based rural information technology (IT) system through which children and adolescents could become familiar with IT and its various applications. His workload includes conducting about 32 classes per week. His teaching of science at Grade VIII (three lessons on the textbook unit "acids, alkalis and salts") was observed. He had 100 students in his Grade VIII science class.

6.6.2 Ashim's perspectives of scientific literacy and teaching approaches.

In the pre-lesson interview, Ashim acknowledged his lack of familiarity with the term "scientific literacy". However, his responses to the question about what he expects from school science education were useful to understand his perspectives of scientific literacy. At first, he described the purpose of school science education as being to provide students with knowledge to deal with everyday issues. He explained,

> *Many of my students are the first generation of [formal] learners in their families. Their parents do not know many important [everyday life] issues. So, they [students] do not have opportunities to learn these issues from their families. For example, when they come to science class, I often teach them about basic cleanliness, hygiene, sanitation, and such kind of health and environment related issues. They will then pass it to their families and they will become aware.*

As is seen in the comment above, Ashim made a point that science education in school helps his students to develop knowledge about basic health and environment related issues. He emphasised that since many of the students' family members might not have knowledge about these issues, the students would be able to convey the messages to their families and help them in developing awareness in these issues. In Bangladesh, more than 50% people do not or cannot go to school (BANBEIS, 2006a) and they often do not have the opportunity to learn about many science-related everyday issues. As a result they lack knowledge about many significant everyday issues, for example, basic cleanliness, hygiene and sanitation. As Ashim expected, if their children are taught about these issues in school, this knowledge could be transferred to their parents.

Ashim also noted that the purposes of science education in school include preparing scientists and science professionals for the country. In his words,

> *No country can run without scientists and science professionals. Look, the development level of a country is associated with the number of these people, such as, doctors and engineers. So, science is the key to the development of our country and thus we should encourage students to take up science related careers.*

It seems from the above comment that Ashim perceived science as playing a major role in the development of a country, and therefore perceived the number of science-related people (e.g., scientists and science professionals) as associated with the notion of development. As was observed in his classroom teaching, he encouraged students to consider science related professions for their career purposes. By way of encouragement he told students a story of a scientist who studied in his school:

> *I'll tell you about a former student of our school. His name is Bijon Kumar Sheel. ... He invented a vaccine for goat plague and became renowned in the field of science. ... 30 years back, Bijon Kumar was a kid like you. Study science well, you may prosper like him.*

In this excerpt from the class lecture, Ashim took the view that students would be encouraged to study science and consider science related professions if they learnt that someone from their school had become renowned in the field of science. The focus group interview with his students revealed that such stories could indeed encourage some of them to study science at upper level and consider science related careers. Here is a student's comment in this respect.

> *Babu: Many ex-students from this school have done very well in life. There are many scientists, engineers, doctors and agriculturists. Sir [Ashim] knows many of them and tells us about their life and work, for example, Dr. Paul. I want to be a doctor like him.*

Babu expressed how he was encouraged to consider a doctor's profession as his career aspiration, however, some students argued it was not necessary to consider science in their career aspirations. For example,

> *Ovi: There are many things to do if I don't go with science. I'll look after my father's shop. So, I don't need science.*

It seems from Ovi's comment above that he thought about science only in relation to careers. As he was not interested in taking a science related career, he thought he did not "need science". This in turn indicates his limited capacity to see science as useful in everyday life. As students' experiences of science in school are a contributing factor in developing their notion of science (Lyons, 2006a; Osborne & Collins, 2000b, 2001), Ovi's limited capacity to see science useful in everyday life might be related to his experiences of science in school. It was observed in Ashim's classroom teaching that he went to great lengths to explain the chemical properties of salts and associated chemical reactions and equations. In addition, he alerted the students to the consequences of iodine deficiency for human health and the importance of eating iodised salt. In the post-lesson interview, he explained the reason for this focus:

> *Chemical reactions and equations are important to know. They [students] have to know them for the exams and for their future [science study]. But I also discussed about iodine*

> *deficiency. This was not in the syllabus, but I did so, because I know many of the students do not know the health hazards due to the shortage of iodine. This health problem is very common in our north Bengal. The students can then help make their families aware about this.*

As the above comment shows, Ashim emphasised the importance of learning about academic content (e.g., chemical reactions and equations) for the exams and for further science study, yet he also saw value in helping students develop an awareness of health-related scientific knowledge that could also be transferred to their families. The focus group interview with Ashim's students revealed their notion of the matter of iodine deficiency in human health that had been discussed in their science class. For example, Tapu's comment below showed his willingness to share his notion of iodine deficiency to others in ways that might help raise awareness.

> *Tapu: If there is a deficiency of iodine in body, it may cause goitre, and so, we need to eat iodised salt. I'll pass this information to others who don't know this.*

However, many students, in the focus group interview, asserted that most of their learning in science classes was not useful in life as no direct use could be envisaged for the learning. Here are two student comments in this respect.

> *Moti: Science is very hard. It's not for me. It's very hard to memorise the chemical reactions. If I make a small mistake, I'll get zero.*
>
> *Ovi: It is hard and I don't know how it is useful in life.*

Academic content such as chemical reactions was perceived as "hard" to Moti as seen in the above comment. Ovi, in addition, indicated the limited connectedness of such content with life. It seems, both of them saw limitations to the immediate use of such content in life (except passing in the exams), and as a result, they found it difficult to make connections between science and their lives. Moti perceived the need to memorise content for the exams focussed on accurate answers. As scientific literacy requires less focus on memorisation (Goodrum, 2004) than on contextual application and problem solving, Moti's point about the rote nature of science learning could be viewed as showing the teaching/learning in his class to be at odds with the notion of scientific literacy.

6.6.3 Values considered in relation to scientific literacy.

6.6.3.1 Curiosity.

In the pre-lesson interview, Ashim acknowledged the importance of curiosity in learning science, as curiosity prompts students to ask questions that lead them to find actions to answer the questions. In his words,

> *Curiosity brings questions and then it generates action to answer the questions. It is necessary to learn science.*

However, observation of his classroom teaching practice revealed that on a number of occasions he did not consider students' questions; indeed, on some 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. 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.*

Whilst Ashim acknowledged the importance of curiosity in science learning and considered the place of students' questioning in promoting curiosity, he also viewed students' questions as responsible for hampering classroom quietness. This practice of maintaining classroom quietness would likely discourage students from raising questions in science classes.

Though Ashim discouraged the asking of 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.

> *Akil: I wonder why spraying water extinguishes fire. I asked my cousin and he explained to me.*
>
> *Mizan: 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 got the explanations.*

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

6.6.3.2 Rational thinking.

Ashim perceived rational thinking to be an important value for scientific literacy. In the pre-lesson interview, he recognised the importance of rational thinking in the following way.

> *Scientifically literate people practise rational thinking in every step in life. When they talk something, they justify it; when they do something, they have the rationale; when they get an idea, they seek the justification. They make decisions [about an idea] based on the justification; they suspend the idea if it is not justified.*

To further demonstrate his view of the importance of rational thinking in every aspect of life, Rashid showed the scientific reasoning behind his rejection of one aspect of a local saying – the reason given for avoiding bathing in water.

> *There is a saying that if you take bath in a water place where laundrymen wash clothes, you will be born as a donkey in reincarnation[5]. So, people often avoid taking a bath in a water place where laundrymen wash clothes. But see, if you think about this issue rationally, you will get the scientific explanation. It is obvious that water is not clean where laundrymen wash clothes; many germs come out from the dirty clothes and mix up with the water. These germs may cause skin problems if you bathe in this water. So, this is the justification to reject the local saying.*

In above comment, Ashim exemplified a local saying and made the case for rational thinking to justify the plausibility of the local saying. He perceived that rational thinking would provide people with scientific explanations, which would act as the basis of justification for accepting the advice but rejecting the supposed consequences if the advice went unheeded.

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[5] Reincarnation refers to a belief that there is no death of the soul, and after the death of the body the soul comes back to life in a new born body. In Hinduism, reincarnation is related with the person's action that carries with it consequent liabilities, by which the person is either hampered (e.g., rebirth as a donkey) or enlightened (e.g., rebirth as a Brahmin) (House, 1991).

Despite these views, Ashim could not articulate how he considered rational thinking in his teaching practice, nor did observation of three of his teaching lessons provide any evidence of his efforts to promote this value. Rather he took the view that

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

As seen in Ashim's comment above, rational thinking would be developed in students as a by-product of science education and would not need any effort from the teacher. This view could be seen as an indication of how little the value of rational thinking explicitly framed his teaching.

His students, with no exception, in the focus group interview, could not recognise how rational thinking is considered in their science classes. For example, none of them could articulate how their teacher encouraged them to speak rationally, and hence they demonstrated the lack of consideration of the value of rational thinking in their science classes.

6.6.3.3 Open-mindedness and Respect for others' opinions.

In the pre-lesson interview, Ashim regarded open-mindedness and respect for others' opinions as two "good human qualities"; however, he believed that his science classes did not have the scope to promote these two values. As he explained,

> *You see, scientific ideas are proven facts. There is only right or wrong when you are talking about science. You can't be open-minded or respectful towards something that is not right.*

Viewing scientific ideas as "proven facts" Ashim disregarded the scope for being open-minded and respectful of others' opinions in science. The above comment also reflects his view of science as an objective element. This view was extended in the following comment:

> *You can interpret a social issue in various ways. But when you are talking about science, you can't do it.*

The above comment illustrates Ashim's perception of the inappropriateness of considering different ideas in science. This perception would also restrict students' ability to pose different ideas in science classes. His students, in the focus group interview, expressed their unwillingness to pose ideas in science classes or consider ideas posed by their classmates. For example, a student, Mizan, responded as follows to the probe "what would you do if your classmate gives an idea in your science class that you think is incorrect?"

> *Mizan: Scientists give the ideas. We need to understand their ideas. We are not scientists, so we can't give our idea on them.*

Mizan made a point that science is only the territory of the "scientists". It seems from the comment that he might not be respectful to his classmates' ideas if they were provided in science classes.

6.6.3.4 Intellectual honesty.

Like the teachers in the previous cases (Sabina and Alam), Ashim could not articulate his notion of intellectual honesty in science education. Similarly, observation of a series of his classroom lessons provided no insights into how he considered intellectual honesty in science classes.

6.6.4 Challenges encountered.

The post-lesson interview with Ashim elicited the challenges he encountered in his teaching for scientific literacy, one of which was the backdated and irrelevant content in the science textbooks:

> *Textbooks are not good for scientific literacy. Much of the content in science textbooks has no application in current real life issues. We are still teaching students about simple Voltaic Cells that I learned about 20 years back in school and there are no advances. Students are happy to study things that they find relevant with their life. Interestingly, there is little content about computers, but learning about computers is very important nowadays.*

Ashim made the insightful point that school science textbooks fail to embrace contemporary content and advances of science, suggesting that such content would be seen as irrelevant to students as they cannot see its applications in real life issues. In particular he expressed his dissatisfaction about the paucity of computer-related and IT content in science textbooks, which prevented him from using his professional training to familiarise children and adolescents with IT and its various applications in real life. Indeed, he argued that the absence of IT may contribute to decreasing students' interest in science. In his words,

> *I have training to familiarise children and adolescents about IT and its applications in real life. But there is no discussion in the science textbooks on IT and I can't use my training to make my students familiar with IT. How do they get interested in science? It [interest in science] will be diminished.*

However, Ashim claimed that wherever possible he discussed applications of science so that students could see the relevance of science in real life:

> *Wherever possible I try to discuss with students about applications of science and help them see the relevance of science in real life. Our school library has some science related*

> *books for children. I encourage them to borrow these books and read at home. These books can help them see the links of science with society.*

Ashim's encouragement of students' reading of science related books, along with his emphasis on science's applications may help students extend their science knowledge and see the connections between science and society.

Observations of Ashim's classroom teaching practice suggested that he mostly depended on a lecture method. In the post-lesson interview, he viewed large class sizes as a reason for depending on a lecture method and saw this as posing a challenge to his teaching for promoting scientific literacy.

> *I have 100 students in my class. I can't take care of every student. Even sometimes I can't answer students' questions. I just try to explain things through lecturing. I know this may not be good for scientific literacy.*

In responding to this issue Ashim employed the small group discussion approach which he also saw as unhelpful:

> *I thought discussion in small groups could be a good approach for my large class. When I put five students in each group, there were 20 groups altogether. I couldn't look after 20 groups. I noticed students were just chatting in groups.*

As is seen in the above comment, the large number of students in Ashim's class resulted in a large number of student groups that became unmanageable for him to look after. Given the situation, he again went back to lecturing, which he perceived as not useful for promoting scientific literacy.

Ashim also perceived the mixed ability class as a challenge in his teaching as he had difficulty in addressing the needs of students with different abilities. In responding to this issue, he proposed to divide the class into three sections based on students' academic ability. In his words,

> *I can't address the needs for all students because their abilities are different. I proposed making three sections with students of specific academic abilities. A category students would be in one group, B category would be in another group, and so on. But the [school] authority didn't listen to [my proposal] as there are not enough science teachers in our school.*

A further consequence of the insufficient staffing for science made it necessary for Ashim to take on a workload that restricted him in getting prepared for the science class. In his words,

> *I have more or less six periods in each day. No time to get prepared for the next class. I just finish in Grade Six and am running for Grade Eight. But what I can do with this?*

Whilst Ashim perceived his workload as a challenge in his teaching, he could not articulate how he could address the challenge. Rather he saw it as a systemic issue and expressed his incapacity to address this challenge in his comment above. It would be reasonable to consider that this sense of incapacity may result in the issue persisting in his teaching of science.

6.7 Case 4 – Morshed

6.7.1 Introducing Morshed.

Morshed is a male science teacher in an urban secondary boys' school. He has been in teaching for 18 years. He holds a master degree in science with Applied Chemistry as a major. He has a Bachelor in Education from the National University, Bangladesh. In his in-service teaching career, he completed three short-term professional development courses organised by the TQI–SEP Project. Moreover, he works as a master trainer for the TQI–SEP. His workload includes conducting about 24 classes per week. His teaching of science at Grade VIII (four lessons on the textbook unit "symbol, formula and valency") was observed in this research. He had 65 students in his Grade VIII science class.

6.7.2 Morshed's perspectives of scientific literacy and teaching approaches.

Morshed perceived scientific literacy as an ability to apply science knowledge in everyday matters. As he explained,

> *In general, scientific literacy means a scientific orientation. This orientation includes getting science knowledge and applying science knowledge in everyday matters. So, for scientific literacy it is important to know the application of science knowledge in everyday matters. For example, we teach students about carbon dioxide. Why is this knowledge important to students? Carbon dioxide is used to extinguish fire. So, I would call them scientifically literate if they know the use of carbon dioxide in extinguishing fire and apply this knowledge to solve a fire problem.*

As is seen in the above comment, Morshed perceived the importance of getting science knowledge that has use in addressing real life problems. This perception, eventually, shaped his notion of scientific literacy, where he characterised a scientifically literate person as one with an ability to apply science knowledge in solving real life problems, for example, fire hazards.

As was observed in Morshed's teaching practice, he started his first lesson of the unit "symbol, formula and valency" with a statement that they are "fundamentals to study chemistry". With this statement, he added,

> *You might have seen a red cylinder in petrol stations or cinema halls. CO_2 is written on the cylinder. If you don't know what CO_2 means, you will not be able to use it when it is needed. ... You need to know about the formula of compounds when you go to buy medicine. The ingredients of a medicine are written in terms of the chemical formula on its label. If you are familiar with the formulas, then you can understand the properties of medicine you are taking.*

In the above classroom lecture excerpt, Morshed discussed the purposes of learning about the chemical formulas in real life. As the quote illustrates, he argued that people would need to know the chemical formula of carbon dioxide in order to use a carbon dioxide cylinder. However, this point seems to be somewhat impractical, because usually the names of the compounds in the cylinder are written in full form and thus one may not need to know the chemical formulas to use the cylinder. What may be needed instead is an individual's reading ability to understand what is written on the cylinder rather than chemical formula itself. Moreover, Morshed's expectations referring to students' ability to understand the chemical properties of medicine with the knowledge of chemical formula gained in science classes was also viewed as overoptimistic for school students because of the high level of chemical knowledge used in the pharmaceutical industry. The focus group interview with students also reflected their inability to understand the properties of medicine with only their school level knowledge. Such a comment follows.

> *Sumit: I looked at some labels [of the medicine], but I could not understand the formula. They seem very hard [to understand].*

Instead of seeing the importance of learning about chemical symbols and formula in real life, students in general viewed the importance of learning about such content for studying chemistry. Here are two such student comments.

> *Atiq: In the laboratory, different chemicals are labelled in terms of their chemical formula. So we need to know the formulas in order to identify them.*
>
> *Anu: They [symbols of elements and the procedures of writing chemical formula] would be needed in learning about chemical reactions and equations.*

It seems that both the students, Atiq and Anu, echoed their teacher, Morshed, in articulating the importance of learning about chemical symbols and formula (i.e., for studying chemistry). This importance, however, was challenged by some other students, for example, Sumit,

> *Sumit: They [symbols of elements and the procedures of writing chemical formula] have no use after this Grade. I'll study Humanities next.*

Though Sumit expressed the notion that learning formulae was irrelevant for his future academic orientation, he nevertheless appeared to view the learning about such content as being exclusively for academic purposes, and in this respect thought similarly to Atiq and Anu.

Moreover, irrespective of their future study interest, students generally expressed the need to study science for examination purposes. Here are two such student comments.

> *Anu: There are many things I memorise for exams. I have to do it. Everyone will ask my result in the exams.*
>
> *Amin: When we watch a good movie, do we memorise it? No, because we enjoy the movie. But we do memorise [science] for the exam, because many things in science are not interesting. ... They have no relevance in real life.*

Anu's comment above illustrates the power of exams, which often assess students' ability to memorise science content. As people value good exam scores, both Anu and Amin memorised such content to do well in the exams. Amin's comment elaborated on the way this practice affected interest in science. It seems from his comment that the limited relevance of science to real life – for him – reinforces the difficulty in making connections between school science and his life and as a result, the science that he and other students learn at school fails to draw their interest.

Summarising the discussion above, it seems that whilst Morshed intended to draw links between school science and students' life, his way of presenting science had limited ability to convince students that the science they learn in school has relevance in their lives.

6.7.3 Values considered in relation to scientific literacy.

Morshed perceived all of the target values (i.e., curiosity, rational thinking, open-mindedness and respect for others' opinions, and intellectual honesty) as important in his teaching science. However, there were differences in his perceptions of their importance and respective teaching approaches to promote the values, as revealed below.

6.7.3.1 Curiosity.

In the pre-lesson interview, Morshed was explicit in recognising the importance of curiosity for his students' scientific literacy:

> *There are always new things in the world that attract your attention and raise questions in your mind. [For example,] why is it happening like this? What would happen if this is done? Science gives the answers to such kind of questions. To be scientifically literate you need to address such questions.*

As Morshed perceived, people come up with questions derived from their curiosity and it is science that helps people get answers to the questions. He perceived peoples' ability to answer the questions as a characteristic of scientifically literate people. He, further, perceived nourishing peoples' life-long questioning attitudes as important. In his words: "the most important thing is not to stop questioning". In order to nourish students' questioning attitudes he perceived the importance of extending science knowledge beyond science classrooms:

> *But the thing is when you get an answer to one question, then there would be another one, and more are coming. You can't get all answers in the classroom. But keep trying to get it. You need to have a mind to look at other resources.*

Although Morshed noted the curious nature of the human mind, he also acknowledged the limited capacity of classroom learning to address peoples' every curious question and therefore, he expected that students would look at various resources to get answers to their questions. This sort of expectation was observed in his classroom teaching in that he encouraged students to go through the books available in the school library:

> *As I told you many times, go to the [school] library. Hundreds of books are there. They will help you open your eyes. (Class observation)*

Students, in the focus group interview, also appreciated Morshed's encouragement to explore various resources to extend their knowledge and satisfy their curiosity:

> *Moni: 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.*

The focus group interview with students also pointed out that Morshed was responsive in helping students get answers to their questions. Here is one such student comment.

> *Atiq: 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.*

As is seen in Atiq's comment above, he was curious to find the explanations for there being two valencies of iron. And it was his teacher, Morshed, who appreciated his question and helped him in getting the explanation. Morshed's appreciation for student questions may further encourage students to raise curious questions in science classes.

6.7.3.2 Rational thinking.

In the pre-lesson interview, Morshed articulated rational thinking as an important value for developing scientific literacy:

> *Rational thinking is important for scientific literacy. A [scientifically literate] person doesn't accept an idea before making justification. He/she accepts only the ideas that are justified.*

As Morshed perceived, scientifically literate people value justification in making decisions about an idea; they only accept the idea if it is justified. This practice, eventually, may help people reject unjustified ideas. This notion of rational thinking, however was not reflected in his practice. The four lessons observed provided no instance of how he taught to promote rational thinking in his science classes. Even, in the post-lesson interview, he could not articulate how he could consider this value in his classroom teaching.

In the focus group interview, his students mentioned the importance of being rational in communicating with others in general terms, for example, "I should speak rationally" (Amin) or "If I speak rationally, people would understand the power of my speech. Otherwise, it would be a stupidity" (Moni). The examples, however, do not show their understanding of rational thinking. Moreover, none of them could exemplify how they speak rationally or how their teacher in science class encouraged them to speak rationally. This could also be seen as an indication of how little the value of rational thinking was considered in their science class.

6.7.3.3 Respect for others' opinions and Open-mindedness.

Considering the pre-lesson interview with Morshed, it appears that he perceived the value of respect for others' opinions as important in science learning. Here is an illustrative quote from his pre-lesson interview:

> *Nowadays you see various discussions are going on about science related issues. Respect is very important here. You have to consider that everyone can have their views and you have to respect them.*

In the above comment, Morshed recognised people's right to hold and express their views and the value of respecting others' views when participating in science related discussions. The evidence for his enactment of this value is Morshed's consideration of diversity in peoples' views as illustrated in his own and students' comments below.

> *Different people would have different views. You must know and appreciate that there is no single way to look at an issue. So, you need to consider what others' views are.*

In the above comment, Morshed articulated the importance of considering different viewpoints to see an issue. In considering different viewpoints, people might get alternatives that would help them to embrace a more plausible alternative and may encourage them to justify their ideas. This is illustrated in one of the student comments in the focus group interview:

> *Mishu: My idea may be wrong or his idea may be wrong. When we come to conversation and try to justify our ideas, then it would be clearer whose idea is right. There is nothing to take personally. ... We do follow this for group discussion in our [science] classes.*

In responding to the probe "what would you do if your classmate gives an idea that you think is incorrect", Mishu suggested that he would engage in conversation with his classmate. As he points out, this conversation would focus on justification of their ideas. His comment also shows his preparedness to accept that there is a possibility he may have a wrong idea that he may eventually change in the light of a more justified idea. This notion of open-mindedness may have encouraged him to make the comment that "there is nothing to take personally", which may be seen as his appreciation of the value of respect for others' opinions. It seems from the comment that this appreciation might be a reflection of classroom discussion norms that were maintained in their science classes and were mentioned in Morshed's post-lesson interview:

> *Students are aware about the norms of discussion that I discussed with them in the beginning of the year. [These norms include that] all have equal opportunity to express their views and that no one can force others to agree with his views. Everyone has to obey the norms.*

The notions of open-mindedness and respect for others' opinions apparent in the classroom discussion norms that Morshed set might be helpful for students in considering different viewpoints and alternatives to look at an issue. Such classroom discussion norms may provide students with an explicit code of conduct and help promote the values of open-mindedness and respect for others' opinions.

6.7.3.4 Intellectual honesty.

Morshed perceived intellectual honesty as an important value in his teaching science. In the pre-lesson interview, he commented,

> *Honesty must be valued everywhere. ... I teach physics and chemistry experiments at the secondary level. I don't care what results students get from the experiments, but I do care how honestly they did the experiments and report them.*

In the above comment Morshed claimed that he encouraged students to value honesty when they conduct and report lab work. As noted previously, reporting correct results in lab reports by manipulation is a common teaching-learning culture in Bangladesh (Siddique & Rahman, 2007) and by promoting intellectual honesty, Morshed could actively discourage this practice.

Whilst Morshed perceived the importance of intellectual honesty in doing and reporting lab work, he did not involve students in any lab work or activity in the lessons I observed. None of the students, in the focus group interview, was able to provide any notion of how their intellectual honesty was demonstrated or required. It may therefore, be reasonable to consider that intellectual honesty was not emphasised in Morshed's science classes at the junior secondary level.

6.7.4 Challenges encountered.

As mentioned previously, besides teaching science in school, Morshed was involved as a master trainer in a teacher development programme. He took the perspective of both a science teacher and a science teacher educator when he articulated the challenges he faced in promoting scientific literacy. One of the challenges Morshed remarked on, was the limited resource facilities:

> *The school does not provide the equipment for science teaching. Sometimes I feel the need for a data projector or even an overhead projector to visualise content to students. Also students do not have lab access. I am teaching them about an experiment but I am just lecturing. How do they learn the experiment?*

In the above comment, Morshed expressed how he was challenged in teaching science due to the limited resource facilities of his school. In the comment below, he articulated how teachers can address the challenge.

> *I work as a master trainer for the TQI–SEP project. My trainee teachers commonly claim that schools do not supply teaching equipment. But there is equipment that teachers can make themselves and use for teaching science, for example, molecular models of carbon dioxide or water. You will just need soil balls, colour pens and thin sticks [to make this model]. You may get the sticks from the coconut leaves. You don't need to spend money to get them and they are easily available. So, what you need is your will to spend some time for your science class. But many teachers are not informed. In my training session, I work to get them informed.*

Morshed's experience as a professional development provider for teachers indicates that teachers, in general, are not informed about making and using their own teaching equipment. In the comment above, he described how teachers can develop a molecular model of carbon dioxide or water (somewhat abstract concepts) from low-cost and easily available resources. Also, the idea of using low-cost equipment in science classes may help teachers to combat the lack of teaching resources. Moreover, with the use of such low-cost equipment in science classes, teachers can involve students in hands-on activities that can be organised without lab support.

With his experience as a teacher trainer Morshed pointed out that the lack of teacher development programmes in Bangladesh focussed on how teachers could promote scientific literacy, suggesting this was a challenge to teachers' success:

> *You are talking about scientific literacy. But I don't know about any training programme for the teachers on this. Teachers' training programmes usually focus on increasing teachers' content knowledge [in science]. They do not work on how teachers can teach for promoting scientific literacy.*

The teacher development programmes in Bangladesh focus primarily on developing teachers' content knowledge in science. The case for this focus might be the content-dominated General Science course, which is integrated with the content from physical sciences, biological sciences and earth sciences. A teacher who is specialised in a particular content area, for example, in biological sciences may lack knowledge in other content areas, for example, in physical sciences. Moreover, it is evident that many teachers with non-science background teach science in school. They may lack content knowledge to teach science at all. These cases might persuade the teacher development programmes to focus mostly on developing teachers' content knowledge in different science subject areas. And Morshed's comment above suggests that the pedagogical approaches to promoting scientific literacy are often overlooked in the teacher development programmes. This practice persuaded Morshed to urge for a shift in the teacher development programmes to developing teachers' pedagogical approaches needed for promoting scientific literacy. He commented,

> *You can't expect teachers to be teaching for scientific literacy, when they don't know how to teach it. They need to be trained in it.*

Morshed also viewed students' mixed ability as a challenge in his teaching, because "different abilities have different needs" and "they require different teaching approaches". It seems he perceived difficulty in attempting to meet the need of all students as some students may require repetition while some may get bored with this. In order to address this issue, Morshed adopted the small group approach where groups are formed with students of different abilities:

> *I have made student groups at the beginning of the year. In a group some are high-ability students, some are with low-ability. All groups have common group norms. Every group member has to obey the norms.*

Whilst Morshed could not articulate how the mixed-ability small group approach helped him in addressing the issue of mixed ability classes, he specified the benefits of a small group approach as illustrated in the comment below.

> *I have 65 students in this class and they are in 13 groups. When I give them group work, it seems I am teaching 13 students. ... I often see group members' satisfaction after completing a task. They feel that they have done the job themselves.*

It seems in the above comment that a small group approach helped Morshed manage his class size. The comment also illustrates that students get self-satisfaction from working in a group which gives them responsibility for the outcome of the group task. Apart from the benefits of the small group approach, Morshed also remarked on a challenge in adopting this approach, the students' examination-oriented learning tendency:

> *When I attempted a small group approach six or seven years back, some students did not like it because group work was not assessed in the exam. Now the SBA*[6] *system is introduced in school that counts students' group work. So, students have no complaint now.*

As the comment above shows, the examination-driven education context in Bangladesh de-motivated students from being involved in group work since group work was not assessed in the exams. This examination-driven context further persuaded students to be happily involved in group work when it was counted in the exams. It seems that if the SBA approach had not been introduced, Morshed would have been challenged in getting students involved in group activities.

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[6] According to Begum and Farooqui (2008) SBA (School Based Assessment) refers to the assessment of students' progress which occurs on an on-going basis during the year. With SBA, teachers give regular feedback to their students to help them learn better. Group work is one of the six areas of student course work that was designed to be assessed in SBA.

6.8 Case 5 – Rashid

6.8.1 Introducing Rashid.

Rashid is a male teacher teaching in a rural secondary girls' school. He has been teaching for 16 years. He has no degree in science, but has a degree in arts (BA). In his in-service teaching career, he completed a 14 day professional development course organised by the TQI–SEP. His workload includes conducting about 22 classes per week. His teaching of science at Grade VIII (three lessons on the textbook unit "population and environment") was observed in this research. He had 85 students in his Grade VIII science class.

6.8.2 Rashid's perspectives of scientific literacy and teaching approaches.

Rashid's perspectives of scientific literacy include having language skills for studying science. In the pre-lesson interview, he explained,

> *For studying science you need to read science books, understand them and write down your understanding. Then you tell someone what you understand. You also listen to others about science. When you can do all of these things, you are then scientifically literate.*

As the above comment illustrates, Rashid emphasised the importance of language skills (reading, writing, speaking and listening) for studying science and for him, scientific literacy is about having all of these skills. Moreover, he went on to discuss how among these skills his students mostly lack speaking skills that are needed for presenting an idea. In his words,

> *Many students come with low level reading and writing ability. But the main problem is with speaking; many of them are in difficulty expressing an idea. Perhaps they understand the idea, but can't express it properly.*

A reflection of this perspective was observed in his classroom teaching practice when he engaged one student from each group in presenting the summary of group discussion. In the post-lesson interview, he contended that this strategy would help students "increase their presentation skills".

Rashid also viewed that science learning would help students obtain explanations of the world in the way that is suggested by the Quran. In the pre-lesson interview, he explained,

> *You see many things happening around you. Science will help you understand why and how the things are happening. If we look at the broader context, the Quran includes the knowledge about our life relating to both your materialistic and spiritual life. This is a full code of conduct. For example, the Quran suggests us to get washed before every prayer and it is science that explains why we need to get washed. ... The aeroplane was invented in the twentieth century, but see, the Quran indicated about aeroplanes a long time ago. But the Quran does not include detailed explanations, it has just an indication. We, the general people, cannot understand the indication. Scientists – the intellectual people, understand it, do research and explain it. So, if you study science, it seems you are studying the Quran in a sense. That's why I think, every student needs to study science in school.*

As the above comment illustrates, Rashid perceived that the Muslim's holy book, the Quran, includes the entire "code of conduct" about human's "materialistic and spiritual life". He argues that the Quran does not explain the code of conduct, but it indicates knowledge to know and it is science that can help explain the indication. It seems he perceived that scientists should at first study the Quran and then conduct research to explain a phenomenon. This perception, however, does not match with the practice of scientists and thus with the nature of science as discussed in Section 2.4.1. The contemporary views of the nature of science suggest that there are no absolutes in science and therefore, all issues are open for scrutiny and reconsideration (Lederman, 2004). In contrast, "religious truths are evaluated by an appeal to authority" (Mansour, 2010, p. 134) and the assertion of this authority suggests that "religious truths" are unquestionable. If there is any conflict between the Quran and science, [for example, the Quran supports creationism (Hameed, 2008; Mansour, 2010), which contradicts the idea of evolution, which is largely supported by science], it seems that Rashid's perception would suggest to him that he rely on the Quranic views rather than the scientific ideas. In the interview, I asked him about this. He responded,

> *Look, there is a limitation in human knowledge. But Allah [God] knows everything and thus he has included all knowledge in the Quran. If there is a mismatch [between science and the Quran], it seems, scientists need to explore more.*

As illustrated in Rashid's comment above, God has the authority of knowledge and the consequent power to accept or reject a scientific claim. As knowledge of God is articulated in the Quran, he articulated his belief that one should follow the Quran if a conflict arises between scientific ideas and the Quranic views. In addition, he perceived the importance of considering Islam in promoting the awareness of good use of science among students:

> *Islam is the religion of peace. If you obey this you can't use science against humankind. If you become a scientist like Kader Khan, you are not working for peace. Can you remember what happened in Hiroshima and Nagasaki? When you are scientifically literate you can't behave like this. So, from the school level students need to get awareness about the good use of science and Islam can help in this regard.*

Rashid emphasised the importance of Islamic views for being "scientifically literate" as these views oppose the use of science against mankind. It seems that he valued the religious power of Islam for its ability to affect scientists' decisions concerning the consequences of the uses of science. He saw Islam as playing a central role in building students' awareness about the uses of science for peace. Whilst there was no explicit evidence in his teaching practice of his encouragement of students to follow Islam in developing their awareness about the use of science for peace, in his classroom teaching he brought in Islam when discussing the impact of population growth on cleanliness, as follows.

> *We all are Muslims. Our religion suggests cleanliness. Cleanliness is the part of iman*[7]*.*
> *If you have too many people you'll have difficulty in maintaining cleanness.*

As is seen in the above classroom lecture excerpt, Rashid discussed cleanliness from the Islamic point of view rather than in scientific terms. It is also interesting to note that he only considered a particular religion – Islam. In his class, however, there might be students from other religions, who may feel alienated, as their religions were not considered. This practice may be seen to be reinforcing the discrimination of students from religions other than Islam.

It is apparent in the above excerpts that Rashid's Islamic belief was a dominant factor in shaping his ideas about science. These ideas could be seen as naive as they are not supported by the contemporary nature of science. It may therefore be unlikely that he would be able to help his students develop contemporary scientific views and orientations. Moreover, his sole consideration of a particular religion may reinforce students' segregation based on their religion.

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[7] Iman is an Arabic term which denotes belief in an idea. In Islamic theology, Iman refers to a believer's faith in the six metaphysical realities of Islam (Zeno, 1996). According to Alawneh (1998), "Iman comprises the strong Islamic base for directing, re-educating, and influencing man's behaviour in life" (p. 27).

6.8.3 Values considered in relation to scientific literacy.

Whilst Rashid perceived most of the curriculum-intended values as important for science education, he had naive perceptions about most of the values. He also found difficulty in formulating suitable teaching approaches to promote the values.

6.8.3.1 Curiosity.

In the pre-lesson interview, Rashid recognised the curious nature of students with the comment, "kids are naturally curious". He also expressed the importance of curiosity for learning science in general terms: "when you are learning science, you need to be curious". Nevertheless, he could not explain why curiosity is important for learning science. It was observed in his classroom teaching practice that he involved students in presenting their experiences regarding population growth. In the post-lesson interview, he described this particular teaching approach as useful in promoting curiosity and scientific literacy:

> *Sharing their experiences may satisfy their curiosity. And when you are sharing your experiences your presentation skills are increasing. So, your scientific literacy is increasing.*

The above comment, however, does not illustrate how sharing experiences may satisfy one's curiosity. The comment does not illustrate how Rashid encouraged students to raise questions from their experiences and eventually, to explore the questions. Rather he viewed that sharing experiences would increase students' presentation skills, which he perceived as important for scientific literacy. Given that this perception seems naive – as suggested earlier – it is likely that Rashid would have limited capacity to formulate teaching approaches that could promote students' curiosity and scientific literacy. The consequence of this limited capacity was evident in the focus group interview with his students in that none of them could exemplify a question derived from their curiosity. One of the students' comments in this regard, "mm, can't remember any question" could be seen as an indication of how little the value of curiosity framed Rashid's teaching practice.

6.8.3.2 Rational thinking.

In the pre-lesson interview, Rashid stated that rational thinking is an important value in science:

> *Science people are more rational than others. When they do experiment they follow fixed rational steps and come to conclusions. If you don't follow the steps, your experiment is not valid. So rational thinking is important in science.*

In the above comment, Rashid expressed his belief in a universal scientific method that he thought is rational and is followed by all scientists in their experiments. This belief points to a recipe-like stepwise procedure typifying all scientific practices. However, this belief could be seen as a myth as in practice, there is no single sequence of activities used in scientific investigations (Abd-El-Khalick & Lederman, 2000a). Belief in such a myth could also persuade Rashid to adopt a teaching approach comprising cookbook or recipe-like hands-on activities.

Observation of a series of classroom lessons, however, did not provide any instance of how Rashid involved students in hands-on activities. Rather in the post-lesson interview, he commented that,

> *They'll do experiments in future. When they do experiments themselves, they'll then understand the rational steps of the experiments.*

The above comment, while illustrating Rashid's belief that rational thinking would develop in doing science experiments in future science study, did not articulate how his current teaching practice could promote rational thinking in students.

6.8.3.3 Respect for others' opinions and Open-mindedness.

In the pre-lesson interview, Rashid expressed a naive notion about the value of respect for others' opinions, based on preferential valuing of the knowledge of 'older and wiser' people:

> *You are a kid. You can't understand many things now. But listen to your elders – your teachers, your parents. They know many things. Just follow them now. You yourself will understand the things when you get older.*

His views suggest that Rashid might not show respect for the right of younger and less experienced people (for example, his students) to hold and express their ideas. This practice, eventually, might discourage students from respecting the ideas of people who are younger and less experienced than themselves. This practice may also inhibit students from presenting and justifying their ideas in classroom. Such ideas were elicited in the focus group interview as below.

> *Beethi: I better ask my teacher. He would give the right decision.*

In responding to the probe "what would you do if your classmate gives an idea that you think is incorrect", Beethi viewed her teacher as more knowledgeable and experienced than her, as one who can make "the right decision". This view suggested she perceived her teacher as the authority and relied on him when conflicting views were found among the students.

Moreover, Beethi's comment does not show her willingness to justify her own views or to listen to her classmate's justification when they have conflicting views. It inhibits the possibility of getting alternative views. As a consideration of available alternatives is an important facet of being open-minded (Hare, 2009), Beethi's notion could be seen as challenging to being open-minded.

6.8.3.4 Intellectual honesty.

Rashid, in general, perceived honesty as an important value in human life. He, however, could not specify his notion of intellectual honesty in science education and scientific literacy. In the pre-lesson interview, he commented,

> *Honesty is the best policy. Society can't benefit from dishonest people. Honesty is important everywhere – you are studying, you are doing jobs, you are doing business – you need to show your honesty.*

It seems from the above comment that Rashid had limited capacity to specify his notion of intellectual honesty from the general notion of honesty. So, it was not surprising that he could not articulate how he considered intellectual honesty in his science teaching. Observation of a series of Rashid's classroom lessons could not provide any evidence of the consideration of intellectual honesty in his teaching practice. For example, there was no instance of him encouraging students to communicate a consistent conclusion based on the evidence. Nor could any of the students provide any notion of their own ideas about intellectual honesty.

6.8.4 Challenges encountered.

The post-lesson interview with Rashid elicited the issues he perceived as challenging to his science teaching, the first challenge being the limited resources and facilities in his school:

> *Our school is very poor in terms of facilities for teaching science. It has a small [science] lab, but it is only for the secondary students. Sometimes I prepare low-cost equipment to use in science class, but there is no proper place to store them. If I could store them, they could be reused.*

While Rashid enthusiastically decried the limited resources and limited equipment storage facilities in his school, he could not articulate how the issues particularly challenged his teaching to promote scientific literacy and how he could respond to the issues. This lack of articulation could be seen as an indication of his limited capacity to foster scientific literacy in his teaching, which consequently would remain a challenge.

In a similar vein, Rashid expressed his limited capacity to respond to the issue of insufficient time allocated for science classes. Nor could he articulate how this issue challenged his teaching for promoting scientific literacy.

> *35 minutes is not enough for a good science class. If the class were of one hour or even of 45 minutes, I could involve students in group work more effectively. I could monitor every group and give them necessary direction and feedback.*

As is seen in the above comment, the limited time allocated for science classes challenged Rashid's ability to monitor students' group work. He viewed the lack of monitoring as resulting in insufficient feedback and direction for students and thereby reducing the effectiveness of the group work.

As previously mentioned, Rashid had 85 students in the Grade VIII class that I observed. Rashid considered this class size as a challenge to his teaching. Large class size, coupled with the exigencies of time for science class challenged his ability and limited opportunities for meeting the needs of students with different abilities:

> *If I had 20 or 30 students in my class I could address individual student's needs. A low ability student needs more time to understand a concept. Say, she may need 10 minutes to understand a concept but a high ability student may understand it in 5 minutes.*

However, in the interview, Rashid could not suggest how he responded to this issue. He did not articulate what approaches he took for the students with different abilities. It seems, he had a tendency to avoid responsibility in addressing the issue as he appeared to be overwhelmed by the reality of the large class with mixed ability students.

Rashid also perceived his academic background as a challenge in his teaching:

> *I studied science up to the higher secondary level. Then I studied humanities and got a BA degree. I teach science at the junior secondary level. Some content is a bit difficult to teach. If I had a science degree I could teach them more effectively.*

Rashid found difficulty teaching some content in the junior secondary General Science course. He had no degree in science and he perceived this as important for teaching science "effectively". As mentioned previously, the General Science course is content-dominated and therefore it requires specialised science content knowledge to teach. Rashid himself admits to having limited science content knowledge. This limitation might well impact on his confidence to teach the science content, and would also not assist his efforts to find possible applications or uses of science content that he could present to students to help them see links between school science and life. In responding to this issue, Rashid urged for "professional development programmes focused on developing science content knowledge for the teachers".

6.9 Case 6 – Jasmine

6.9.1 Introducing Jasmine.

Jasmine is a female science teacher in a semi-urban secondary girls' school where she started her teaching career and has been teaching for nine years. She holds a master degree in science with mathematics as a major. In her in-service teaching career, she completed three short-term professional development courses organised by the TQI–SEP Project. Her workload includes conducting about 25 classes per week. Her teaching of science at Grade VIII (three lessons on the textbook unit "a flowering plant: chilli plant") was observed. She had 70 students in her Grade VIII science class.

6.9.2 Jasmine's perspectives of scientific literacy and teaching approaches.

For Jasmine, scientific literacy is about "applying science learning in everyday life". As she explained,

> *Applications of science are everywhere around you. When you are learning science, it is necessary that you learn these applications. [For example,] you learn about the vitamins in science class, so you understand the importance of vitamins in maintaining your health. Now if you use this learning in making a food chart for you or your family, you are scientifically literate.*

As is seen in the above comment, Jasmine perceived the importance of learning about the applications of science in everyday life. Learning about such applications would enable students to use science for practical applications in everyday life. It seems that Jasmine emphasised the importance of acquiring the functional knowledge of science more than the academic science knowledge. This functional knowledge would help students draw the links between science they learn in school and their everyday life.

Moreover, Jasmine articulated the importance of functional knowledge for all students. She commented,

> *All [students] need to know how they can use their knowledge in life. It is not like you are studying this because it will be needed in the next years. You may not study [science] in the next years. But you will see many things around you and will use your science knowledge appropriately.*

As is seen in the comment above, the purpose of science learning for Jasmine was to enable students to be informed users of science knowledge in life, rather than simply to act as a basis for further science study. She emphasised the need for functional knowledge to be acquired in school science education.

As observed in Jasmine's classroom lessons, she discussed with students the purpose of the lessons. For example, she pointed out that plants are important elements of the natural environment and that learning about the life cycle of plants would help students understand the natural environment. She also explained the importance of taking care of plants for maintaining the sustainability of the environment. Such input may help students become familiar with sustainability issues. It was also observed in her classroom lessons that she intended to link the science topics with the outside world beyond a science classroom. She provided students with a list of items including seeds, flowers, adult plants, fruits and seedlings. Then she asked students to make small groups. Student groups were then asked to find and observe the items on the list around the schoolyard. When the groups had completed their observations, they were then asked to have discussions on their observations and produce a brief discussion report. In the discussion report, students were suggested to include any questions they had about their observations. Each of the student groups was then asked to present their report. With their reports, a whole class discussion was arranged. Jasmine acted as a moderator of this discussion, which was elaborated on further in theoretical discussion on the life cycle of plants in general, and then the life cycle of a chilli plant in specific. Students were enthusiastic in engaging with the activity. Their enthusiasm and engagement with such activities was also expressed in the focus group interview.

> *Toma: I like when she [the teacher] asks us to do something.*
>
> *Moon: In the last week, we did an experiment on germination. We brought chick peas and did the experiment in the class. It was very interesting.*

The focus group interview with students also suggested that students perceived the usefulness of learning about the life cycle of plants in their lives. Here are two such comments.

> *Jenny: I have learnt how I can preserve some chilli seeds and can use them to grow further chilli plants and make a garden. It [gardening] is my hobby.*
>
> *Tushi: I can use my learning about the life cycle of plants in tree plantations. Trees are very important for the environment.*

Jenny indicated how learning about plants in science classes helped her to see the possible uses of the learning in life, for example, in her hobby, gardening. Tushi, on the other hand, did not mention how she could use her learning about the life cycle of plants in tree plantations, though she perceived the importance of trees for the well-being of the environment.

6.9.3 Values considered in relation to scientific literacy.

6.9.3.1 Curiosity.

Jasmine perceived the importance of science learning in satisfying peoples' curiosity about the natural world. In the pre-lesson interview, she commented,

> *People have questions about the world around them. Science gives answers to these questions. So, science learning in school helps get answers to the questions.*

It seems from Jasmine's comment that she valued curiosity for the intrinsic interest of learning science in school as this learning helps people get answers to the questions derived from their curiosity about the "world around them". As presented before, in her classroom teaching practice, she engaged students in discussing their observations on different parts of plants. 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 have observed and what questions they have found in their observations. Then I led a discussion in order to address their questions.*

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

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

As observed in Jasmine's teaching practice, a student, Saba, raised a question from her observation. Jasmine expressly appreciated Saba's question and went on to answer it. This appreciation may encourage students to find further questions and ask their teacher. In the focus group interview, students also exemplified questions that they thought were generated from their curiosity about plants and showed their comfort in posing these questions to Jasmine. Here is an example of such a comment.

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

Toma shows how she came to generate a question and sought an answer to the question in science classes. It seems from her comment that Jasmine was meticulous about responding to student questions.

6.9.3.2 Rational thinking.

In the pre-lesson interview, Jasmine recognised the importance of rational thinking. However, in talking about rational thinking, she expressed a possibly naive view of scientific practice:

> *You have to think rationally. Look, when I was discussing about the life cycle of the chilli plant, I started from the chilli seeds, then I discussed the next step, seedling, and so on. When you are talking about this cycle you can't start from the seedling. Science is like this. You have the systematic steps to follow when you are doing scientific activity and your rational thinking is developing.*

The above comment illustrates Jasmine's apparent belief in a universal scientific method that typifies all scientific practices rather than a sense that there are many types of systematic approaches to scientific investigations. As discussed previously, this belief is seen as a myth that may also persuade Jasmine to adopt a teaching approach comprising cookbook or recipe-like hands-on activities. Observation of her classroom teaching also suggested that she did not explicitly encourage students to design and conduct the activity in different ways. This lack of encouragement may convey an implicit message to students that there is only a single way to conduct an activity in science. This message further may discourage students from thinking and considering different ways of conducting scientific activity.

Students in the focus group interview also confirmed that they do the activity in the way their teacher asks them to. For example,

> *Tushi: Madam tells us how to do [an activity]. It is good that she tells us how we will go. It would be difficult otherwise.*

Tushi's comment indicates that students are directed on how to perform an activity in their science class, and that Tushi preferred a recipe-like approach to perform the activity. This preference confirms the prevalent practice in doing science activities in Bangladesh. As noted previously, this practice includes conducting recipe-like science activities where students engage in verifying the results rather than in planning and designing activities.

6.9.3.3 Open-mindedness and Respect for others' opinions.

Considering the pre-lesson interview with Jasmine, it appears that she perceived open-mindedness as important in science learning:

> *It [open-mindedness] is important in science learning as new knowledge is coming and is replacing old knowledge. If you are rigid in considering new knowledge you would be backdated.*

The above comment reflects Jasmine's recognition that science knowledge is never absolute or certain; rather it is always open for revision. As discussed previously, if teachers consider and appreciate this revisionary notion in their teaching science, students may also appreciate the message that they need to keep their mind open to consider new science knowledge. Jasmine also articulated the place of alternative views in science:

> *There is no single view in the world. Different people can see a thing differently. There are many scientists who have different views about the big bang theory.*

It seems from above comment that Jasmine acknowledged diversity in people's views. This acknowledgement may persuade her to view science from a subjective point of view; for example, she considered that a scientific theory may be viewed from different viewpoints by different scientists. This view could be seen as aligned with contemporary views on the nature of science relating to subjectivity. As discussed previously, this notion of subjectivity acknowledges the influence of background factors (e.g., scientists' knowledge, beliefs, commitments) in scientific inquiry, which may result in different views about science knowledge and diversity in scientific theory.

In talking about subjectivity in people's views, Jasmine made the point that different viewpoints may result in conflict and perceived this as "good". She perceived the importance of respect for others' opinions in such a conflicting situation as illustrated in the comment below.

> *Conflict of views is good. It may encourage you to explore more. But it's not good that you think people are nonsense because they have different views.*

As seen in the comment above, Jasmine viewed disregarding people for holding different views as "not good". This view might be seen as an indication of valuing people's right to hold and express their views, which might also be seen as valuing respect for others' opinions.

Whilst Jasmine expressed her notion of open-mindedness and respect for others' opinions in the pre-lesson interview, observation of two of her classroom lessons could not provide any instance of how she considered these two values in her teaching. However, in the post-lesson interview she claimed that

> *I encourage them to consider others' views in group activities or in the classroom discussion. Maybe I didn't do it in the lessons you observed, but I do.*

Her claim of considering these values in classroom teaching practice was reflected in the focus group interview with students. Here is a student comment.

> *Jenny: In the group discussion, we listen to what others say. I may not agree with one's idea. I try to make her understand why I don't agree with [her idea]. But if she can establish her idea, I'll take it.*

In the above comment Jenny articulated the practice of group discussion in science classes. This comment suggests her openness to revise her idea if she is convinced by another's reasons. This notion of open-mindedness might persuade her to respect her classmate's right to express ideas different to hers.

6.9.3.4 Intellectual honesty.

The interviews with Jasmine and the observations of her classroom teaching did not suggest her consideration of intellectual honesty in science teaching. In the pre-lesson interview, she commented,

> *I am not sure how it [intellectual honesty] is in science. When you are doing an experiment, it is important how accurately you are doing it. If you can do it accurately, you will get the correct result.*

It seems from above comment that Jasmine viewed the importance of being accurate in conducting experiments. She saw this accuracy as helping get the "correct result" of an experiment. This view may persuade her to value correct results in assessing students' practical reports. This assessment practice further may encourage students to report the correct result of the experiments by manipulation, which is, as discussed before, a common teaching-learning culture in Bangladesh (Siddique & Rahman, 2007). Promoting this culture may reinforce students to practise manipulation, which might reasonably challenge the promotion of intellectual honesty in science classes. A reflection of this challenge was observed in her classroom teaching practice and in the focus group interview with students. Observation of her classroom teaching did not provide any evidence of considering intellectual honesty (for example, consideration of honest reporting) in her science classes; students' focus group interview also revealed students' inability to articulate their notion of intellectual honesty. This observed classroom practice and students' inability to discuss the concept could also be seen as an indication of how little intellectual honesty was considered in Jasmine's science classes.

6.9.4 Challenges encountered.

While talking about the challenges Jasmine encountered in her teaching for scientific literacy, in the post-lesson interview, she viewed the assessment system as a major challenge:

> *A big challenge is the assessment system. All [teaching-learning activities] are directed towards getting good marks in the exams. Students, their parents, school authorities – everyone is concerned with students' results.*

In Bangladesh, students' exam scores are often used to determine the quality of teaching and the achievements of the school; the stakeholders of education, therefore, place most value on students' exam results. This examination-driven practice often persuades students to memorise some content to be recalled in the exams. The practice does not encourage students to learn how they can apply their science learning in everyday situations. As a result, they often lack the ability to apply science knowledge in everyday situations that is important for their scientific literacy. In order to respond to this challenge, Jasmine "tries to prepare exams that do not require memorisation of content". However, as she stated in the comment below, this strategy would not work in the case of external exams.

> *But when they'll go for the external exams, my strategy won't work.*

As the external exams often count students' ability to memorise the content, the examination-driven practice would oppose students learning to apply science knowledge in everyday situations and would challenge the promotion of scientific literacy.

Jasmine also viewed the allocated time for science class as insufficient and her class size as large. These two factors together, as she explained in the following comment, challenged her teaching.

> *I think students learn better and get involved when multiple techniques are used. So I try to use individual work, pair work and group work. But how can I do these in 35 minutes for 70 students. They discuss in groups and I think how much time is left for the class. All groups can't present their discussion report. If I had 40 students and a one hour class, then we could listen to all of them.*

In the above comment, Jasmine made the point that due to insufficient time and large classes all of her student groups could not present their group discussion reports in the class. The groups who could not present their discussion report may be deprived from getting feedback on their discussion from their teacher and other groups. It also seems from Jasmine's comment above that insufficient time for science class may lead her to rush through the discussion. In the interview, she proposed a strategy to use the allocated time for science class:

> *Each class is of 35 minutes and there are 5 classes in a week. If it were 3 classes of 1 hour each per week, I could ensure more student engagement. But the school had to follow the government rule.*

As seen in Jasmine's above comment, for science classes, a weekly total of 175 minutes was allocated, which was divided into five periods. She did not propose to make a major change in total time allocation for science classes (i.e., she proposed 180 minutes per week) but proposed to decrease the number of periods so as to increase an individual class time period. She expected her proposed one hour science classes would help her ensure student engagement. However, her proposal for one hour classes was not consistent with "the government rule" and therefore, it could not be implemented in her school. This reflects a lack of flexibility in government policy and this may be due to the use of a centralised system followed in school education in Bangladesh. This centralised system does not provide autonomy to schools to make any changes, for example, in class allocation.

Jasmine also characterised the General Science course as being one with content having "limited use in everyday life". Inclusion of such academic content may impede students seeing that the science content they learn in school has potential to be used in everyday life issues. This eventually may challenge students in their attempts to draw the links between school science and everyday life. In addition, Jasmine pointed out that this predominantly academic nature of the General Science course was reflected in its use of language.

> *The content in the textbook is written in complex language. It also makes the content difficult to understand.*

The complex language used in the presentation of content in the textbook also challenged students' understanding of the content. Jasmine proposed that the textbook developers address this issue.

> *They [textbook developers] need to understand the language ability of kids.*

Jasmine also considered that her "students love to do practical activities", so, students' inaccessibility to the school science lab was a challenge to her science teaching. However, Jasmine added that she responded to this issue by organising practical activities with low-cost materials.

> *We use low-cost materials. Students helped me make an apparatus to experiment on the expansion of liquid. We used a glass container, rubber stopper, colour, a tube and spirit lamp. The students made the spirit lamp themselves with low cost materials and did the experiment in the class.*

In the above comment, Jasmine revealed how she involved students in making low-cost materials from easily available resources and organised practical activities with such materials in the classroom. Given that getting lab access for the junior secondary students is a challenge in Bangladesh, Jasmine's attempt to organise practical activities with low-cost materials in science classroom may be seen as a useful measure to address the challenge.

6.10 Chapter Summary

In this chapter, I have reported data on how six Bangladeshi science teachers perceive scientific literacy as well as values underpinning their perspectives and how these are considered in their teaching practice. The teachers also identify the issues they perceive as challenging in their teaching. The implications of the data presented here and in the previous chapter, are discussed in the next chapter in relation to the research questions and the aspects of literature presented in Chapter 2.

CHAPTER 7
Discussion

7.1 Introduction

This chapter discusses how the findings of this study, as presented in the previous two chapters, have been used to understand how scientific literacy is promoted through junior secondary science education in Bangladesh. The discussion focuses in particular on teachers' perspectives of and teaching approaches to promote scientific literacy and associated challenges (presented in Chapters 5 and 6). The discussion offers responses to the research questions of this study as outlined in Chapter 1, and listed again below, which contribute to an understanding of how scientific literacy is promoted through junior secondary science education in Bangladesh.

1. How do teachers perceive scientific literacy?
2. How are teachers' perspectives of scientific literacy translated into classroom teaching?
3. What values do teachers consider in relation to scientific literacy and how are they considered in science classes?
4. What issues do teachers perceive as challenging in their teaching for scientific literacy?

A macro view of how scientific literacy is considered in teachers' science classes was articulated in Chapter 5. This macro view was gained from responses from 159 Bangladeshi junior secondary science teachers to a questionnaire addressing the abovementioned four sub-questions. Along with this macro view, six teachers' science classes were considered as six cases for gaining a micro view of how scientific literacy is considered in teachers' classrooms, as presented in Chapter 6. Two main data sources (interviews and classroom observations) were used to gain the micro view; in addition, students' focus group interviews were also used as supporting data sources. The patterns of teachers' considerations evident in the micro-view data, after a cross-case analysis of the cases was undertaken, are used to present an analysis of how these macro and micro views provide a picture of teachers' consideration of scientific literacy in classroom teaching.

7.2 Teachers' Perspectives of Scientific Literacy

In order to gain a macro view of teachers' perspectives of scientific literacy, they were asked to respond to three questions in the questionnaire regarding their familiarity with the term of scientific literacy, their perspectives of the primary purpose of school science education that reflected the notion of scientific literacy, and their conceptions of scientific literacy. The questionnaire data showed that two-thirds of the teacher participants were not familiar with the term "scientific literacy". This may be because the term is not mentioned in the curriculum documents, for example, in the official curriculum report or in the textbooks, on which teachers in Bangladesh rely heavily for getting information about science teaching and learning (Holbrook, 2005).

Whilst the particular term "scientific literacy" was not familiar to many of the teacher participants, most of them (93%) acknowledged one notion associated with scientific literacy – that is, the use of science learning in everyday life – as the primary purpose of school science education (see Section 5.3.1). When they were asked to explain what scientific literacy would mean to them, "use of science learning in everyday life" appeared as the most frequent theme (50.75%). The theme may be viewed as reflecting the utilitarian perspective of science learning (Millar, 1996), which would provide students with the functional science knowledge to be used in everyday life.

An aspect of this utilitarian perspective was also implicitly reflected in the second most frequent theme, "developing values/ attitudes/ scientific temper", which appeared in 29.35% of the teachers' written responses as their conceptions of scientific literacy. It should be noted that teachers used the terms "values", "attitudes" and "scientific temper" synonymously and articulated their importance in making decisions in everyday life issues. Teachers elaborated on how the Bangladeshi culture is imbued with superstitions and that learning science would help students defend themselves with a scientific view against a superstitious view. For example, as a teacher explained, rational thinking would help students evaluate the plausibility of these differing views and encourage students to adopt the scientific view in everyday life issues. Therefore, it seems that teachers' responses representing the theme of "developing values/ attitudes/ scientific temper" were related to the utilitarian perspective of science held by the majority of teachers as both of these ideas have the theme of "use of science learning in everyday life".

Thus, it would be reasonable to argue that the majority of the teacher participants had an appreciation for the utilitarian perspective of science learning needing to be used in everyday life and the place of attitudinal aspects in the use of science learning (see Rennie, 2007). This aspect of a utilitarian perspective, as noted previously, has been emphasised in a Vision I-II approach of scientific literacy, which aims at providing a relevant science education to all students to prepare them as informed users and consumers of science learning in their everyday lives. This Vision I-II approach is intended to help students see the connections between the science they learn in school and their everyday lives. Therefore, it seems that the majority of the teacher participants' perspectives, articulated above as a macro view, are broadly aligned with the perspective associated with a Vision I-II approach (I have labelled this perspective the 'Vision I-II perspective'). From the micro view, this Vision I-II perspective was seen in four of the teachers' cases, namely those of Sabina, Ashim, Morshed and Jasmine.

7.2.1 Vision I-II perspective.

As presented in Chapter 6, Sabina, Ashim, Morshed and Jasmine expressed the importance of drawing links between what the science students learn in school and their everyday life. For example, Sabina viewed scientific literacy as an ability to use science knowledge in everyday life relating to food, nutrition and environmental pollution, and to understand media reports on contemporary science related issues that have relevance in everyday life (e.g., acid rain). This view, however, does not reflect how students' everyday life could provide contexts for science learning or dictate the content to be learned in school. Rather her perspective of scientific literacy started with learning the science content in school but with an emphasis on the content that is useful in students' everyday life. Such an emphasis, as noted previously, is considered in a Vision I-II scientific literacy (Aikenhead, 2008).

In a similar vein, Ashim claimed that he considered teaching students about "basic cleanliness, hygiene, sanitation, and such kind of health and environment related issues" whether or not they were in the syllabus. Discussion on such health and environment related issues in science classes could provide students with knowledge to be used to make decisions about their own health and that of others, as well as about environmental matters. As noted in the OECD (2006) report, health and environment are two of the application areas of science that people encounter in their lives; therefore, such health and environment related knowledge could help students see the relevance of science with life beyond school. In addition, Ashim also perceived the preparation of science professionals as another purpose of school science education as he viewed the importance of science professionals for the development of a country.

It seems that Ashim viewed the importance of satisfying both of the major purposes of science education (i.e., preparing a scientifically literate citizenry and preparing science professionals) (see Bybee & DeBoer, 1994; Fensham, 1985; Millar, 1996). This view was also evident in Morshed's perspective (see Section 6.7.2), which centres around catering for both the future science professionals group (often the minority in terms of number) and scientifically literate group (all students). As discussed previously, in Bangladesh, at the junior secondary level, a single General Science curriculum caters for both of these groups of students with the expectation that the curriculum would provide all students with science knowledge to use in everyday life and encourage more students to take further studies in science, eventually leading to a science-related profession (NCTB, 1995). However, my experience as a school student, a teacher and a teacher educator in Bangladesh, as noted in Chapter 1, suggest to me that this balance is violated, with teachers often emphasising the need for a good foundation for the future science profession more than catering to the scientifically literate group. Such an emphasis could be considered as aligned closely with Vision I, which was observed in Alam's perspectives of scientific literacy as below.

7.2.2 Vision I perspective.

Alam's perspectives of scientific literacy involved being "able to work as a science professional" and therefore, he encouraged students to consider science related professions for their career aspirations. Like many people in developing countries (see Rampal, 1994; Sjøberg & Schreiner, 2005), Alam perceived science professional status as a vehicle of social and economic mobility. Such perceptions may have persuaded

Alam to take more care of the future science professional group than providing all students with a good foundation in science for being effective citizens. As Aikenhead (2008) pointed out, focusing on the future science professional group to provide them with a pre-professional training in science is a characteristic of a Vision I approach. In order to provide the pre-professional training, this Vision I approach emphasises the promotion of disciplinary-based academic science knowledge that may not be connected to students' everyday life (Aikenhead, 2008; Roberts, 2007). In this research, such an emphasis was observed in 26 (12.9%) of the teachers' written responses (see Section 5.3.3), which considered having academic science knowledge to constitute scientific literacy. Therefore, it seems that 12.9% of the teachers' responses are broadly aligned with a Vision I perspective, which sits at odds with engaging students with science in everyday life (Aikenhead, 2008; Rennie, 2011). Besides a Vision I perspective, teachers in this research also articulated perspectives that could be considered "naive" and which might not be helpful in promoting scientific literacy as below.

7.2.3 Naive perspectives.

Teachers' naive perspectives included a failure to differentiate between language literacy and scientific literacy and the dominance of religious views over scientific views.

7.2.3.1 Language literacy as scientific literacy.

In general, 14 of the teachers' written responses (7%) to the questionnaire illustrated their conception of scientific literacy as the language ability to study science. This naive perspective was explored in the case of Rashid, in detail. Rashid's notion of scientific literacy was limited to the language and communication skills (reading, writing, speaking and listening) in studying science. Such naive perspectives of scientific literacy constrain the opportunities Rashid may have had for promoting scientific literacy in his science class. Rashid's case also provided insights into how his religious views dominated his perspectives about the nature of science, and eventually scientific literacy as discussed below.

7.2.3.2 Dominance of religious views.

Rashid believed in Islam as "the religion of peace" and viewed his role as one of importance in considering Islamic views to build students' awareness about the use of science for peace. Such religious beliefs further persuaded him to consider that learning science in school was to help students gain explanations of the Quranic views about human life. As he explained, the Quran includes the entire knowledge that is articulated by God. Believing in God as the authority of knowledge with the power to accept or reject a scientific claim, he made the comment that one should follow the Quran if a conflict arises between scientific ideas and the Quranic views. However, ideas of the nature of science suggest that scientific ideas are accepted or rejected after rigorous review by the scientific community and there is provision for continuous scrutiny and reconsideration in establishing scientific ideas (Lederman, 2004) rather than these being based on the authority of any one entity or individual. Such scrutiny and reconsideration is not encouraged in Islam (Mansour, 2010) as shown in the way Rashid claimed God as the authority of all knowledge. Therefore, Rashid's Islamic belief could be seen as contradicting the ideas of how science knowledge becomes acceptable. It therefore seems unlikely that he would be able to help his students develop the science views that are important for scientific literacy according to NRC (1996).

7.3 Translation of Teachers' Perspectives into Classroom Teaching

This section discusses the findings regarding teachers' teaching approaches to promote scientific literacy. To understanding teachers' teaching approaches, a macro view of their verbalised teaching practice was gained through the questionnaire (see Section 5.4) and then a micro view of their teaching practices was explored with the cases through teachers' interviews, class observations and students' focus group interviews.

As argued previously, drawing links between school science and students' everyday life is an important aspect for promoting scientific literacy and has been considered in this research. In the questionnaire, teachers were asked to indicate their views on the extent to which they consider certain aspects in science classes to draw links between school science and students' everyday life. The aspects, for example, included explaining the application of science in everyday life, providing real life examples of science, bringing students' personal stories into the science classes, linking science with students' interests and hobbies, and so on. As discussed in Section 2.6.1, emphases on these aspects generally reflect the emphases required in teaching for promoting scientific literacy (Goodrum, 2004) and are aligned with a Vision I-II practice. Teachers' responses to these aspects as reported in Section 5.4 indicated that in general, the aspects are emphasised in their science classes. This finding therefore could be seen as representing a macro view of Vision I-II teaching practice. However, individual teachers' cases as presented in Chapter 6, mostly demonstrated that the classroom practices were somewhat at odds with such Vision I-II practice.

As presented in the previous section, among the six teachers' cases, four teachers' perspectives were considered to be in line with Vision I-II orientation, one teacher's perspectives were aligned with Vision I and the remaining teacher's perspectives were considered naive. The following sections discuss how teachers' perspectives were translated into classroom teaching in action.

7.3.1 Vision I-II perspective leading to Vision I practice.

Analysis of the cases reveals that Sabina, Ashim and Morshed did not translate their Vision I-II perspectives into classroom teaching. For example, it was observed in Sabina's classroom teaching that she gave an extensive theoretical lecture on the properties of acids, chemical reactions of acids with alkalis and their respective chemical equations. In addition to such theoretical input, she described the use of acids in personal life and life beyond the personal level, such as in industries. She also presented a global issue (acid rain), which she thought would help students to follow the media reports on acid rain. However, she did not consider this particular situation of acid rain as a context for learning about acids. As was observed, she told students about acid-related content (as noted above) and then exemplified situations or contexts (acid rain, for example) in which the content may have a role. In this manner, she used contexts as add-ons to the theoretical content, and eventually, her teaching in action remained like Vision I practice according to Roberts (2007) and Aikenhead (2008). A reflection of this Vision I practice was also evident in the focus group interview with her students, where many of the students found difficulty in seeing the use in everyday life of learning about the properties of acids, and the chemical reactions of acids with alkalis. Rather, students' consideration of the importance of learning about such content for their future science study and examination purpose could be seen as an indication of Vision I practice in Sabina's science class.

In a similar vein, in practice, Morshed and Ashim emphasised the theoretical content and additionally went on to identify the possible use of the content in everyday life. For example, describing the content about chemical symbols and formula as forming the foundation for studying chemistry at the upper level, Morshed presented a theoretical explanation of the symbols of different elements and their use in writing formulas of different compounds. In addition to this theoretical presentation, he expounded on the use of learning about chemical symbols and formula in everyday life, such as using a carbon dioxide cylinder in response to a fire problem and understanding the properties of medicines when making decisions about purchasing them. However, as detailed in Section 6.7.2, Morshed's presentation did not provide students with the notion that the theoretical content could be useful in everyday life, since students found difficulty in understanding the properties of medicine with their school science knowledge. Such difficulties for students, as suggested by Aikenhead (2008), may also be seen as indicating a Vision I practice in science classes.

7.3.2 Vision I-II perspective leading to Vision I-II practice.

As an exception, Jasmine's teaching practice was consistent with her Vision I-II perspective. As elaborated in Section 6.9.2, she started the lesson about flowering plants with remarks on how learning about plants would help students understand the natural environment. Her points included the importance of caring for plants to maintain the sustainability of the environment. Then she engaged students in observing the schoolyard to find different parts of flowering plants and hold discussion on their observations in groups. With the students' discussion report, she arranged a whole class discussion and acted as a moderator by providing questions and clues to students in order to direct the discussion. With this whole class input, she went on to explaining the theoretical aspects about flowering plants. However, it may be worth noting that she did not spend much time on the theoretical aspects. Rather most of her classroom discussion centred around how tree plantations could be a contributing factor in managing the sustainability of the natural environment of Bangladesh. Students, in the focus group interview, recognised how they could use learning about plants in their everyday life, for example, in tree plantations and gardening. As Aikenhead (2008) suggested, a Vision I-II practice helps students recognise the use of school science learning in their everyday life. Jasmine's students' recognition of this relevance to their everyday lives could therefore be seen as a reflection of Vision I-II practice in her science class.

7.3.3 Vision I perspective leading to Vision I practice.

As noted previously, a Vision I policy leads to a Vision I practice (Aikenhead, 2008; Roberts, 2007); therefore, it was not surprising that Alam's Vision I perspective would be translated to Vision I, in practice. Perceiving scientific literacy as synonymous to being able to work as science professionals, Alam constantly encouraged students to consider the "prestigious" science-related professions for their career aspirations. Such encouragement was also recognised by the students in the focus group interview in that many of them recognised the science-related professions as "prestigious" and expressed their wishes to take up such professions. However, they found difficulty in articulating the use of their science learning in everyday life. This could be seen as a reflection of the lack of emphasis on the use of science in everyday life and the greater emphasis on preparing future science professionals through ascription to traditional canonical science knowledge as observed in Alam's classroom teaching practice. This Vision I practice is argued to fail to engage students with science in everyday life (Aikenhead, 2008; Rennie, 2011; Roberts, 2007).

7.3.4 Naive perspectives leading to naive practice.

Rashid's perspectives of scientific literacy were perceived as naive as he could not explicate scientific literacy beyond language literacy. This naive perspective was translated in his teaching with an emphasis on developing the language skills of his students. Moreover, Rashid's religious beliefs were also reflected in his teaching practice as observed. For example, he discussed the importance of cleanliness from the Islamic point of view rather than a scientific point of view. This practice may not help students understand cleanliness from the scientific point of view. The point is that the explanation of cleanliness from a religious point of view could vary within different religions, while the power of scientific explanation is that it is relatively universal. Thus, neglecting the scientific explanation of an idea would likely compromise students' ability to develop and appreciate the power of scientific explanation. Moreover, as discussed previously, Rashid only considered the religion of Islam in explaining cleanliness. This sole consideration of a particular religion might reinforce discrimination against students from other religions than Islam in his class.

One of the possible reasons for such practice may be Rashid's academic background. As described in Section 6.8.1, Rashid did not have a background in science. This limited education in science may limit any effort to develop and appreciate scientific explanations over his religious beliefs. Coming from a culture with an Islamic tradition (the majority of people in Bangladesh profess Islam and hence Islamic values dominate in determination of the educational purposes, as noted previously), Rashid permitted his Islamic beliefs to hold sway in his decision about how to teach science. This may point to an issue in the teaching of science by teachers from a non-science background. This point might be vital in the context of Bangladesh where it is very common that teachers with non-science background teach science at the junior secondary level (for example, 23% teachers in this research did not have a degree in science).

7.4 Values Teachers Consider in Relation to Scientific Literacy

As discussed previously in Section 2.5, this research focuses on five selected values identified in the Bangladesh junior secondary science curriculum (e.g., curiosity, rational thinking, open-mindedness, respect for others' opinions and intellectual honesty) because they may influence the ways people use (or fail to use) science knowledge in making and evaluating decisions and arguments, and thus have importance for scientific literacy. A macro view of teachers' consideration of these values in their science classes suggested a general emphasis was placed on promoting the values (see Section 5.4.2). A micro view of how teachers perceive the importance of these values and how they consider them in their teaching practices was made through conducting a cross-case analysis of the cases presented in Chapter 6. This section discusses the findings of the cross-case analysis to portray this micro view.

It is apparent in the cross-case analysis that among the selected values curiosity and rational thinking have been perceived as the most important values for scientific literacy by the teachers. However, there are some differences in their perceived importance and the respective teaching approaches as discussed in the following sections. Moreover, there is evidence that teachers also considered open-mindedness and respect for others' opinions in science classes, but with varying conceptualisations of these values. Teachers' cases also revealed that the least emphasis was placed on the value of intellectual honesty in science classes. At this stage, let us move on to discuss the pattern of teachers' perspectives of the importance of each of the values along with teaching approaches they adopt to promote the values.

7.4.1 Curiosity.

7.4.1.1 Perceived importance of curiosity.

From the cross-case analysis, it appeared that the teachers perceived curiosity as important for scientific literacy. For example, Ashim made the case for curiosity in science learning as it prompted students to find the questions about the natural world and 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.

Whilst teachers all articulated their perception that the value of curiosity was important, they had varied notions of teaching approaches to promote this value. Based on the 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 fail to promote 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 three categories are discussed in the following Section 7.4.1.2. The categories were also found pertinent in regard to the values of rational thinking and open-mindedness and respect for others' opinions, which will be discussed in Sections 7.4.2.2 and 7.4.3.2 respectively.

7.4.1.2 Teaching approaches to promote curiosity.

The three categories for the teachers' teaching approaches to promote curiosity are discussed below.

Teachers who articulate a teaching approach but whose practice may fail to promote curiosity.

Analysis of the cases reveals that while both Sabina and Alam attempted to promote curiosity in science teaching, their attempts in practice may fail to 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 seems she considered modelling the asking of questions as important in helping students to perceive this as a good thing to do. However, it appeared in her classroom teaching practice that she asked students only verification-type questions. Such questions prompted students to answer the questions, but failed to encourage reflection on their experiences. As Wallace and Louden (2002) argued, asking 'what if' type questions could help students generate new 'what if' type questions from themselves and help promote their curiosity. However, Sabina's classroom questioning did not include any 'what if' type questions. Therefore, it seems that she was not knowledgeable about the kinds of questioning that could promote students' curiosity.

In a similar vein, whilst Alam perceived his students as very curious and the focus group interview with students also revealed their curious nature, Alam's teaching approach may be seen as failing to promote students' curiosity. Alam felt 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 to represent how an incident could trigger people to wonder the reason behind the incident. When presenting the story he asked students questions; he did not, however, leave any "wait time" (Goodrum, 2004) for students to think for themselves. Goodrum argued that wait time provides students with the opportunity to articulate their thoughts and reflections. Rather, it was observed that Alam gave students no space to present thoughts that could be useful in promoting their curiosity. It seems he asked students questions that could provoke their thinking, but was not very interested in listening to what his students thought about. As Goodrum (2004) argued, 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 help students extend their thinking and thus may not be 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 are argued to fail to promote students' curiosity as discussed above, they were able to articulate their attempt to promote curiosity. In contrast, Ashim and Rashid could not specify how they teach to promote curiosity. For example, it was observed in Ashim's classroom teaching practice that he did not consider students' questions; on some occasions, he even stopped students from asking questions because he viewed these as responsible for creating "noise in the class". Classroom quietness, often in a form of pin-drop silence, is a traditionally expected norm in Bangladeshi classrooms as it is in the nearest developing country, India (Rampal, 1994). It seems that Ashim also was concerned with maintaining classroom quietness by preventing students from asking questions. Input from the focus group with his students also indicated their discomfort in asking him questions. This practice would discourage students' curiosity.

Teachers who articulate and practise a teaching approach that may promote curiosity.

The teaching approaches of Jasmine and Morshed could be seen as useful in promoting students' curiosity in science classes. However, there was difference between their teaching approaches as discussed below.

In her classroom teaching practice, Jasmine engaged students in observing different parts of the flowering plants available in their school surroundings and then had them discuss their observations. This engagement helped students find questions from their observations. The evidence in her classroom teaching was that students asked her questions from their observations and she was found to be enthusiastic in addressing such questions. Her practice may also encourage students to ask questions from their experiences and would encourage students' curiosity. 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 were generated from their curiosity about plants and who appreciated Jasmine's encouragement to ask her such questions.

In a similar vein, Morshed was found to be empathic in addressing student's questions in science class. In addition, he acknowledged the limited capacity 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. He 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. His students, in the focus group interview, also reported how they appreciated Morshed's encouragement to explore various resources seeking responses to their questions in more depth. This appreciation from the students' side could also be seen as an indication of how they were encouraged to pose and explore questions in their science class.

7.4.2 Rational thinking.

7.4.2.1 Perceived importance of rational thinking.

From the cross-case analysis it seems that all the teachers within the cases perceived rational thinking as an important value of science education and scientific literacy. They articulated their belief that rational thinking could help students in making justifications and rejecting unjustified things. In particular, Sabina and Ashim extended the importance of rational thinking to the challenge it represented to superstitions that are embedded in Bangladeshi society as in other developing countries (e.g., Asian Development Bank [ADB], 1998; Nargund-Joshi, et al., 2011; Rampal, 1994). For example, Sabina exemplified a superstition relating to acidity and explained how rational thinking could help students challenge the superstition. The superstition she referred to held that if one does not thank God before taking food, the person would suffer from acidity. She made the point that science learning in school can help students form a scientific explanation of acidity. Such an explanation would challenge the superstition and it is rational thinking that would help students decide which explanation (scientific explanation or the superstition) is more plausible and fruitful to adopt. The point here is that the causes of acidity may be explained in various superstitious ways (ignoring thanks to the God may be one of them) and they may vary in different local contexts. However, the power of scientific explanations (e.g., explaining acidity in a scientific way) is that they are relatively universal and hence usable in different contexts. Sabina seems to have expected that rational thinking would help students to understand the power of scientific explanations in explaining phenomena.

In a similar vein, Ashim gave the example of a superstition referring to being born as a donkey in reincarnation as a consequence of taking a bath in a laundryman's place. Ashim explained this superstition in a scientific manner and made the point that rational thinking would help people understand the plausibility of the scientific explanation. The point here is that belief in reincarnation is associated with some religions, for example Hinduism (House, 1991); therefore, people believing in Hinduism may accept the reincarnation-related explanation. However, reincarnation is rejected in other religions, for example in Islam (Gulluce, 2008); therefore people believing in Islam may oppose such an explanation and they could have other ways of discouraging people from taking a bath in a laundryman's place. As a result, there would be different explanations from context to context. As noted previously, the power of scientific explanation is that it could be applied in different contexts. In this case, whilst both the scientific explanation and the superstition discourage people from bathing in a laundrymen's place, Ashim perceived that rational thinking would help people understand the plausibility and fruitfulness of the scientific explanation.

7.4.2.2 Teaching approaches to promote rational thinking.

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

Teachers who do not identify teaching approaches to promote rational thinking.

Whilst the cross-case analysis suggests that teachers perceived the importance of rational thinking in science teaching, there is evidence that Ashim and Morshed could not identify how they considered rational thinking in their teaching practices. For example, Ashim claimed that rational thinking would be developed as a by-product of science education since in his words, "there is no scope for any irrational thing in science". This view may be seen as an indication of how little he understands how rational thinking needs to be developed in his students. 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 as none of the students were able to recognise how rational thinking was considered in science class.

Teachers who express a teaching approach but may fail 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 not had 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. Moreover, observation of her approach to engaging students in activities suggested that her belief in the myth of a single universal scientific method (see Abd-El-Khalick & Lederman, 2000a; Abd-El-Khalick, et al., 2008; Lederman, 2004, 2006), which she had uttered in the interview, was similar to Alam and Rashid's views of science. As was observed in her class, she did not explicitly encourage students to design and conduct the activity in different ways. This lack of explicit encouragement may implicitly suggest to students that there is only a single way to conduct an activity in science. This message further may 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 if they were asked to justify the plausibility of their suggestions, they would have used rational thinking in making the justification. 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 she failed to promote rational thinking. Rather it seems that her approach did not go beyond adopting cookbook or recipe-like science activities that are very common 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 perceived 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 scientific argument. Corrigan and Gunstone (2007) described emphasising justification and arguments as concepts of rational thinking; Sabina's practice thus may be viewed as promoting rational thinking. The focus group interview with her students also provided evidence of students' appreciation of Sabina's constant encouragement of providing justifications when communicating ideas. Moreover, the focus group interview elicited evidence of students being able to identify the use of rational thinking in justifying their rejection of a superstitious belief regarding acidity (see Section 6.4.3.2). The students' capacity to exemplify the use of rational thinking suggests that Sabina's teaching approach was helpful in promoting it.

7.4.3 Open-mindedness and Respect for others' opinions.

7.4.3.1 Perceived importance accorded promoting open-mindedness and respect for others' opinions.

The cross-case analysis suggests that Ashim and Rashid did not perceive open-mindedness and respect for others' opinions as important in science classes. However, varying notions underpinned their perceptions. For example, whilst Ashim regarded open-mindedness and respect for others' opinions as "good human qualities", he believed that his science class did not have the scope to promote these values. He viewed scientific ideas as "proven facts" and objective in nature and therefore felt there was no place for offering opinions on scientific ideas and looking for alternative ideas. This view is at odds with the contemporary understanding of the subjective nature of science, suggesting that background factors (e.g., scientists' knowledge, beliefs, commitments) influence scientific investigations in terms of choice of problems, methods of investigation, observations and interpretations of the observations (Lederman, 1992, 2004, 2006, 2007; Lederman & Lederman, 2004). Considering this subjectivity in science, it was argued previously in Section 2.5.3 that a portrayal of subjectivity in science might help students appreciate the importance of keeping their minds open to accepting new/ different ideas. This may, in turn, be helpful in being respectful to people's right to hold and express ideas whether they are different or similar to their own. Ashim's disregard for subjectivity was echoed in his students' focus group interview, where students expressed their unwillingness to pose opinions about a scientific idea or consider opinions posed by their classmates. This unwillingness may be seen as at odds with the notions of open-mindedness and respect for others' opinions.

In a similar vein, Rashid showed his unwillingness to accept the right of his students to hold and express opinions, but with a different emphasis. He considered his students as 'kids' with limited knowledge and experience that would challenge them to understand many issues. This consideration persuaded him to argue that students need to "just follow" their elders. One of his students, in the focus group interview, also showed her desire to follow her elders (her teacher, in this case) if her classmates posed an idea conflicting with hers. She viewed her teacher as the authority with knowledge and experience. A corollary of her reasoning is that she might not consider what the justifications of her classmates' ideas were. This practice could be seen as conflicting with the notion of respect for others' (her classmates, in this case) ideas. Moreover, if she listened to her classmates' justifications of their ideas, she could get alternative ideas that could even suggest her to revise her existing idea. Consideration of available alternatives and willingness to revise ideas are required for being open-minded (Hare, 2009; Hildebrand, 2007; Hodson & Reid, 1988a). In sum, the student's verbalised practice sits at odds with the notion of open-mindedness.

On the other hand, Sabina, Alam, Morshed and Jasmine perceived open-mindedness and respect for others' opinions as important values in science education. For example, in the interviews, Jasmine appreciated subjectivity in science and the revisionary nature of science. Such an appreciation may help students heed the message that they need to keep their mind open to consider new science ideas. It may also encourage students to consider alternative views in science, which can vary from person to person. In consideration of such alternative views, Jasmine was appreciative of the possible "conflicts" arising in people as a result of different views. In order to address such a conflicting situation, she perceived the importance of promoting the value of respect for others' opinions.

Whilst Sabina, Alam, Morshed and Jasmine perceived the importance of the values of open-mindedness and respect for others' opinions in science education, all of their teaching approaches may not be useful in promoting these values as discussed below.

7.4.3.2 Teaching approaches to promote open-mindedness and respect for others' opinions.

The three categories for the teachers' teaching approaches to promote open-mindedness and respect for others' opinions are discussed below.

Teachers who do not identify teaching approaches to promote open-mindedness and respect for others' opinions.

As noted previously, among the teachers within the cases, Ashim and Rashid did not perceive open-mindedness and respect for others' opinions as important in science classes. Therefore, it was not surprising that they failed to identify teaching approaches to promote these values in science classes.

Teachers who express a teaching approach but may fail to promote open-mindedness and respect for others' opinions.

In the interviews, Alam made the case for the value of respect for others' opinions in his approach to creating mixed ability student groups where the "brighter students" are involved in helping the "less able" ones. Moreover, he believed "the weaker student may also have some distinctive things that others can learn". This approach could be seen to be developing mutual respect among students. In addition, Alam claimed that he discussed with students how they might propose possible alternatives for looking at an issue by carefully listening to other group members' voices. By encouraging students to consider the alternatives, as suggested by Hare (2009), this approach could help develop open-mindedness in his students. This open-mindedness could help students look for alternative views and evaluate such views before accepting or rejecting the views. However, observation of a series of his teaching lessons did not provide any instance of such a practice. Rather, his students, in the focus group interview, raised the point that Alam was not always respectful to students' alternative ideas (for example, he showed annoyance – or impatience – to a student's alternative idea and labelled it as a "stupid" one) and this may inhibit students from presenting their alternative views in the classroom. Such practice of Alam's may also build confusion among students about whether they would respect an idea presented by younger and less experienced people (as they are younger and less experienced than their teacher). If this was the practice, it may be reasonable to argue that it might not be useful in promoting open-mindedness and respect for others' opinions in science classes.

Teachers who articulate a teaching approach that may promote open-mindedness and respect for others' opinions.

Morshed, Sabina and Jasmine considered group discussion approaches as useful for promoting open-mindedness and respect for others' opinions in their science classes. For example, Morshed set a number of classroom discussion norms including "no one can force others into accepting his/her views and all have equal opportunity to express their views" and suggested students follow these norms. These norms could encourage students to appreciate their classmates' views and use them to get possible alternatives to look at an issue. In the focus group interview, students also appreciated the discussion norms and expressed their openness to revising their thinking in the light of a more justified idea provided by their classmates. This notion of open-mindedness encouraged students to appreciate the rights of others to hold and express their opinions and ideas. Such students' appreciation of open-mindedness and respect for others' opinions could reasonably be seen as a reflection of their teacher's explicit consideration of these values in the code of classroom practice that he had set for students at the beginning of the year.

7.4.4 Intellectual honesty.

The cross-case analysis suggests that all the teachers had difficulty articulating their notions of intellectual honesty in science classes. Whilst Sabina, Alam and Ashim could not express what they meant by intellectual honesty or how they considered it in teaching science, Rashid and Jasmine articulated naive perceptions of this value as below.

Rashid could not specify his notion of intellectual honesty in science education beyond a general notion of honesty as a societal value; and therefore, could not articulate how he considered intellectual honesty in his science teaching. Jasmine, on the other hand, perceived intellectual honesty in science education as being related to accuracy. She contended that being accurate in conducting experiments would help get the "correct result" of an experiment. This view may be seen as indicating her inclination to value correct results in assessing students' practical reports. According to APEID (1991b), if correct results are the only ones valued in assessing students' practical reports, students might be tempted to manipulate their results and observations in the report in order to present the "correct" results. Such a practice, according to APEID, contradicts the notion of intellectual honesty. Reporting correct results by manipulation, as discussed before, is a common feature of the teaching-learning culture in Bangladesh (Siddique & Rahman, 2007). Promoting this culture may reinforce students to practice manipulation and is likely to challenge the promotion of intellectual honesty. Challenging this culture was evident in Morshed's perspectives as discussed below.

Morshed claimed that he encouraged secondary students to report their lab work honestly. However, as students at junior secondary level (which is the focus of this research) are not required to prepare lab reports, there was no instance of encouraging honest lab reporting for the lessons I observed within this research. None of the students in the focus group interview could also provide a single instance of the use of intellectual honesty. As intellectual honesty is important to encourage students to communicate a consistent conclusion based on the evidence and therefore is important for scientific literacy (NRC, 1996), having little or no emphasis on intellectual honesty in science classes may challenge the promotion of scientific literacy. Like this challenge, there were a number of challenges in teaching for promoting scientific literacy facing these teachers; these are discussed in the following Section 7.5.

7.5 Challenging Issues in Teaching for Scientific Literacy

A macro view of teachers' perceived challenges in their teaching for promoting scientific literacy has been illustrated previously in Section 5.5. Teachers were given some issues identified in previous research in the Bangladesh context (e.g., APEID, 1991a; Tapan, 2010) and asked to rank the issues in terms of their perceived dominance. Teachers' ranking suggested that the large class size was the leading challenge to teaching for scientific literacy. As noted previously, this finding was not unexpected, as almost half of the participant teachers' science classes in this research accommodated more than 80 students (see Section 5.2.5) which is twice the standard class size recommended in Bangladesh education policy (Ministry of Education, 2000). It seems that this policy does not translate into practice, and as a result, science classes in

Bangladesh accommodate huge numbers of students. This scenario has been reported as being the case in other Asian contexts, for example, India (Nargund-Joshi, et al., 2011) and China (Zhang, et al., 2003). Large class size, as suggested by Goodrum et al. (2001), would reasonably challenge teachers in engaging students in science activities and focusing on individual learning opportunities for every student.

The macro view of teachers' perceived challenges also suggested that "lack of scope in the curriculum" and "heavy workload" were the second most prevalent challenges to promoting scientific literacy, while "lack of resources" received a rank order of fourth as a challenge followed by the "school assessment system". It is interesting to note that whilst studies conducted in Asian contexts (e.g., Nargund-Joshi, et al., 2011; Zhang, et al., 2003) have reported teachers' perceptions of assessment issues and scarcity of resources as the major stumbling blocks in teaching science, these two issues were ranked with limited emphasis by the teachers in this research. In the questionnaire, teachers also added their poor content knowledge in science, lack of training opportunities for them and the students' academic ability as challenges in their teaching for promoting scientific literacy.

Whilst the macro view of teachers' perceived challenges, as discussed above, provides a general picture, in order to obtain a more complete picture of teachers' perceived challenges in teaching for promoting scientific literacy it was important to explore, in depth, why teachers perceived an issue as challenging and how they addressed the issue in their science classes. As noted previously, this in-depth understanding was referred to as a micro view, and was presented in six cases in Chapter 6. A cross-case analysis was conducted among the cases to understand the pattern of the themes that emerged from them. These are discussed below.

The cross-case analysis suggests that whilst teachers identified many issues they perceived as challenging in their teaching for scientific literacy, in most cases, they could not articulate how the issues affected their teaching to promote scientific literacy, and in many cases, they expressed their limited capacity to meet these challenges. The analysis also suggests clustering teachers' perceived challenging issues into four broad categories relating to curriculum, school, assessment, and teacher development.

7.5.1 Curriculum issues.

Several sub-themes appeared in the cross-case analysis of teachers' perceived challenges relating to curriculum issues: overloaded curriculum; academic content-dominated curriculum that is irrelevant to students' everyday lives; outdated content; and the complex language used in the recommended science textbooks.

7.5.1.1 Curriculum is overloaded.

Sabina and Alam perceived the General Science course as overloaded with a huge amount of content to cover and considered this a challenge to their teaching. For example, Sabina made the point that this "overloaded" course, coupled with the exigencies of "limited time", forced her to rush through the syllabus and left little time to reflect on her teaching, resulting in lack of monitoring of students' learning. Alam extended the point that rushing through the syllabus in "35 minute" class packages restricts students' "good discussion" in groups, which he perceived to be useful in promoting students' open-mindedness and respect for others' opinions. However, neither Sabina nor Alam talked about how they could be engaged in making a decision about what is worth learning in science, what needs to be taught (i.e., where the teacher assists in the learning) and what the students can learn on their own or may already know. Consideration of these aspects could be useful in maximising the time available for learning in science classes rather than placing the responsibility only on the size of the syllabus and the limited time to complete it. Alam's comment in this respect "what can I do?" reflects his limited capacity to face the perceived challenge.

7.5.1.2 Content is mostly academic and irrelevant to students' everyday lives.

Sabina, Ashim and Jasmine observed that school science textbooks place little emphasis on content that is relevant to students' everyday life. This observation concurs with the characteristics of science textbooks in Bangladesh (see Chapter 3). The academic nature of the textbooks is a characteristic of a Vision I orientation, which may result in reduced capacity for students to see the relevance of their school science learning for effective functioning in everyday life (Aikenhead, 2008). Moreover, the common practice of using textbooks for teaching-learning purposes in Bangladesh, as noted in Section 3.2.3, suggests that academically oriented textbooks used for the General Science course, in turn, characterise the course as an academic one. This academic course may fail to meet the needs of all students as they strive to become effective citizens, and eventually, may raise the question of suitability of a common academic course for all. This question is vital in a context like Bangladesh, as only 25% of students go on to study specialised science courses after the junior secondary level (BANBEIS, 2006b).

In order to respond to the issue of irrelevancy of content, wherever possible, Sabina and Ashim identified the possible applications of the content that they feel important for students to draw on, and explain the links between the content and the world around them (for example, Sabina described acid rain in her teaching about acids even though it was not in the textbook). However, the academically oriented General Science course challenged Sabina to find the possible applications of much of the content in the physical sciences that could help students to draw on their science knowledge and explain these links between their knowledge and its application. Sabina was not confident with her content knowledge of physical sciences since this was not her academic background and perceived the importance of specialised content knowledge to teach the academically oriented General Science course. In a similar vein, Rashid's non-science academic background challenged him in teaching the academically oriented General Science course. When this is the case, it may raise a further question – "how can the teachers without science degrees (23% of the participant teachers in this research did not have any science degrees) teach this academically oriented course". It may be reasonable to assume that they would just present the content to students in the way it is presented in the recommended textbook, which is what Sabina does for much of the physical sciences content.

7.5.1.3 Content is outdated.

In addition to the lack of relevancy of science content to students' lives, Ashim made the point that "much of the content in science textbooks has no application in current real life issues". For example, while perceiving the importance of contemporary IT-related knowledge for promoting students' interest in science, he could not find the scope for teaching students about IT because there is no IT-related content in the textbooks. As promoting students' interest in science is central in promoting scientific literacy (Solomon, 2001), Ashim's teaching was challenged in a textbook-dominated teaching-learning context. A centralised curriculum and prescribed textbooks guide the teaching-learning activities in Bangladesh, and therefore, curriculum does not seem to provide teachers with the flexibility to make changes to it. If some content is not included in the textbook (even if the teachers think the content has importance), there is little scope for teachers to teach it in class.

7.5.1.4 Complex language is used in textbooks.

Jasmine considered the language used in science textbooks as "complex" compared with the language ability of young students. This complexity of language, as she pointed out, would challenge students' ability to understand the content. The complexity of language could be seen as very important in the Bangladesh context, as the provision of a single textbook in Bangladesh means students rely heavily on its contents for learning science (Holbrook, 2005). Moreover, as discussed before, there is no flexibility for any modification to textbooks by teachers and schools; it was therefore beyond Jasmine's capacity to respond to this issue. As a result, she urged the textbook developers to consider the language issue.

7.5.2 School issues.

Several sub-themes appeared in the cross-case analysis of teachers' perceived challenges relating to school issues: science classes with mixed ability students; large class size; limited resources; limited time allocation for science classes, and teachers' workload.

7.5.2.1 Mixed ability class.

From the cross-case analysis, it appears that teachers mostly characterised their science classes as accommodating students with diverse academic abilities and they found it difficult to meet the needs of all students. For example, Alam claimed that some of his students needed to revisit some content that they were taught in earlier years, but others were bored with this repetition and were not willing to go through the content again. This resulted in tension among students with different abilities.

Whilst teachers perceived their mixed ability classes as a challenge in their teaching, many of them were not equipped to respond to this challenge. Among the teachers, Sabina and Rashid expressed their incapacity to respond to this challenge; Ashim proposed splitting the class into different sections based on students' abilities, an approach that is at odds with the philosophy of inclusive education that Bangladesh is trying to endorse in schools (Ministry of Education, 2010).

Alam and Morshed, on the other hand, took a mixed-ability small group approach to maximise the benefits from a mixed ability class. For example, Alam categorised students based on their academic achievement and made groups with students from different categories. These mixed ability groups involved students with a better understanding of a topic working with those with less understanding, each contributing in distinctive ways (e.g., conceptual understanding, leadership or creativity), from which others could learn. This approach to maximising the benefit of a mixed ability class may help students in developing support, mutual respect, understanding and tolerance in working in mixed ability groups. In a similar vein, Morshed also noted how his small group approach helped students gain self-satisfaction after completing a group task.

7.5.2.2 Large class size.

Among the cases, the classes of Ashim, Rashid and Jasmine accommodated a huge number of students (100, 85 and 70 students respectively), compared with the other cases. It was, therefore, not surprising that they would perceive their large classes as a challenge in their teaching for scientific literacy. For example, perceiving that scientific literacy requires less emphasis on lecturing, as suggested by Goodrum (2004, 2007), Ashim claimed his large class reinforced his reliance upon lecturing, which posed a challenge in his teaching for scientific literacy.

In responding to this issue, Ashim tried the small group approach. However, large numbers of students resulted in large numbers of small groups and looking after them all seemed to him unmanageable. Given the situation, he continued to rely upon lecturing and consequently the issue remained unresolved. In a similar vein, the large class issue was beyond the capacity for Rashid and Jasmine to resolve.

7.5.2.3 Limited resources.

As discussed previously, limited resources is one of the major stumbling blocks in science teaching in developing countries, for example, in India (Nargund-Joshi, et al., 2011) and China (Zhang, et al., 2003), and this may be due to the lower economic status of these countries (Lewin, 2000). Teachers, in this research, also identified the limited resource facilities in their schools as a challenge to their teaching for scientific literacy. As most teachers remarked, schools do not provide junior secondary students with access to the school science lab, which can also be limited in its facilities. Teachers were worried that this failure to provide lab access to students might hamper their science learning and decrease their interest in science. This may indicate the prevailing perception among these teachers that they need a lab for science activities; certainly, other options to do science activities (e.g., fieldwork) did not seem all that prevalent in their thinking.

Perceiving the importance of practical activities in science, some teachers intended to organise activities that could be carried out without lab support. For example, Sabina involved students in testing the acidity of household items using hand-made litmus and organised practical activities without lab support. In a similar manner, Morshed and Jasmine reported how they prepared low-cost materials from easily available resources and organised practical activities for students in the classrooms. As Morshed pointed out, use of such low-cost materials (e.g., a low-cost molecular model of carbon dioxide) could help students understand the abstract concept (model) of the structure of carbon dioxide. Furthermore, the use of low-cost materials would help combat the scarcity of science teaching equipment in schools. However, Morshed's experience as a master trainer for secondary science teachers suggested to him that many teachers were not aware of finding teaching equipment through their own initiative. This observation concurs with Tapan (2010) who suggests that poor motivation to improve teaching practice inhibits teachers from using their initiative to find teaching equipment. Indeed, from my own experience in teacher education, where I observed many classes of experienced and novice teachers, it appears to be uncommon in Bangladesh for teachers to make and find teaching equipment to use in science classes or to organise practical activities without lab support. Teachers' naive conceptions about science activities might also be a reason for teachers' reluctance in organising practical activities without lab support. For example, Alam viewed that "when you are learning science, it is obvious you are doing some experiments in the lab". This view may reflect the belief that science activities only happen in labs, which may in turn restrict him from thinking about activities that can be organised without a lab support.

7.5.2.4 Limited time for science classes.

Alam, Jasmine, Sabina and Rashid considered the allocated time for science classes to be insufficient and perceived this as a challenge to their teaching for scientific literacy. This challenge includes insufficient time for group discussion, which Alam perceived to be useful in promoting some values, for example, open-mindedness and respect for others' opinions. However, teachers could mostly not articulate how they could respond to this challenge with one exception – Jasmine. Jasmine proposed to decrease the number of science classes in a week that would increase an individual class time from 35 minutes to one hour. Whilst her proposal did not conflict with the total time allocated for science in a week, a centralised time allocation system opposed implementation of the proposal. This could be seen as an instance of the lack of flexibility of teachers and schools to make any modification to a centralised system.

7.5.2.5 Heavy workload.

Whilst in the questionnaire teachers indicated their workload as the second most serious challenge to their teaching for promoting scientific literacy, among the cases, only Ashim perceived his workload as a challenge. The reason might be that he had a huge class commitment compared with the other cases. He, on average, had a commitment of six classes per day and needed to spend time in addition to this preparing for these classes. He perceived that he did not have sufficient time to get prepared as he had to run from one class to another. However, he could not articulate strategies he could use to maximise his time in order to secure some preparation time. Rather he seemed overwhelmed and accepted that he had a heavy workload and there was insufficient time to get prepared.

7.5.3 Assessment issues.

Two assessment issues appeared in the cross-case analysis of teachers' perceived challenges, the examination-driven education system and formative assessment issues.

7.5.3.1 Examination-driven education.

Analysis of the cases reveals that teachers perceived the exam-driven education practice as a challenge to their teaching for scientific literacy. For example, Jasmine explained how students' exam results are used as measures to determine the quality of teaching and the achievements of schools in Bangladesh, a practice that leads to an overemphasis on students' results. These exams, traditionally, assess students' ability of memorisation rather than their ability to apply science knowledge in everyday situations. This characteristic of exams in an exam-driven education persuades teachers to place more emphasis on assessing students' memorisation ability (see Section 5.4.3), which may in turn encourage students to adopt rote memorisation as a 'learning' strategy. As a result of such exam practice, students often lack the ability to apply science knowledge in everyday situations that is important for their scientific literacy, as suggested by Goodrum (2004, 2007). Among the teachers, Jasmine attempted to challenge this assessment practice by preparing exams that would require less memorisation. However, she was worried that her attempt would not work in the case of external exams as they still assess students' memorisation ability.

As in the external exams, there are some cases (especially in rural schools) where teachers do not have autonomy to prepare exams for their students. For example, Sabina's students are assessed by the exams prepared by an external local board. In such a case, this reduced autonomy to assess teachers' own students, in an examination-driven education system (Holbrook, 2005), made Sabina feel that the issue was beyond her capacity to resolve.

There was evidence in the cases to suggest that a change in assessment practice could help students develop a positive attitude towards a particular teaching approach. For example, Morshed's small group approach did not attract students' interest as they thought that group work would not be assessed in the exams. However, with the government's initiation of the School Based Assessment in schools, which counted students' group work as being assessed (Begum & Farooqui, 2008), Morshed was able to draw students' interest towards being involved in small group activities.

7.5.3.2 Challenges for adopting formative assessment.

Formative assessment provides students with feedback to assist their learning (Black, 1993), which is argued to be suitable for promoting scientific literacy (Goodrum, 2004; Goodrum, et al., 2001). Whilst formative assessment is emphasised in the teacher macro view of their assessment practice as reported in Section 5.4.3, none of the teachers' cases provided any instance reflecting their formative assessment practices. However, the cases provided insights into teachers' obstacles to adopting formative assessment practices. For example, Sabina articulated how the rushed General Science course coupled with the exigencies of limited time challenged her to monitor students' learning and provide feedback that they could use in assisting their learning. However, she could not explain how she could address these issues. This indicates that the issues would likely remain unresolved and would keep challenging her notion of formative assessment practice and her teaching for promoting scientific literacy.

7.5.4 Teacher development issues.

Whilst the questionnaire data suggested that most of the teachers in this research (93%) have gone through professional development programmes in their in-service teaching career (see Section 5.2.3), Morshed's case suggests that existing teacher development programmes in Bangladesh have limited capacity to help teachers teach for promoting scientific literacy. As Morshed explained, existing teacher development programmes primarily focus on increasing teachers' content knowledge in science. There might be two reasons for this focus. Firstly, as is the practice in developing countries (Ware, 1992), in Bangladesh, teachers' science background often presents a challenge for them to teach the General Science course (this course comprises content from different subject areas). For example, as we have seen in Sabina's case (see Section 6.4.4) she was not confident with her content knowledge to teach the physical sciences content as her background was in biological sciences. Secondly, there is evidence that teachers from non-science background teach the General Science course. For example, 23% of the participant teachers in this research did not have a science degree but were teaching science in schools (see Section 5.2.1). Therefore, there is some imperative to increase the science content knowledge of the teachers from non-science background and this is why Rashid, a science teacher with a non-science background, urged for in-service professional development programmes dedicated to increase his science content knowledge (see Section 6.8.4). However, Morshed made the point that if scientific literacy is counted as a curricular aim for science education, professional development programmes for science teachers have to focus on increasing teachers' pedagogic knowledge related to promoting scientific literacy.

7.6 Chapter Summary

In this chapter, I have discussed the findings of this research in relation to the research questions of this study focused on Bangladeshi science teachers' perspectives of scientific literacy, the translation of their perspectives into classroom teaching practice, the values they consider in their teaching for scientific literacy and the issues they perceived as challenging in their teaching. Based on the discussion presented in this chapter, the concluding chapter presents the implications from this study for science educational practice and research.

CHAPTER 8
Conclusion

This thesis has explored how scientific literacy is promoted through junior secondary science education in Bangladesh, looking particularly at four areas: how teachers perceive scientific literacy; how they translate their perspectives into teaching practices; what values they consider in science teaching in relation to scientific literacy, and what issues they perceive as challenging in their teaching for promoting scientific literacy. In this exploration, the research followed a mixed methods design where qualitative approaches dominated the overall research process. In addition, some quantitative data, collected through a questionnaire, were also used to gain a macro view from science teachers of how scientific literacy is considered in their science classes. The questionnaire data were also used in selecting appropriate participants to illustrate a micro view of how scientific literacy is considered in science classes. These two views were presented in Chapters 5 and 6 respectively, while Chapter 7 draws on both views to provide a picture of teachers' consideration of scientific literacy in science classes. In this chapter, findings will be highlighted from the research, with discussion on the significance of these findings for science educational practice and research.

This study revealed that science teachers in Bangladesh hold a range of perspectives of scientific literacy, including some naive perspectives. Moreover, teachers found difficulty in conceptualising many of the curriculum-identified values, and consequently found it difficult to find, develop and implement suitable teaching approaches to promote the values. Teachers cannot really be blamed for this difficulty, since very little of their own academic and professional education in science have included attempts to understand the idea of scientific literacy and its underpinning values. In addition, little to no attempt has been made in the curriculum to provide a framework explaining the ideas of scientific literacy and its underpinning values.

In similar fashion, this research highlighted teachers' naive perspective of the nature of science. Teachers should also not be blamed for their naive perspective since they rarely have the opportunity to learn about the nature of science in their own studies in the context of Bangladesh (Sarkar & Gomes, 2010). As the ideas regarding the nature of science have importance to understand the ideas of scientific literacy and its underpinning values, they should be taught explicitly in science studies at different educational levels and in different teacher education programmes designed for science teachers in Bangladesh. In this context, I would argue that how the participant teachers have articulated their perspectives of scientific literacy and its underpinning values (whether they are informed or naive) is appreciating. It has provided insights to better understand how they model scientific literacy in their classroom teaching practices and how the science education context in Bangladesh influences this modelling.

This research also identified the tension which teachers encountered between their religious values and science values while they were teaching science in a culture with a religious tradition. For example, Rashid's case exemplified how his religious values shaped his worldview and encouraged him to believe in God as the sole authority to make judgements about what constitutes valid scientific knowledge. This belief persuaded him to feel comfortable with religious views that conflicted with scientific ideas. Moreover, it was observed in his teaching practice that he preferred to explain an idea (e.g., cleanliness) from a religious point of view rather than a scientific view, even though he was teaching in a science class. This research, however, has not explored how teachers' religious values are formed and how they influence teachers' teaching practice in science. Further research may explore this issue with more depth.

It was found in this research that whilst the participating teachers held a range of perspectives of scientific literacy, in practice they demonstrated limited capacity to translate their perspectives into their classroom teaching. Many of their teaching practices promoted the culture of academic science that centres on catering for future science students to build a strong foundation in academic science. In contrast, in some cases teachers attempted to draw links between school science and students' everyday lives by providing explanations and examples of how the school science content could be used by students beyond the school contexts. However, in most such attempts, teachers used everyday life contexts as add-ons to the academic content rather than providing students with the opportunities to think and use their science learning in their everyday lives. Students are able to relate their school science with everyday life when they are given opportunities to think and use their knowledge, skills and values acquired in science classes in a variety of situations they encounter in everyday life beyond the school contexts. However, there is little evidence of teachers providing students with such opportunities. This eventually may result in students' difficulty in finding connections between the science they study in school and their everyday lives.

This research indicates that the gap between teachers' perspectives and teaching practices are perhaps due to the many constraints they felt have been placed upon them. Teachers in this research often expressed their discomfort in teaching the content-dominated General Science course in a large class with limited resource facilities. In addition, they often lamented the fact that they are obliged to prepare their students for exams that mainly assess students' memorisation of factual content knowledge. This obligation may result in an emphasis placed on memorising the factual content of science from the recommended textbooks. Teachers, therefore, may resort to using the textbooks as the authority of knowledge while students passively absorb information.

Such contextual issues could be seen as contributing factors for the gap between teachers' perspectives and practices. The issues may also have implications regarding the culture of science teaching and learning in Bangladesh as discussed below.

In this research, teachers often expressed their dissatisfaction about the science textbooks as they are overly academic, emphasising content that caters for the future science study group and which has limited importance in everyday life. A similar observation about science textbooks has been reported in this research (see Chapter 3) and elsewhere (Sarkar, 2012). Such academically oriented textbooks may have several implications for science teaching and learning. Firstly since the textbooks supposedly aimed at helping all students see the connections of science with everyday life in fact focus on preparing the future science study group to build an academic foundation in science, the intentions of the curriculum are called into question. In a textbook dominated education context like Bangladesh textbooks often set the priorities for teachers and are generally used as the principal learning resource for students. Secondly, some teachers in this research expressed lack of confidence in their own content knowledge in science to teach the academically oriented General Science course as represented in the textbooks. This could be seen as a significant issue in Bangladesh, where there is evidence that nearly a quarter (23%) of teachers teach the General Science course at the junior secondary level come from non-science background (see Chapter 5).

Moreover, these two issues (the requirement of specialised content knowledge to teach the General Science course together with the fact that many teachers from non-science background teach the course) may have implications for the current practice of professional development programmes designed for science teachers. These focus primarily on promoting science content knowledge to the teachers as they often lack specialised content knowledge in science. One of the participant teachers in this research remarked how this practice limits the scope for developing pedagogic knowledge for teachers so that they can learn to teach for promoting scientific literacy. As scientific literacy is considered a curricular aim of school science education in Bangladesh, professional development programmes for science teachers need to focus on developing the pedagogic knowledge teachers need to promote scientific literacy.

As many of the teachers reported, preparing students for the exams is a challenge in their teaching practice. This form of assessment focuses on students' ability to memorise rather than on the ability of applying science knowledge in everyday situations. Due to the need to concentrate on exams, students often lack the ability to apply science knowledge in everyday situations that is important for their scientific literacy. Even though some teachers (e.g., Jasmine) in this research attempted to challenge this assessment practice by preparing exams that would require less memorisation, they expressed their worry about the fate of their approach in the case of external exams. In 2010, a junior secondary certificate (JSC) public exam was introduced at the end of Grade VIII in Bangladesh (Ministry of Education, 2010). Students' results in this exam largely determine their future study direction. Moreover, teachers' performances would also be determined by their students' results in this exam. It therefore seems that introducing the JSC exam would persuade teachers to focus on preparing students for this exam rather than developing scientific literacy.

This research also elicited teachers' perspective that limited resources and facilities constitute a stumbling block in their teaching of science. This included students' inability to access school science labs, which are also limited in facilities. Whilst the teachers, in general, perceived this to be an important issue, many of them did not attempt to organise activities that could be done without the support of a lab. A possible reason for this is the naive view that activities in science only happen in labs. In addition, teachers' lack of awareness of appropriate activities, as one of the participants noted, could be another reason for teachers' unwillingness to devise and use such activities. Thus teacher development programmes for science teachers could begin to build awareness among teachers of how they could develop such science activities. Instances of the teacher's initiative in this respect is evident in this research as some of the teachers talked about how they prepared low-cost materials from easily available resources and organised activities for students in their classrooms.

The culture of science teaching and learning in Bangladesh is often dictated by the traditional 'chalk and talk' approaches, for example, lecturing. The teachers in this research stated that large class size is why many of them focus on lecturing. Almost half of the participant teachers' science classes accommodate more than 80 students, which is twice the recommended class size and is quite common in Bangladesh. In such a science class, it may be over-optimistic to expect that teachers engage students in science activities and focus on providing individual learning opportunities to every student. Similar to this issue of large class size, there were many other issues where teachers articulated their belief that the issues were beyond their capacity to respond. This belief may have hindered them from initiating teaching/learning approaches that could challenge many of the issues to some extent. A lack of flexibility in existing education practice in Bangladesh may contribute to discouraging teachers from devising and implementing approaches to challenge the issues. For example, Jasmine revealed how her proposed time allocation for science classes could not be implemented in her school due to the centralised system, which does not provide autonomy to teachers or schools to make any changes in the prescribed time allocation. When this is the case, it is very likely that the issues would still remain in their teaching, and therefore, would challenge the promotion of scientific literacy in Bangladesh.

During this research journey, I encountered much that was worthy of further investigation; questions arose that could not be answered, and some issues clamoured for closer study. I conclude this thesis with a brief discussion on some of the issues and questions as below.

The representativeness of the participants in this research was limited. Given the practical conditions and inherent constraints noted in Chapter 4, I was able to get responses to the questionnaire from a total of 159 voluntary teachers. This number is quite small compared to the number of teachers teaching the General Science course at the junior secondary level in Bangladesh. Thus, mapping a macro view of scientific literacy with the responses from a small number of participants may not represent a macro view of scientific literacy in Bangladesh as a whole, and therefore further inquiry with a larger sample of teachers could help illustrate a comprehensive macro view of perspectives of scientific literacy in Bangladesh. In a similar vein, as observation data are only a sample of possible observations by the observer (see Chapter 4), increasing the number of lesson observations could enhance the representativeness of research such as mine.

Teachers' perspectives of, and practices to promote scientific literacy have been the concern of this research. However, further research could benefit from considering various stakeholders in science education, for example, policy makers and students. As a top-down approach to the development of policy is a common practice in Bangladesh, exploring the policy-makers' perspectives could help understand their intentions and perspectives in making such policies. Moreover, whilst in this research students' perceptions about their experiences of science classes have been considered as supporting data to understand how scientific literacy is considered in science classes, there is scope for in-depth study to understand the factors (students' school science experiences could be one of them) contributing to students' decisions about their future study aspirations. Such an in-depth study is important in the context of Bangladesh, where a decline in student enrolment in science has been observed during the last decade.

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Appendices

Appendix 1: Human Ethics Certificate of Approval

MONASH University

Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

Date:	**3 August 2009**
Project Number:	**CF09/1352 - 2009000712**
Project Title:	**Scientific literacy promoted through junior secondary science education in Bangladesh**
Chief Investigator:	**Assoc Prof Deborah Corrigan**
Approved:	**From: 3 August 2009 To: 3 August 2014**

Terms of approval

1. The Chief investigator is responsible for ensuring that permission letters are obtained, if relevant, and a copy forwarded to MUHREC before any data collection can occur at the specified organisation. **Failure to provide permission letters to MUHREC before data collection commences is in breach of the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research.**
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must contain your project number.
6. **Amendments to the approved project (including changes in personnel):** Requires the submission of a Request for Amendment form to MUHREC and must not begin without written approval from MUHREC. Substantial variations may require a new application.
7. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
8. **Annual reports:** Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

[redacted]

Professor Ben Canny
Chair, MUHREC

cc: Mr Md. Mahbub Alam Sarkar

Postal – Monash University, Vic 3800, Australia
Building 3E, Room 111, Clayton Campus, Wellington Road, Clayton
Telephone +61 3 9905 5490 Facsimile +61 3 9905 3831
Email muhrec@adm.monash.edu.au www.monash.edu/research/ethics/human/index/html
ABN 12 377 614 012 CRICOS Provider #00008C

Appendix 2: Permission Letter from the Directorate of Secondary and Higher Education (DSHE), Bangladesh

DIRECTOR GENERAL
DIRECTORATE OF SECONDARY AND HIGHER EDUCATION
SHIKKHA BHABAN, ABDUL GANI ROAD,
BANGLADESH, DHAKA.

D.O. No. DM/159-SHAMA/07/8887-SHAMA Dated, the 05.07.2009

To Whom It May Concern

I am happy to know that Mr. Md. Mahbub Alam Sarkar is conducting his PhD research entitled "Scientific literacy promoted through junior secondary science education in Bangladesh" in Monash University, Australia. This letter is evident that he is given permission to collect data from secondary schools in Bangladesh for his research purpose.

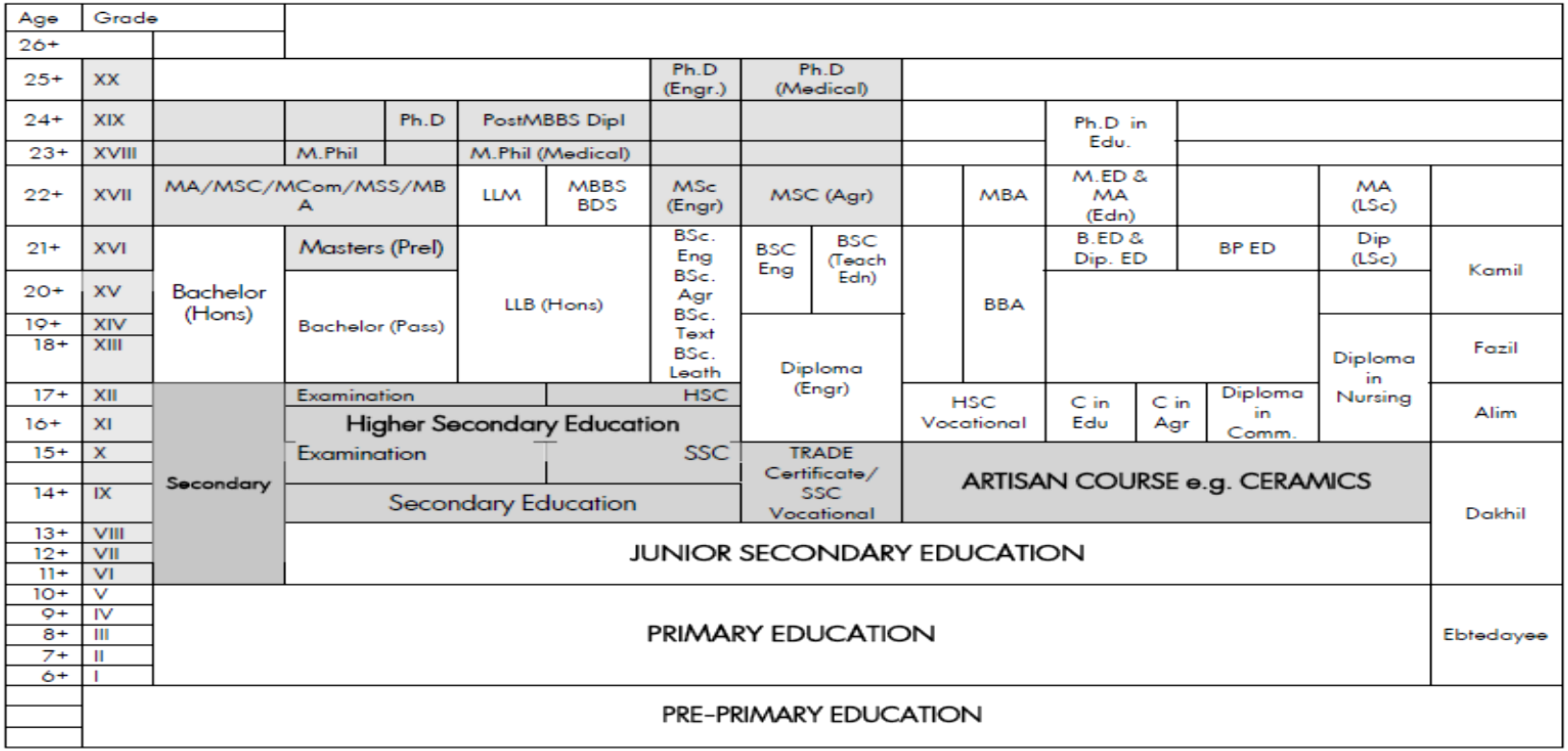
I wish success in his PhD research.

[redacted]

Director General
Directorate of Secondary & Higher Education
Bangladesh

Phone : 9553542, 9563390, Fax : 088-02-9564098

Appendix 3: Education Structure of Bangladesh



Source: BANBEIS. Retrieved March 23, 2012, from http://www.banbeis.gov.bd/webnew/images/edusystem.pdf

Appendix 4: Questionnaire for the Teachers

Thank you very much for participating in this research project entitled "Scientific literacy promoted through junior secondary science education in Bangladesh". This questionnaire requires your information about your perspectives of, and teaching practices for promoting scientific literacy.

The questionnaire is divided into five sections, which ask about:

A. Your general information

B. Information related to your work load and class size

C. Your views about teaching science and your perspectives of scientific literacy

D. Information regarding your science teaching practices

E. Challenges encountered in your teaching for scientific literacy

Please fill out the questionnaire carefully. Please note that the questionnaire ask for your views and that there are no expected "correct" answers.

A. General information

1. Please Tick one box to mention your sex.

☐ Male ☐ Female

2. Please Tick one box to mention the location of your school.

☐ Urban ☐ Semi-urban ☐ Rural

3. Please <u>fill in the table below</u> for the highest level of education you have completed.

Degree	Year	Major academic field	Institution

4. How many years will you have been teaching altogether by the end of this year?

………………………… years

5. Please <u>fill in the table below</u> if you participated in any professional development activities in the last 5 years.

Name of the programme	Organisation	Duration (in days)	Comment

6. If you are interested to participate in further activities of this research (e.g. follow up interviews, classroom observation), please <u>give your contact details</u> below.

Name: ……………………………………………………………………………..

School: ……………………………………………………………………………

Post Office: ……………… Police Station: ……………… District: ....

Phone number: …………… E-mail address: ……………………………………...

B. Information regarding work load and class size

7. In one week, how many single periods are you formally assigned to teach?

For science subject	For other subjects
………………………… periods	………………………… periods

8. On average, how many students are there in each of your grade six to eight science classes?

Boys	Girls

C. Information regarding your views about teaching science and your perspectives of scientific literacy

9. Of the two alternatives, which do you believe should be the primary purpose of the General Science course at the junior secondary level?

Please Tick one box only.

Make all students able to use their science learning in everyday life ☐

Build a solid foundation in science for the students who will study science in the next level ☐

10 (a). Have you heard of scientific literacy?

Please Tick one box only.

Yes ☐ No ☐

10 (b). What do you think it means?

Please write in your words.

D. Information regarding your science teaching practices

For answering the question in this section, please use the criteria presented in the box below.

Always – in every lesson	Often – in most of the lessons
Sometimes – in some lessons	Rarely – in very few lessons

11. How often do you emphasize the following aspects in teaching science?

Please a *<u>Tick</u>* *for each row.*

How often do you	Always	Often	Sometimes	Rarely
explain the application of science in everyday life				
provide students with everyday life examples in teaching particular science content				
exemplify science from the students' interests and hobbies (e.g. give examples regarding musical instruments while teaching about sound; games and sports related examples etc.)				
use the science textbook in the class				
encourage students to learn science from various sources, such as newspapers, books other than textbooks, science fiction, TV, radio, internet etc.				
encourage students to contribute personal stories into class discussion				
assess students' ability to recall scientific terms and facts				
assess students' understanding of science concepts and its application to new situations				

give students feedback after the assessment				
use a variety of methods to assess students' understanding, including open-ended questions, checklists, project work, practical reports etc.				
encourage students raising questions from their experiences				
encourage students to seek information to explain new phenomena or solve problems				
give students examples of how scientific ideas can be revised				
encourage students revise their ideas if any new idea evolves				
encourage students to debate/ argue with each other in your class				
encourage students in providing justification on their ideas in science class				
encourage students to present their views and ideas in science class				
encourage students to respect other's views and beliefs that differ from them in group discussion or any other activities				
encourage students to perform an activity (e.g., an experiment) honestly in science class				
encourage students to report results from an activity honestly rather than report the correct result by manipulation				

12. Some instructional strategies are mentioned below that could be used in teaching science. How often do you use these strategies in your science teaching at the junior secondary level?

Please a Tick for each row.

	Always	Often	Sometimes	Rarely
Lecture				
Question-Answer				
Teacher demonstration				
Whole class discussion				
Small group discussion				
Brain storming				
Individual projects				
Group projects				
Hands-on investigations				
Field trips				
Others (please, specify)				

13. Here some teaching aids are mentioned that could be used in teaching science. How often do you use these in teaching science at the junior secondary level?

Please a Tick for each row.

	Always	Often	Sometimes	Rarely
Low cost apparatus/teaching aids prepared by the students				
Low cost apparatus/teaching aids prepared by the teacher				
Chart/poster				
Model				
Real objects				
Radio				
Video				
Projectors				
Newspapers/ magazines				
Others (please, specify)				

E. Challenges encountered in teaching for scientific literacy

14. Are there any aspects of scientific literacy in which you feel less confident to teach?

Please write in your words.

15. Do you find any challenge in your teaching for scientific literacy?

Please Tick in one box.

Yes ☐	**No** ☐
Go to question 21 & 22	*Thank you*

16. Please rank the following aspects as challenges to your teaching for scientific literacy. '1' indicates your first choice, '2' your second choice, and so on. You can give the same rank to more than one aspect.

Lack of scope in the curriculum	
School assessment system does not support	
Large class size	
Heavy workload	
Lack of resources	

Please write in if any challenge you face is missing in the above and rank for that.

17. How do you overcome those challenges?

Please, write in your words.

Thank you very much for your time

Appendix 5: Questions/ Themes for the Teachers' Pre-lesson Interview

1. Do you think all students should learn science in school? Why or why not?
2. What outcomes do you expect from your students when you teach science?
3. How would the outcomes characterise scientific literacy?
4. The General Science curriculum aims at promoting some values (e.g., curiosity, rational thinking, open-mindedness, respect for others' opinions and intellectual honesty). Do you think the values are important for your students' scientific literacy? How?
5. How do you consider the values in your teaching science?

Appendix 6: Questions/ Themes for the Teachers' Post-lesson Interview

1. What were the purposes of your teaching of the lessons I observed?
2. Would you please explain why you did (referring to classroom activity that needs to be clarified)?
3. If you think you could promote scientific literacy in a better way by modifying/ changing your strategy, please explain.
4. If you think so, then why did you not employ that strategy in the classroom?
5. How could you overcome this situation?
6. Do you want to tell anything more regarding your science teaching?

Appendix 7: Questions/ Themes for the Focus Group Interview with Students

1. What did you learn in the lessons on (referring to the lessons I observed)?
2. How can you use your science learning?
3. Do you think them worth to learn? How are they worth learning?
4. How do you get to generate questions to explore? Can you give me examples of question that came to your mind while you learn science?
5. What do you like to do in your science class?
6. Is it encouraged to present your ideas rationally in your science class? Do you think that important? Why or why not?
7. One of your classmates gave an idea in the class, which you did not think correct. What would you do in this respect?
8. How do you do activities in science class?

Appendix 8: A Sample of the Pre-lesson Interview Transcript

Date: 13/05/2010

Teacher: Sabina Akhter (pseudonym)

I: At first let me thank you for participating in this research project. As I told you before, this research aims at exploring how scientific literacy is promoted through junior secondary science education in Bangladesh. Being a science teacher at the junior secondary level, your views are important in this research. I would like to confirm that I will not assess your knowledge or teaching performance; rather I will try to understand your perspectives of, and teaching approaches to promoting scientific literacy and the challenges you encounter in your teaching. You can avoid answering questions if you feel them too personal, sensitive or uncomfortable. I assure you that I will not share your information with anyone else. The information will only be used for the purpose of this research. Your identity will not be disclosed in reporting this research; rather pseudonyms will be used in such reporting. If you would like to know anything more or any clarification, you can ask me now.

S: No, it's OK. You can proceed.

I: Do you think all students should learn science in school? Why or why not?

S: Thanks. I think, to become a competent citizen for the current age, all students should learn science in school. This is the age of science. If you don't learn science you can't survive in this age. That's why science is compulsory for all students. So, I think everyone should learn science in their school.

I: You just said, learning science is important to survive in this age. Why do you think so?

S: Look, whatever you do, wherever you go, there is some science. You are going to buy food, there is science. If you don't know the vitamins and minerals in food elements and the importance of them to your health, you will not be able to maintain your health. Then you may need to go to a doctor. He is a science person. He will give you treatment. Treatments come from science. So, you see, science is again important for your survival.

I: What outcomes do you expect from your students when you teach science?

S: Students need to understand why science is important to their lives. This will help them get interested in learning science. Science is important as it is a part of life from buying foods to following the weather report in the TV. You cannot really escape from it. So, students have to understand this. If you do not understand this, you will not be able to deal with science related issues. I expect that my students will be able to deal with science related issues.

I: For example?

S: Hygiene, environmental pollution, etc.

I: OK, how would the outcomes characterise scientific literacy?

S: To me, scientific literacy is something like using science in your life. When you need to deal with science related issues, you have to use your science knowledge. Let me give you an example. Science can provide students with the knowledge about their health and environment. They often make decisions about food, nutrition, environmental pollution and so on. This knowledge can help them to make a decision about these everyday issues. Not only this, science will help you in many other aspects. In this age, it is very common that you read newspapers or watch TV. Most of my friends start their day by looking at what is in the media. Many reports in the media are science related. Scientifically literate people need to understand science related reports in the media. For example, acid rain related news is common in media like TV and newspapers. Now students can follow such kinds of media reporting.

I: At this stage, we will talk about values. You know, the General Science curriculum aims at promoting some values. For example, they are curiosity, rational thinking, open-mindedness, respect for others' opinions and intellectual honesty. Do you think the values are important for your students' scientific literacy? Why? How do you consider them in your teaching?

S: Yes they are important. And in many ways.

I: Could you please explain why they are important?

S: Rational thinking is very important. This helps you work out how you will make justification in decision making about an issue. Scientifically literate students will value being rational in every step in their lives. In villages, people believe in many irrational things that we may call superstition. Students can analyse them rationally and can prove them false. Most of my students come from remote villages. Many of their family members are not formally educated, so they often have beliefs in superstitious things. My students can make their family members and others aware about these superstitions. I can give you an example of such superstition. Last year, one of my students told me that she heard that if one does not say Bismillah before eating something, God produces acids and the person will suffer from acidity pain. From learning about acids, they will know that we have acids in our stomach. When these 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.

I: Anything more?

S: Curiosity has importance. If I can foster students' curiosity, this will provide students with questions to explore. This 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. This science knowledge can satisfy their curiosity and they can use this in their everyday life as well. So, you see, curiosity is important for scientific literacy. I know it is important that I should do something so that they can generate questions.

I: How do you help students generate questions in your science class?

S: I regularly ask them many questions. I think this will teach them how to ask questions. As their teacher it is my job to help them in this regard. When they will see I am asking them questions, they will follow me to learn how questions can be asked. I mean, if I ask students questions, they will in turn learn to ask questions themselves. And, you know, the questions are coming from their curiosity.

I: What about the other values? Open-mindedness, respect for others' opinions and intellectual honesty?

S: Yes, respect is important. You have to have respect about what others are thinking. You cannot just impose your thinking to others. You have to listen to others. It becomes very important in my class when I involve my students in group work. In group work, they will listen to others and practice respecting others' views. This is very important, you see, people in my country often don't respect others' views. If one's view is different to them, they often attack one personally. But everyone has the right to express views. If my students learn valuing respect for others' views in science class, they will not attack anyone personally for holding a different view.

I: What about intellectual honesty?

S: mm, I am not sure how it is in my science teaching.

I: Would you like to tell me more about this?

S: mm, no.

I: OK, that's all for now. Thanks. You know, I'll observe some of your lessons and then will talk to you again. Thanks once again for your time.

S: You are welcome.

Appendix 9: A Sample of the Post-lesson Interview Transcript

Date: 19/05/2010

Teacher: Sabina Akhter (pseudonym)

I: In the last few days, I observed your teaching lessons. What were the purposes of your teaching of the lessons I observed?

S: I was teaching about acids, alkalis and salts. They are the three classes in which compounds are classified based on their chemical properties. I tried to present the content about acids, alkalis, salts to students so that they can understand the content. Maybe you observed that many students did not know the uses of acids in our life. They did not even know that our stomach contains acid. They have learned about these in the lessons. In the lessons, I tried to involve them in some activities. They did an experiment to test which compounds are acidic and which compounds are alkaline. Now if you give them two bottles containing acid in one and alkali in the other, they will able to identify which solution contains acid and which one contains alkali. I also taught them how acids react with alkalis to produce salt and water. They were taught the chemical equations of the reactions.

I: I observed that you asked your students to make litmus paper at home. Would you please explain why you did so?

S: Oh, yes. Our school does not have a good lab. We have a lab but it is for the secondary students only. But if you look at the content of the chapter of acids, alkalis and salts in the textbook, you will find that many of them require students do experiments. When they cannot use the lab, how will they learn the content? So, I looked for something that my students can get from other places than a lab. I used the idea of making litmus papers from available resources. Litmus papers can be made from the materials students get very easily and without any cost. I explained to them how they would make the litmus papers and they did it. At least they got an opportunity to do an experiment, even though that was a very simple one.

I: I also observed that you discussed about acid rain in your class. But it was not in the syllabus. Would you please explain why you discussed about acid rain in your class?

S: Well, I felt that important. Acid rain is a global issue and one that everyone needs to know. I tried to inform my students about the issue and its importance in our life. This content is not in the textbook, but I think they should know about this. I have informed students about how acid rain occurs and why it occurs. These things are important to understand the process of acid rain occurring. Also, I have explained that many of our activities are responsible for the acid rain. You see many brick fields around and the number is increasing day by day as the population is increasing and the need of bricks is increasing. You see, we use coals as fuel in the brick fields. It releases sulphur and nitrogen in the air. These elements react with the water molecules in the atmosphere to produce acids, and acid rain occurs. Now my students will be aware about the occurrence and consequences of such an environmental hazard.

I: At this stage, you will be asked to articulate the challenges you encounter in your teaching for promoting scientific literacy. For example, if you think you could teach in a better way by modifying/ changing your strategy, then it would be helpful if you could explain why you did not employ that strategy in the classroom. Please also articulate how you could overcome this situation.

S: There are many issues that distract my teaching for promoting scientific literacy. And it is a fact that I cannot overcome many of them. My school is not such a school you may call well-off. It is poor in many ways. As I told you before, we have a science lab, but with poor facilities. It cannot accommodate many students. Only secondary students can use the lab as they have to go through practical exams. But junior secondary students do not have any practical exams. No practical exam, so no lab work. But in order to understand some content lab work is necessary. You see, today I taught about the properties of acid. The syllabus suggests students will do some experiments on this. I used some household items to do some experiments on this but I could not give them the lab access where it was necessary. I just recited the procedures and findings from the textbook, for example, if acid reacts with a metal, salt and water is produced. They could not do the experiment and I could not even show them. Perhaps, they would just memorise this. This learning may not last long. Also their interest in science may be decreased. If I had a good lab in my school and if I could use it for my students of the junior secondary students, then they would get opportunities to do lab works and would get interested in science.

I: What are the other issues?

S: There are many like this. I cannot assess my students to see how they are learning. You know, our syllabus is overloaded. I have to complete this within a very limited time as school contact hours are short. Schools remain closed due to various unavoidable and unwanted circumstances. This time constraint hampers my teaching. I often cannot give them feedback after assessment. On one side, I cannot monitor their learning, and on the other side, they cannot monitor their learning either. Sometimes I feel that I just try to complete the syllabus and get them ready for the exams. I need to get them ready for the exams so that they can get good marks. If students do not do well in the exams, the school authority will think that I have not taught them well.

I: So, it seems students' exam results are very important ...

S: Yes, they are.

I: How do you make your students' exams?

S: It is interesting. I do not make the exams. I have no rights to make students' exams, you see. Exams are made by a board that makes the traditional exams. No application, just memorisation of a large amount of factual content. Students have to memorise this and recall it in the exams. But the students' results are important. The school and parents want them to do well. It is important to me as their teacher as well.

I: Oh, it seems in your school you do not prepare students' exams. Why is it?

S: In many school like ours, exams are made by a local board. We go to them and buy exams from them. It is cost effective. If we want to prepare exams by ourselves the exam cost would be higher. So, in order to reduce the exam cost many schools prefer to buy exams.

I: Any other issues?

S: My academic background is biology, so I feel more interested and confident in teaching biological content. I am not confident about my theoretical understanding about some physics and chemistry topics. They seem to be difficult to teach. Sometimes, I am not sure about the possible applications of many physics and chemistry topics in everyday life that I could present to students. I just follow the textbook.

I: It seems you think specialised science knowledge is necessary to teach the General Science course.

S: Yes. When you will have specialised knowledge in a particular science topic, you will be in better position to teach the topic. You then will be able to explain the applications of the topic.

I: Is there any other issue you find challenging?

S: One more thing I find challenging is about my students. Some are very weak. They just want to pass. Some are good. They want to learn. It is very difficult for me to balance the needs for these two groups. When I try to explain a topic for weak students for more than twice, good students get bored.

I: How do you deal with the issue?

S: Our school is not so renowned. We cannot be so choosy about student intake because our school is not renowned. We do not offer any admission test when we take students in. So we get many students who could not get enrolled in good schools. These students often lack understanding in much of the content that they should have learned in the previous grades. And you know, there are some good students in the class. Then the problem arises. But I am not sure how to deal with this issue.

I: Would you like to tell me anything more about your science teaching?

S: mm, no. That's all, I think.

I: Thanks once again for your participation in my research project. It was wonderful to work with you for some days.

S: It was a wonderful experience for me as well. Thank you for selecting me in your research.

Appendix 10: A Sample of the Focus Group Interview Transcript

Date: 19/05/2010

I: At first let me thank you all for participating in this research project. I hope we will have a lovely discussion in this session. I am conducting research about science teaching and learning at the junior secondary level for my study purpose. So, you see, I am also a student like you and thus you do not need to have any hesitation. In this discussion, you are requested to present your views about your experiences of science class. I would like to confirm that this is not a sort of assessment; rather I will try to understand your views about your school science experiences. You can avoid answering questions if you feel them too personal, sensitive or uncomfortable. I assure you that I will not share your information to anyone else. I will use the information only for the purpose of this research. Your identity will not be disclosed in reporting this research; rather pseudonyms [made-up names] will be used in such reporting. If you would like to know anything more or any clarification, you can ask me now.

Students: It is OK, sir.

I: No need to call me sir; you may just call me vaia, OK? Here there are some name tags for you. Take one each, write your name and wear it. And we are heading to start now. My first question would be: What did you learn in the lessons about acids, alkalis and salts?

Jalal: I have learned about the properties of acids and alkalis. I have also learned about the uses of acids. In what ways acids are harmful and how we can avoid the harms.

Benu: I have learned about acid rain and its drawbacks, the properties of acids and the testing of acids.

I: What about others?

Sagar: I have learned about acid rain and how we can stop acid rain. If acid rain touches my skin, it can be burnt; trees and other animals would be in danger and soil would be polluted. I have also learned about the cautions for using acids. If I go to work with strong acids, I can protect myself from the possible harms of acids.

Arun: I have learned how we can test acidity of different foods using our homemade litmus.

Abu: I have learned about how acid reacts with alkalis and other metals and produces other things. I also learned about acid rain and testing about acidity.

Champa: mm, like others I have learned about acid rain and properties of acids and alkalis.

I: Lovely. Now, tell me how you can use your science learning. Do you think the topics worth learning?

Sagar: I have learned that human activity is responsible for acid rain. We are burning plenty of coals in brick fields. It is producing different chemicals like sulphur, nitrogen, and releases them into the air and causes acid rain. So, we need to be careful in using coals in brick fields.

Benu: You see acid rain in newspapers and TV. What I learned in the last few lessons will help me to understand the reports.

Abu: Yes, acid rain may be useful. But many things are not useful. Madam taught us about the chemical reactions between acid and alkali. She wrote down some equations on the board. I am not sure what to do with this.

Champa: You will memorise them and will write down in the exams. You want to pass, don't you?

Arun: Well said. We all need to pass and Madam said they are important.

Jalal: I will memorise some equations important for the exams. It is enough for me if I can just write down in the exam and then lose them. I don't see any other use of this knowledge.

Sagar: No, no, I think they are important. If I don't know the symbol, I can't write the formula and can't write a chemical equation. If I don't learn the symbols, formulas and equations, how will I study chemistry?

Abu: I am not going to study chemistry after school. Perhaps I am not going to study any science at all. It doesn't have any use in my life.

I: Oh, lovely discussion is going on ... Now, I would ask you how do you get to generate questions to explore?

No response from the students.

I: Can you give me examples of question that came to your mind while you were learning science?

Sagar: 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.

I: What about others? Any question ...

Jalal: Cannot remember at this moment.

I: That is OK. Others ... what about you?

No response from others.

I: Let us go to the next question. I observed that your teacher asked a student (Benu) to justify why she thought the taste of acid would be sour. Does it happen very often? Do you think making justification is important?

Benu: Madam always encourages us to talk rationally. When I go to say something, she will ask me to justify it.

Sagar: It is important. She tells that if you cannot justify your point you cannot establish your point to others.

I: What about others? Do all of you think it is important?

Students: Yes

I: OK. Can you please give me an example how you can use rational thinking?

Abu: There is a superstition that if you eat pineapple after taking milk, you may die from the 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 more 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.

Champa: I learned that red litmus turns blue in contacting with alkali. When I put red litmus in the washing powder solution, it turns blue. So, washing powder solution has alkali in it.

I: OK. Now let's think about a scenario. One of your classmates gave an idea in the class, which you did not think correct. What would you do in this respect?

Arun: I would oppose their ideas and present mine. You know, every person is different; they have different ideas and they can see a thing differently. So I don't think I would go to hurt them. But I must present what I know and will rethink about this.

Jalal: Yes, everyone will not know everything. Sometimes we are correct, sometimes not. We have to accept this.

I: What do others think in this respect?

Sagar: I agree with them. I do not know everything. No one knows everything and everyone's thinking is different.

Benu: One may have a wrong idea about an issue. But she may have the correct idea about many issues. It is natural. People will think differently.

I: OK. We are at the last stage of this discussion. Now you will tell me what you wish to do in your science class?

Sagar: I want the teacher to show us experiment in science class. I want to go to the lab and do experiments. I do not want to just sit and listen to her lecture.

Champa: My teacher says, science is something that you have to learn by doing. But what activities do we do? We do some, but not much. I have never been to the lab but I am learning science.

I: It seems Sagar and Champa like to do lab activities. What about others? Do have any other liking?

No response from others.

I: Do you like lab activities?

Students: Yes.

Arun: It would be a fun.

I: It was a lovely experience of talking with you. Thanks very much.

Students: Thank you too.

Appendix 11: A Sample of the Lesson Observation Report

Date: 17/05/2010 Lesson time: 08:35 AM – 09:05 AM

Name of the teacher: Sabina Akhter (pseudonym)

Grade: VIII Number of students present: 37 (Boys: 19; Girls: 18)

Topic of the lesson: Acids, alkalis and salts (Lesson 2)

Beginning of the lesson (about 5 minutes)

The teacher exchanged greetings with students and started the lesson with the question "what did you learn in the last lesson?". She invited one student (a boy) to describe what he learned in the last lesson. With the student's description, she provided an overview of what was going to happen in this lesson. The overview included an intended activity to test acidity of several household substances. She asked students to rearrange their seating positions according to the groups. (In the last lesson, she had made some small groups and assigned them to prepare some homemade litmus. She asked the groups to bring several household items or substances, for example, lemon, tamarind, vinegar, laundry powder, soap, etc.).

Activity/ Task (about 10 minutes)

The teacher provided students with a working procedure of the activity. She drew a table in the chalkboard. She mentioned the table as a sample and asked students that they could make their own tables. The table she drew on the chalkboard looked like the one below.

Substance	Taste	Litmus colour	Change in colour	Comments
e.g., Vinegar				
Conclusion:				

The teacher explained the responsibilities of the group members in doing the group activity. She asked every member's active participation in the activity. She also told them to express if someone had a different idea about the procedures of the activity or different idea about the conclusion of the activity. She asked students to consider and discuss whether such ideas were elicited. She then asked students to perform the activity and write down their observations in their notebooks. She monitored students while they were performing the activity. When students completed the activity, she asked students about their conclusion regarding the taste of acids. Here is the classroom conversation below:

> Teacher: Now, can you describe what the taste of acid would be?
>
> Some of the students raised their hands indicating they can answer. She addressed one of them by name and invited her to explain.
>
> Student: It would be sour.
>
> Teacher: Sour? But why do you think so? What is your justification?
>
> Student: 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.
>
> Student: Hmm … Good justification.

The teacher then asked if students have any different observation. And she moved to the chalkboard and started presenting her lecture indicating it was very important for the exams.

Lecture (about 20 minutes)

The teacher provided a lecture on the properties of acid. The lecture dealt with a description of how several experiments could be conducted to describe the properties of acid. She read some experiment procedures from the textbook and wrote down the chemical reactions of the experiment in the chalkboard. She explained to students how chemical equations were drawn for the reactions and how balance was made in the equations. She asked students to copy the equations into their notebooks. She described the importance of writing correct equations to get good marks in the exams. While presenting the lecture she hardly asked any questions to students or encouraged students to ask her questions. Once she asked students if they understood her lecture but did not spend time to listen to their responses.

Summarising the lesson

The teacher could not summarise the lesson or provide a signpost of what would be discussed in the next lesson. This may have been because all of her class time was spent and the teacher for the next class was waiting at the door.