Visual Representations of the Water Cycle in Science Textbooks[1]

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Abstract

Visual representations, including photographs, sketches and schematic diagrams, are a valuable yet often neglected aspect of textbooks. Visual means of communication are particularly helpful in introducing abstract concepts in science. For effective communication, visuals and text need to be appropriately integrated within the textbook.

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This study is based on an analysis of the science textbooks of the National Council of Educational Research and Training (NCERT) and the Maharashtra State Board (MSB) for Classes 3–10. We first assess these textbooks for the use of visual representations generally. Then we focus on the water cycle, looking at how this topic is treated in the school science curriculum, at the types of visual representations used, and how effectively text and visuals are integrated to teach the water cycle over the course of the school years. We conclude with some observations on the visual treatment of the water cycle in two exemplar textbooks, and examine the implications for the use of visualisation to understand the concept of the water cycle.

Keywords

Diagram, visual communication, water cycle, textbook

Introduction

Water plays an important role in the biosphere as it is linked with numerous physical, chemical and biological processes in nature. In the school science curriculum, students are introduced to the special characteristics of water and its role in natural processes. Although the complexities inherent in these processes are not introduced at this early stage, school instruction does aim to develop a composite and somewhat abstract concept called the 'water cycle'.

The idea of the water cycle in the school curriculum is unique in many ways. It is the students' first introduction in the abstract to the powerful and ubiquitous notion of a 'cycle'. It is the first example of a matter cycle, in contrast to the familiar event cycles like daily routine, day/night and crop cycles. It is one of the earliest abstract concepts to be used and one of the first to be introduced to students through a schematic diagram. Finally, its manifestations in nature are highly complex; the entire scope of the cycle therefore unfolds only gradually, over the school years and beyond.

The water cycle is critical to the survival of life on earth, and the availability of usable and potable water is projected to be a major issue for human survival in the coming decades. India's economy is critically dependent on the large-scale water cycle of the monsoons. Understanding

and appreciating this cycle, and our own role in conserving and caring for water resources, is a necessary and vital task, in which the school curriculum can play an important role.

Students are familiar with phenomena associated with the water cycle (like drying or boiling of water), but they do not necessarily interpret these phenomena in terms of evaporation and condensation, nor are they conversant with the related terminology. Further, the chemical and biological aspects of the cycle, though equally part of our everyday experience, are known to us only through their gross macroscopic manifestations. Thus, in the curriculum, beginning with a simple substance called water that is such a vital part of our lives, students are gradually introduced to the abstract notion of a cycle, understood first at an elementary level ('water evaporates into vapour and condenses back to liquid'). Then, over the years, incorporated into this basic cycle are various complex concepts and processes, such as groundwater, monsoon, rainfall, ice and snowfall, water conservation and water pollution. Further, we learn about metabolic processes like transpiration and respiration, and the role of water more widely in biological, geological and chemical processes.

Visual representations are an invaluable aid in depicting the abstraction and complexity of the water cycle. How can these visuals be deployed effectively in the writing and designing of textbooks? In this article, we propose some general pedagogical guidelines and analyse some widely used science textbooks in India based on these guidelines.

Students' Understanding of the Water Cycle and the Pedagogic Role of Visuals

Students' understanding of the water cycle has been well documented, beginning with Piaget (1929) in the city of Geneva and followed up by studies in New Zealand (Osborne and Cosgrove, 1983), Australia (Schibeci et al., 1993), Israel (Bar, 1989; Bar and Travis, 1991) and the United States (US) (Brody, 1993; Henriques, 2000). Osborne and Cosgrove (1983) used an 'interview about events' technique to investigate students' interpretation of familiar water-related phenomena like melting, boiling, condensation and evaporation. They found the prevalence of similar views across the age groups (8–17 year old students), for example, that 'bubbles in boiling water are bubbles of air' and 'coldness

comes through the glass'. Bar (1989) and Bar and Travis (1991) studied the ideas held by 6–14 year old students about phase change and the water cycle. They found that ideas about evaporation evolve with age, with the younger children saying that evaporated water gets lost or disappears and later that it penetrates the floor of the table. At the age of 9–10 years, students hold that water turns into vapour and enters a room, or a cloud, and still later that the vapour or water actually constitutes clouds. The authors interpreted these results in terms of conservation, first of water, and then of air.

Later studies (Brody, 1993; Henriques, 2000; Schibeci et al., 1993) broadened the scope of their investigation to include students' ideas related to the atmosphere, weather, water quality and water resources, emphasising the interdisciplinary nature of concepts dealing with water and the implications of students' ideas for curriculum development in earth science and environment science. Classroom trials of the Small Science Curriculum in India (Ramadas, 2001), documented in the Teacher's Books of this series, showed that students in Class 4 could be introduced to the concepts of evaporation and condensation, but that they had trouble dealing with the idea of air and water vapour as material substances. An idea like 'cold water comes out of the glass' could be challenged through argument or experimentation in a simple situation, yet it might recur strongly when the same students encounter another, more complex situation (*Small Science Teacher's Book*, Class 4, pp. 171–177).

Two recent studies (Ben-zvi-Assarf and Orion, 2005; Cardak, 2009) combined an examination of students' conceptions of the water cycle and the diagrammatic representations of this phenomenon. Ben-zvi-Assarf and Orion's (2005) study of the perceptions of Israeli junior high school students of the water cycle took into account the students' higher-order cognitive skills, such as systems-cyclic thinking and their perceptions of magnitudes, proportions and rates of processes within and among the various earth systems. This study, as well as that of Cardak (2009) on Turkish university students, used drawings as a means of diagnosing students' misconceptions about the cyclic-dynamic nature of the processes and about their correlations between the atmospheric and the geospheric components of the water cycle.

Visual representations play a powerful role in shaping students' complex notions of the water cycle from an early age. Visuals in the textbook

are known to attract attention, to help in the retention of information, to enhance understanding and to create a context for learning. Harp and Mayer (1997) recommended that visuals related to scientific explanations should accord a greater role to 'cognitive interest' rather than 'emotional interest'. The work of Carney and Levin (2002) focused on five functions of visuals: decorational, representational, organisational, interpretational and transformational. Similarly, the linkage between pictures and text has been emphasised by Kearsey and Turner (1999) and Paivio (1971, 1986).

Science Curriculum and Visuals in Indian Textbooks

The National Focus Group on the Teaching of Science (2006) emphasises that for a great majority of school-going children in India, as also for their teachers, the textbook is the only accessible and affordable resource for education. As a means of improving textbook-writing procedures, the Focus Group called for a conscious and concerted effort to fully exploit the modern techniques of layout, design and graphics. The National Curriculum Framework (NCF) (2005) further emphasises the importance of using visuals, good design of textbooks and mental visualisation processes in learning. The NCF recommended the introduction of the subject of environment studies (EVS), a combination of science and social science, for Classes 3–5, and of science for Classes 6–10. EVS and science textbooks based on the recommendations of NCF 2005 were published by the National Council of Educational Research and Training (NCERT) between 2006 and 2008. A list of these NCERT books, which are used in this study, is given in Appendix A. In this article, these books are referred to as NCERT textbooks.

Most of the larger states in India produce their own textbooks, often with reference to the NCERT textbooks. For the purpose of our study, we selected, along with the NCERT books, science textbooks produced by the state of Maharashtra. The Maharashtra State Bureau of Textbook Production and Curriculum Research produces textbooks on general science for Classes 3–8, and the Maharashtra State Board of Secondary and Higher Secondary Education produces science and technology textbooks for Classes 9 and 10 (see list in Appendix B). All of these

books are referred to in this article as Maharashtra State Board (MSB) textbooks.

The study also makes some observations on the treatment of the water cycle in the Global 2000 study (Botkin and Keller, 1995) and in Small Science (the Homi Bhabha Curriculum for Primary Science, Homi Bhabha Centre for Science Education [HBCSE]) for Class 4 (Ramadas, 2001) in order to illustrate the use of visuals to enrich the understanding of the water cycle. Small Science is an alternative curriculum for Classes 1–5 developed by HBCSE through research and classroom trials. The stated aim of this curriculum is to engage students and teachers together in a joyful, meaningful and active learning experience. This programme, for the first time in India, introduced professional design and visual inputs into the development of a curriculum. Some of the pedagogical and design ideas used by Small Science were later adopted by various State Council of Educational Research and Training (SCERT) and NCERT curricula.

Methodology

The NCERT and MSB science textbooks for Classes 3–10 were the focus of this study. The textbooks were first assessed for the use of visual representations generally. Next, visual representations of the water cycle, along with textual matter associated with the water cycle, were examined. The textbooks were scrutinised for the ways in which the water cycle was treated (explained or interpreted), the frequency of occurrence of text and visuals, the connection between text and visuals, the types of visual representations and the development of the water cycle theme over the school years. A coding scheme was developed, and the categorisation in all cases was carried out through mutual agreement between the authors. Figure 1 shows the components of the study.

Place of Visuals in the Textbooks

Consistent with the emphasis on visuals in the NCF 2005, the NCERT textbooks from 2008 onwards appear to have moved towards using a

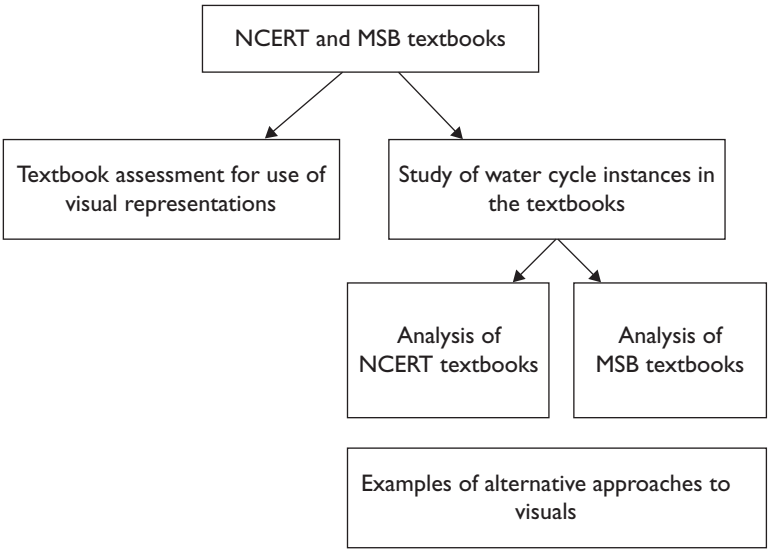

Figure 1. Components of the Study

Source: Authors' own.

large number of visuals (Chunawala et al., 2009). Table 1 shows the incidence of visuals in NCERT textbooks. The class-wise breakup (not shown in the table) reveals that from Class 3 to Class 7, it is rare to find a page in a book that has no visuals at all (only 11 pages out of a total of 978 had no visuals). A significant proportion of the pages have visuals for predominantly decorative purposes, for example, colourful borders, background, boxes and icons, and also occasionally tables, which break the monotony of the running text (referred to as 'minor visuals' in Table 1). The majority of pages, however, have picture-like visuals (that is, photographs, sketches and diagrams) that are connected to the content or flow of the text (referred to as 'major visuals' in Table 1). The pages with major visuals may also include some minor visuals. In the entire series of NCERT books, 26 per cent of the pages have minor visuals only and 70 per cent have major visuals.

The MSB books have a smaller page size (20 cm x 13.5 cm) than the NCERT books (27 cm x 20 cm) (rounded-off averages), and the MSB books up to Class 8 also have fewer pages compared to the NCERT

Table 1. Incidence of Visuals in the NCERT and MSB Science Textbooks (Classes 3–10)

Curricula	Number of Pages (Initial + Content)	Number of Content Pages with No Visuals	Number of Content Pages with Visuals	
			Minor Visuals	Major Visuals
NCERT	94 + 1,733	82 (5%)	442 (26%)	1,209 (70%)
MSB	82 + 1,625	440 (27%)	346 (21%)	839 (52%)

Source: Authors' own.

books. Taking the entire series of MSB books, 21 per cent of the pages have minor visuals only and 52 per cent have major visuals (Table 1). However, even more striking than the difference in the number of pages and the number of visuals between the NCERT and the MSB books is the size of the visuals, which is smaller, on account of the smaller page size of the MSB textbooks. The analysis of the presentation of the water cycle in these textbooks should be placed in the perspective of these overall observations.

Criteria for the Analysis of the Water Cycle

For an analysis of the water cycle, we considered the major visuals only. Carney and Levin (2002) cite earlier studies to argue that purely decorative pictures provide virtually no beneficial effects on text learning, while the size of this effect increases from moderate for 'representational' pictures, to successively more beneficial effects for pictures that enable the organisation, interpretation and transformation of ideas presented in the text. In the textbooks analysed here, we found a predominance of a single category, that is, the 'representational' type of pictures, with only a few (three out of 43) visuals, containing arrows, that we might place in one of the higher explanatory categories. Since only a single category predominated, the criteria of Carney and Levin (2002) were unsuitable for an analysis of our data.

However, we identified another relevant consideration in the text and in the visuals, namely, the type of linkages within and between the text and the visuals. In the case of the water cycle, an effective treatment in the textbooks would be considered on the basis of linkages between various related concepts and phenomena, and also linkages between their

representations in text and visual forms. A combination of text and visuals can be used effectively to link structure and function concepts in biological systems (Mathai and Ramadas, 2009), and the same might be said for other systems.

The type of visuals used, and how well these visuals are placed and utilised, is also an important aspect that needs to be considered. All of the visuals considered here turned out to be sketches at various levels of detail and abstraction. We focused specifically on the schematic aspect of the visuals as this aspect is important in representing the water cycle. Given these considerations and priorities, we outline here some pedagogical guidelines on the basis of which the treatment of the water cycle in the textbooks was assessed.

Direct and Indirect Linkages to the Water Cycle

In common teaching practice, the water cycle is introduced through everyday experiences, such as the drying of clothes, the condensing of water on the surface of a cold-drink bottle and the steam arising from a boiling pot of water. The terminology for talking about these experiences, namely, 'evaporation' and 'condensation', is then introduced. It is expected that these ideas and terminology would be reinforced through a consideration of a variety of contexts, and by discussing linkages between them. In the textbooks, we would expect both direct and indirect references to the water cycle as well as to various other phenomena in which water plays a role.

All the instances of the water cycle were thus screened and broadly categorised into 'direct topics' and 'indirect topics'. Instances that made a reference to the water cycle as a whole were called 'direct topics' and those that dealt with its components separately, without referring to the cycle, were classified as 'indirect topics'. Indirect topics included references to evaporation, condensation, transpiration and precipitation (although not in reference to the water cycle). Four instances of rainwater harvesting and one in which artificial rain was (indirectly) linked to the water cycle were categorised as indirect references.

Besides these direct and indirect references to the water cycle, there were a large number of other references to phenomena related to water that could potentially be related to the water cycle, for example, water in

the soil, groundwater recharge and water as a constituent of living things. Due to the difficulty of unambiguously identifying these topics, they did not form part of our analysis. While acknowledging such necessary (and desirable) complexities and the grey areas in the curriculum topics, this study nonetheless attempted to isolate a separate system, namely, the 'water cycle', based on the criterion of simplicity and the easy discernment of the concept of 'cycle'.

Use of Visuals, Linkage of Text with Visuals

Apart from the requirements intrinsic to visuals, such as clarity, visibility and internal organisation, visuals need to be properly placed in relation to the associated text materials. An appropriate placing of text and visuals is likely to encourage 'dual coding' (Paivio, 1971, 1986), implying that the text and visuals together reinforce the learning of the topic.

Naturally, there were some textual references to the water cycle that were not accompanied by visuals. Direct and indirect instances of the water cycle in the textbooks were, therefore, classified into 'text' and 'text with visual'. The term 'text' was used to describe the content material that used words only. The text might consist of a few sentences or a paragraph, or it might include one or more pages. The term 'visual' was used to refer only to sketches and schematic diagrams, since in these textbooks (all 18 books together) most of the visuals were sketches, two were a combination of sketches and arrows and only one was a schematic diagram. Note that every text description in a given context might refer to one or more visuals.

Instances belonging to the category 'text with visual' were examined further for the type of relation that existed between the text and the visual. The relation between the text and the associated visual may be implicit, that is, it may be based simply on the placement or the layout (Figure 2), or it may be explicit, that is, it may be brought out by a reference to the visual in the text. An 'explicit' relation existed when the text attended to the visual in an explicit manner (Figure 3). In an 'implicit' relation, the text did not attend to the visual, but a relationship was nevertheless implied between the content of the text and the visual and their placement in the page layout. In other words, the absence of the visual would not affect the wording of the textual matter in the case of an

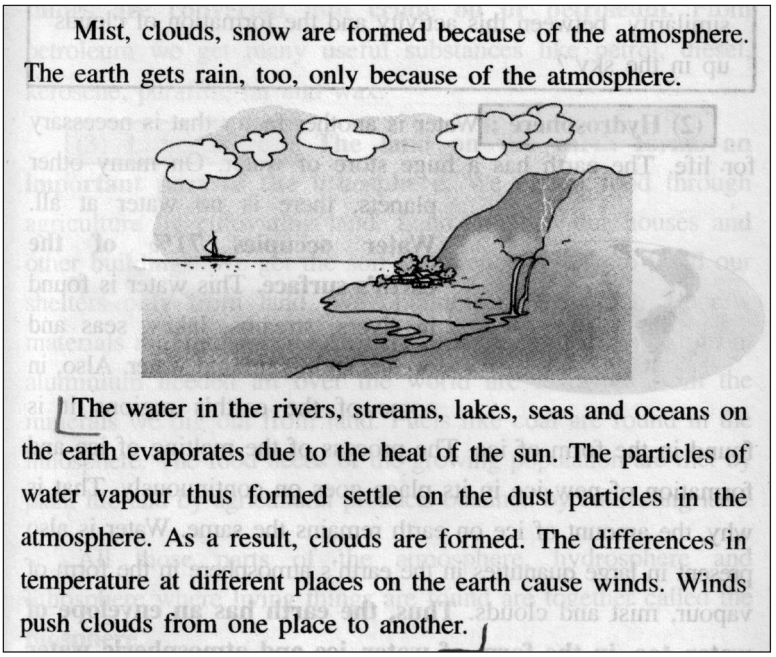

Figure 2. Implicit Connection between Text and Visual (MSB, Class 6)
Source: NCERT and Maharashtra State textbooks listed in Appendices A and B.

implicit relation, whereas the visuals were necessary to make sense of the text in the case of an explicit relation.

Besides the aspects of direct/indirect and implicit/explicit, the visuals were also screened for the presence of labels. Labelling of parts of the sketch or diagram may indeed be another way of establishing a linkage of the visual with the text. Labels in a visual serve to distinguish its constituent parts or processes, and provide additional, concise information, thus aiding better understanding.

Use of a Variety of Visuals

Visual resources available to textbook producers include photographs, sketches, diagrams, maps and graphs. Choosing the right kind of visual

14.4.1 THE WATER-CYCLE

You have seen how the water evaporates from the water bodies and subsequent condensation of this water vapour leads to rain. But we don't see the seas and oceans drying up. So, how is the water returning to these water bodies? The whole process in which water evaporates and falls on the land as rain and later flows back into the sea via rivers is known as the water-cycle. This cycle is not as straight-forward and simple as this statement seems to imply. All of the water that falls on the land does not immediately flow back into the sea. Some of it seeps into the soil and becomes part of the underground reservoir of fresh-water. Some of this underground water finds its way to the surface through springs. Or we bring it to the surface for our use through wells or tube-wells. Water is also used by terrestrial animals and plants for various life-processes (Fig. 14.5).

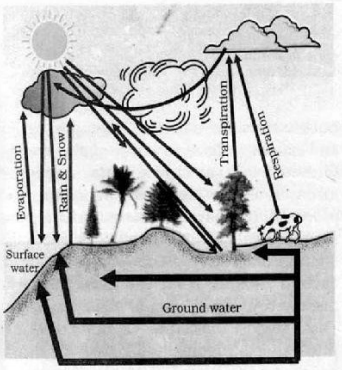

Fig. 14.5: Water-cycle in nature

Let us look at another aspect of what happens to water during the water-cycle. As you know, water is capable of dissolving a large number of substances. As water flows through or over rocks containing soluble minerals, some of them get dissolved in the water. Thus rivers carry many nutrients from the land to the sea, and these are used by the marine organisms.

Figure 3. Explicit Connection between Text and Visual (NCERT, Class 9)

Source: NCERT and Maharashtra State textbooks listed in Appendices A and B.

for the proper explanation of a particular concept still remains a challenge, as is evident from even a casual examination of most textbooks. To go from the concrete phenomenon to the abstract concept of the water cycle, one would need a range of visual representations, from concrete pictorial to abstract schematic. Mathai and Ramadas (2009) note that schematic diagrams are often neglected in Indian school textbooks. They recommend the use of a variety of visuals, especially for the teaching of biology in schools, which tends to rely exclusively on depictive, exact representations.

Given these considerations, visual representations of the water cycle in the textbooks were categorised into 'sketches' and 'schematic diagrams'. Sketches, which formed the predominant category, are artistically made drawings. Schematic diagrams represent the elements of a system using abstract, graphic symbols rather than realistic pictures.

Apart from considering the content and style of the visuals, the colours in which these visuals were rendered (in colour or grey/black and white scale) were examined. Colours in a visual could also play an important role. Apart from aesthetically enhancing the visual display, they could be used effectively to convey information, order, direction and categorisation, to draw attention, to emphasise, and so on.

Analysis of Water Cycle Instances

All the water cycle instances in the textbooks were assessed based on the pedagogical guidelines and criteria outlined earlier. In case of any doubts about, or contradictions in, the categorisation of the visuals, a decision was taken jointly by the authors after reaching a consensus.

Direct and Indirect Linkages

Linkages that referred to the water cycle directly and indirectly occurred in the following manner in the NCERT and MSB textbooks.

NCERT Textbooks

The NCERT textbooks (Tables 2 and 3) carry a total of 27 instances of the water cycle, of which 20 are indirect and 7 are direct. Thus, the

Table 2. Occurrences Related to the Water Cycle in the NCERT Textbooks

Class	Concept	Topic/Context	Type of Relation: Direct (D)/ Indirect (I)
3	Condensation	Clouds (poem)	I
5	Conservation	Every drop counts (activity)	I
	Evaporation	Where did the water go?	I
	Precipitation	Camp in the snow	I
	Precipitation	Snow storm	I
6	Evaporation	Evaporation (activity)	I
	Condensation	Condensation (activity)	I
	Evaporation/ Condensation	Changes around us	I
	Transpiration	Getting to know plants	I
	Water cycle	Disappearing trick of water	D
	Water cycle	Loss of water by plants	D
	Water cycle	How are clouds formed?	D
	Water cycle	Back to the oceans	D
	Water cycle	Water cycle	D
	Conservation	Rainwater harvesting	I
	Condensation	Water vapour	I
7	Precipitation	The monsoon winds carry water	I
	Precipitation	Thunderstorms and cyclones	I
	Transpiration	Transport of water and minerals	I
	Water cycle	Forms of water	D
	Precipitation	Distribution of water	I
	Precipitation	Uses of forests	I
9	Evaporation	Evaporation	I
	Condensation	Condensation	I
	Water cycle	Water cycle	D
10	Transpiration	Transportation in plants	I
	Conservation	Rainwater harvesting	I

Source: Authors' own.

number of indirect instances is more than twice the number of direct instances.

Table 2 lists all 27 topics or concepts related to the water cycle in the NCERT textbooks, along with the context in which they occur. Where that context is the water cycle, the relationship is labelled 'direct'. In the

Table 3. Type of Content Relating to the Water Cycle in the NCERT and MSB Textbooks (Classes 3 to 10)

Curriculum	Number of Instances	Relation of Content with Water Cycle		Content as 'Text Only' or 'Text with Visual'		Connection of Text with Visual		Total Number of Visuals
		Direct	Indirect	Text Only	Text with Visual(s)	Explicit/ Implicit	Labelled Visuals	
NCERT	27	7	20	8	19	19/0	7	31
MSB	15	5	10	6	9	7/2	0	12

Source: Authors' own.

remaining cases, the context happens to be one of the component processes in the water cycle or, in some instances, it deals with phenomena and human activities closely connected with the water cycle. In these cases, the relationship is labelled 'indirect'.

The first occurrence of an idea related to the water cycle comes in Class 3 in a poem titled 'Clouds'. In Class 4, a chapter, 'A River's Tale', describes a river ecosystem, focusing on water pollution (it is not included in Table 2 since there is no reference to the component processes related to the water cycle). In Class 5, a chapter on traditional systems of rainwater harvesting, experiments on evaporation and a reference to falling snow provide indirect linkages to the water cycle.

The class-wise breakup (not included in Table 3) shows that the Class 6 textbook contains the maximum number of references (11 out of 27) to the water cycle (Table 2). It begins with a description of evaporation and condensation in the context of the separation of substances and of 'changes around us', and a description of transpiration in the context of getting to know plants. Later in this book, a chapter on 'Water' begins with an account on the uses and sources of water, followed by an account of the water cycle as a major topic and then a description of modern methods of rainwater harvesting. The place of processes such as evaporation, transpiration, condensation and precipitation in the water cycle is described in detail. Class 7 follows (six out of 27 instances) with further topics related to precipitation, such as the monsoon winds, thunderstorms and cyclones, and transpiration in the context of the 'transport of water and minerals'. In an activity on 'forms of water', a sketch on the processes involved in the water cycle is included. The processes are indicated by numbers in the sketch, and are accompanied by a set of words given in jumbled letters. The activity requires students to rearrange the jumbled letters to construct the right word representing a process. The correct words are then to be matched with the numbered labels in the sketch. In a subsequent chapter, 'Forests: Our Lifeline', some processes of the water cycle are illustrated and described in the context of the uses of forests. Class 8 has discussions on acid rain and water pollution, which, however, are not connected to the 'water cycle' as delineated in this study.

The textbook for Class 9 discusses evaporation and condensation in the context of 'states of matter'. A description of the water cycle is given along with a description of other 'biogeochemical cycles', mentioning

groundwater seepage and the leaching of minerals. This is the first use of a schematic diagram in the entire NCERT series of textbooks. The Class 10 textbook describes transpiration in the context of 'transportation in plants' and rainwater harvesting as a part of the management of natural resources, both indirect references to the water cycle.

Table 3 enumerates the total number of instances related to the water cycle at all levels in the NCERT and MSB textbooks: the number of direct and indirect instances; the number of instances of text only and of text accompanied by one or more visuals; and finally, the number of labelled visuals. Tables 2 and 3 show that the water cycle occupies an important place in the NCERT curriculum. The teaching of phenomena and activities related to the water cycle occur from the earliest classes. The core ideas are developed in Classes 6 and 7, and continue to be developed and reinforced until Class 10. A large number of visuals are used to illustrate the topics, particularly in Classes 6 and 7. These visuals are described further in the later section on 'Use of visuals, linkage of text with visuals'.

MSB Textbooks

Tables 3 and 4 show the distribution of the instances relating to the water cycle and the contexts in which they are introduced in the MSB textbooks for the different classes.

The MSB textbooks (Tables 3 and 4) have a total of 15 instances of the water cycle, of which 10 are indirect and 5 are direct. Here, too, the number of indirect instances is more than the number of direct instances. Class 3 has a chapter on 'Our Food and Water', where the uses of water and its purification are discussed (not included in the table since there is no reference to the processes related to the water cycle). Core concepts related to the water cycle are introduced in Class 4 (as compared with Class 6 in NCERT). Class 4 has the maximum number of direct references to the water cycle. This book begins with a chapter on 'Water' that discusses the aspects relating to the sources, importance, purification and conservation, and then moves on to a discussion of the water cycle. Further, the water cycle is a part of another new chapter, 'Changes in the Weather', in which a detailed description of processes such as evaporation, condensation and precipitation is given. In the same chapter, a discussion on 'artificial rain' is included, which has been considered for the purposes of this analysis as an indirect reference to the water cycle. Class 5

Table 4. Occurrences Related to the Water Cycle in the MSB Textbooks

Class	Concept	Topic/Context	Type of Relation: Direct (D)/ Indirect (I)
4	Water cycle	Changes in the weather	D
	Water cycle	Changes in the weather	D
	Water cycle	Changes in the weather	D
	Precipitation	Artificial rain	I
5	Evaporation	Evaporation	I
	Condensation	Condensation	I
	Evaporation/ Condensation	Evaporation/ Condensation	I
6	Evaporation/ Condensation	Factors that support life	I
	Water cycle	Our environment	D
7	Water cycle	Natural resources	D
	Evaporation	Evaporation (activity)	I
	Evaporation	Evaporation	**I**
	Conservation	Rainwater harvesting	**I**
8	Condensation	Water vapour in air	I
9	Transpiration	Transport of water and minerals	I

Source: Authors' own.

has discussions on evaporation and condensation as described in the context of 'physical changes'.

Other than Class 4, direct references to the water cycle also occur in Classes 6 and 7. Class 6 has topics related to evaporation and condensation, followed by a brief description of the water cycle accompanied by an illustration, which is a combination of sketches and arrows. Class 7 has one direct instance of the water cycle, which is discussed in the chapter on natural resources. Later, in the context of 'forms of water', evaporation is discussed, to be continued along with a discussion on aspects of water management and rainwater harvesting, which has been considered here as an indirect reference to the water cycle.

Class 8 has an activity related to condensation. Class 9 has a brief note on transpiration in the context of 'transport of water and minerals'. Class 10 does not have any topic that relates to the water cycle as delineated in this study.

Use of Visuals, Linkage of Text with Visuals

Having described the references to the water cycle in the NCERT and MSB textbooks, we now assess the types of visuals and text used in both these series of books. In the NCERT textbooks, 19 out of 27 instances consist of text accompanied by visuals; in the MSB textbooks, 9 out of 15 instances consist of text accompanied by visuals (Table 3). The text related to the water cycle in the NCERT textbooks contains nine topics with 15–30 sentences, and 18 topics with 10 or fewer sentences. In the MSB textbooks, on the other hand, all instances (15) of the water cycle are described in 10 sentences or less. The visuals, too, are fewer (12 in the MSB books compared with 31 in the NCERT books). This is consistent with the overall trend of less text and fewer visuals per page in the MSB books (see Table 1). As noted earlier, the size of the visuals in the MSB books is also smaller.

Explicit visuals were largely present in both the series of textbooks. In the NCERT textbooks, all the texts and the associated visuals (19) were explicitly related. In the MSB series, two out of nine instances were found where this relation was lacking. As for the linkages of text through the labelling of visuals, the NCERT textbook had seven such sketches. None of the MSB textbooks had labelled visuals of the water cycle. We next discuss the qualitative characteristics of the visuals.

Use of a Variety of Visuals

Table 5 shows that in the NCERT textbooks, all except one of the 31 visuals are sketches and only one visual is depicted in the form of a schematic diagram. A class-wise breakup (not shown in the table) revealed that most of the sketches (12 out of 31) are in Class 6, where the largest number of water cycle instances was found. In the same class, we came across one illustration that was 'partially schematic', but in the overall assessment, we have placed it under the 'sketches' category (Figure 4).

The salient aspect of the visual concerns its rendering, which may be either in full colour or in a single colour (see Table 5). The majority of the visuals (28 out of 31) in the NCERT textbooks were in colour.

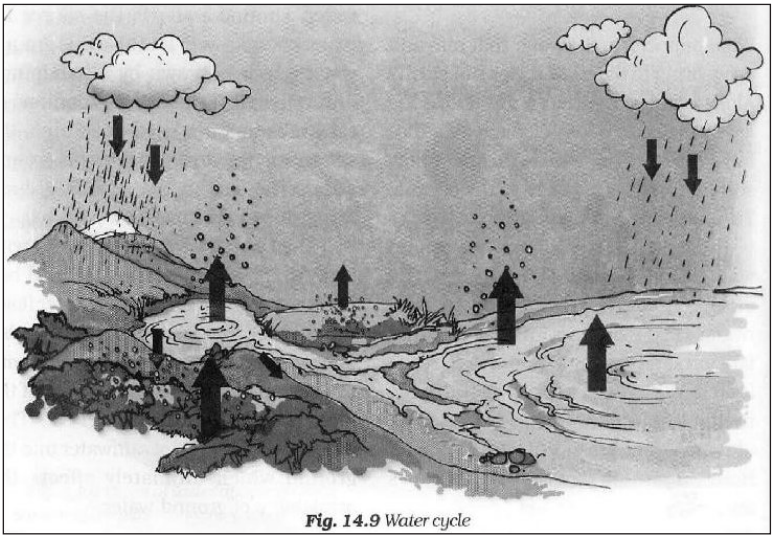

Figure 4. Partially Schematic Diagram (NCERT, Class 6)

Source: NCERT and Maharashtra State textbooks listed in Appendices A and B.

Table 5. Details of the Water Cycle Visuals in the NCERT and MSB Textbooks (Classes 3 to 10)

		Type of Visuals		Visual Display	
Class	Water Cycle Visuals	Sketch	Schematic Diagram	Grey Scale/ Single Colour	Coloured
NCERT	31	30	1	3	28
MSB	12	12	0	7	5

Source: Authors' own.

Table 5 also summarises the data for the MSB textbooks. The MSB textbooks have a total of 12 sketches of the water cycle. This number is less than half the number of the total number of water cycle visuals (31) in the NCERT textbooks. A class-wise breakup (not shown in the table) reveals that Class 4 (5 out of 12) has the largest number of sketches compared to any other class. There were no schematic representations of the water cycle, although there was one partially schematic diagram (Figure 5), which was placed under the 'sketches' category.

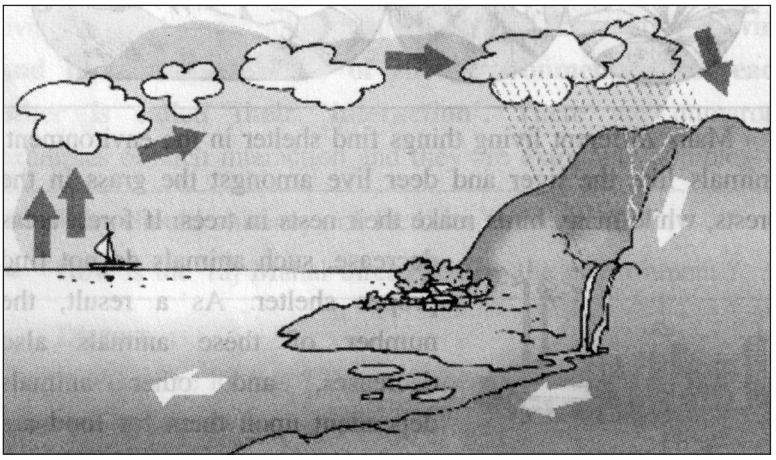

Figure 5. Partially Schematic Diagram (MSB, Class 6)

Source: NCERT and Maharashtra State textbooks listed in Appendices A and B.

Most of the visuals are either in grey scale or in a single colour, unlike the visuals of the NCERT textbooks, which are in full colour.

Overall Observations on the Textbooks

General Observations on Visuals

An overall examination of the textbooks (including the water cycle) showed that the NCERT science textbooks have not only more text and more visuals than the MSB science textbooks, but also that the size of the visuals in the former is larger than it is in the latter. Scrutiny of all the visuals revealed that the NCERT textbooks had a larger proportion of pages with major visuals in comparison with the MSB textbooks. Pages with major visuals in the entire series of the NCERT and MSB textbooks were 70 per cent and 52 per cent respectively, and pages with only minor visuals were 26 per cent and 21 per cent respectively. Sketches formed the predominant category in both the series of textbooks. Most visuals in the NCERT textbooks were rendered in more colour and in greater detail than the visuals in the MSB textbooks.

Treatment of the Water Cycle

Coming to the water cycle instances in both the series of textbooks, NCERT had more instances of the water cycle (27) compared to MSB (15). In addition, the water cycle received a much more comprehensive treatment in the NCERT textbooks, through both direct and indirect references. In the NCERT series, the Class 6 textbook has the first direct introduction to the water cycle; it includes the largest number of direct incidences (11) (which follow up the indirect references made in the lower Classes 3 and 5). Classes 7–9 have further direct as well as indirect references. In the MSB series, the water cycle is introduced in Class 4 with three direct instances and one indirect instance. Classes after Class 4 also have references to the water cycle (mostly indirect), with one to three references in each class from Classes 5 to 9. Figure 6 summarises and compares the number of water cycle instances in each class for the two series as a percentage of the total instances in that series.

Figure 6 shows that the percentage count of the instances of the water cycle is distributed across Classes 4–9 in the MSB textbooks. However, the treatment of the aspects of water conservation and management is more prominent and more comprehensive in the NCERT textbooks from a pedagogical point of view. Concepts pertaining to water conservation (particularly rainwater harvesting) are dealt with explicitly and in detail in the NCERT textbooks. The NCERT Class 5 book has an entire chapter on the aspects of water conservation and

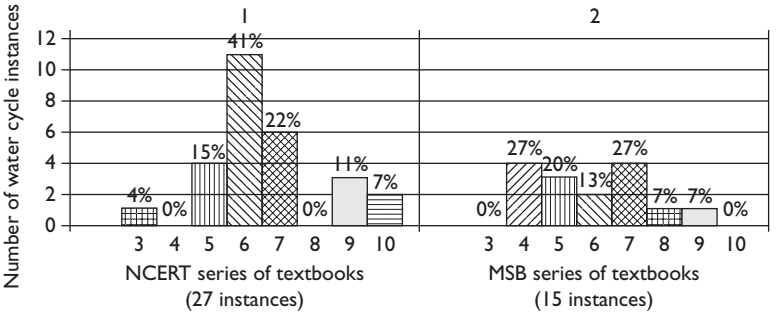

Figure 6. Percentage Distribution over Classes of the Total Number of Water Cycle Instances in the NCERT and MSB Textbooks

management. In terms of colour, most water cycle visuals (28 out of 31) in the NCERT books are in colour, whereas in the MSB books, seven out of 12 visuals are depicted in either grey scale or in single colour. The visuals are also rendered more attractively in the NCERT books. On the whole, the use of visuals and the linkage between text and visuals are more striking in the NCERT books.

Pedagogic Role of Visuals in the Treatment of the Water Cycle

In both the series of textbooks, most of the visuals are illustrative or 'representational' sketches. In both the series of textbooks, schematic diagrams are used less. Only three out of 43 visuals contained arrows. In the context of the water cycle, only one visual was depicted as a schematic diagram in Class 9 in the NCERT series. The MSB series did not have any schematic diagrams pertaining to the water cycle. The use of visuals for the organisation, interpretation and transformation of ideas is rarely seen in either the NCERT or the MSB textbooks. The interactive aspect of visuals is used less frequently (except for one instance in Class 7, NCERT, in an activity involving jumbled words pertaining to the processes involved in the water cycle). The MSB books do not have any interactive visuals. Connections between visuals and text were made largely in both the series of textbooks other than two water cycle instances in the MSB textbooks. Labels were rarely used in these textbooks. In the NCERT books, labelled water cycle visuals were introduced in Class 7. In the entire NCERT series, there were only seven such labelled visuals, whereas MSB did not have any such labelled visuals.

Alternative Approaches to Visuals

The large number of interconnected concepts and phenomena related to the water cycle, and the complex relative connections between them, means that suitably designed diagrams can play a useful and facilitating role in the presentation of this topic. While the NCERT textbooks have attractive visuals, we see that the treatment of the water cycle in both the NCERT and MSB series of books relies on the use of visuals largely in the form of sketches or 'representational pictures' (representational pictures

aid readers to visualise something, whether a place, person or event), followed by 'decorative' visuals. The use of visuals for 'organisation' (visuals that aid in organising or providing a structural framework), 'interpretation' (visuals that aid in understanding) and 'transformation' (visuals that aid in remembering or transforming key information), as described by Carney and Levin (2002), is almost absent.

We now consider two exemplary instances of visuals that depict several aspects of the water cycle in a clear and easily understood manner. The first visual is from the *Global 2000 Report*, cited in Botkin and Keller (1995). This visual, shown in Figure 7, is coloured in the original. Clouds are represented in greyish white, the sun is orange, the land surface is green, surface water bodies and the ocean are blue, the groundwater is brown, the soil is light brown and rocks are represented in a darker shade of grey. Most tellingly, arrows in the visual also follow a particular colour scheme. Red arrows represent evaporation and transpiration; dark blue arrows depict precipitation and surface runoff; and brown arrows

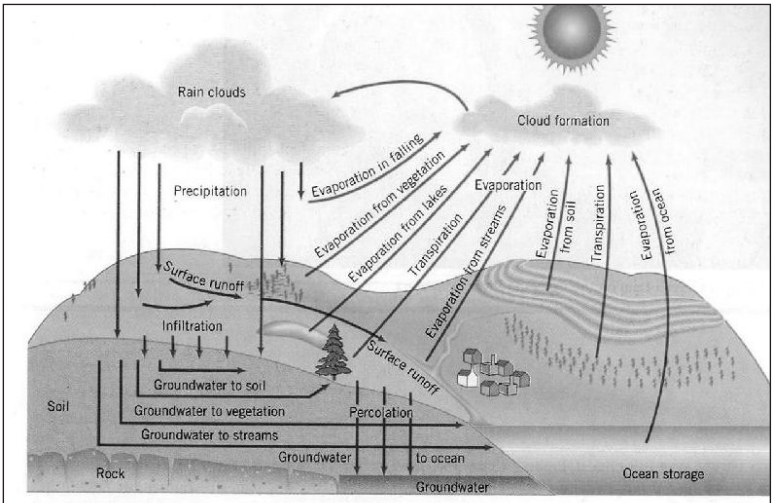

FIGURE 19.4 The hydrologic cycle showing important processes and transfer of water. (*SOURCE:* Modified after Council on Environment Quality and the Department of State, 1980, *The Global 2000 Report to the President*, vol. 2, Washington, D.C.)

Figure 7. Alternative Water Cycle, Visual 1

Source: Botkin and Keller (1995).

represent *infiltration* and *percolation*. This visual presents a holistic and comprehensive view of the water cycle through the use of colours. It may be suitable for use for Classes 8–10 because by then, students have been introduced to the basic ideas and concepts related to the water cycle and are ready to put them together into an understanding of an abstract and complex cycle.

Figure 7 is also an example of the organisation, interpretation and transformation of ideas in a visual. The different components of the water cycle—the contrast, the background and the use of distinct icons—make the visual appealing, while simultaneously conveying the relevant concepts with clarity. Details like the blurring of the outline during cloud formation and the inclusion of pores in the rock strata are well depicted. Labels are placed precisely against the arrows, so that the explanation is immediately obvious (for example, to show that *infiltration* is the entry of water into the soil surface or that *percolation* is the downward movement of water through soil and rock). The distinct representation of the minor components of, and the processes involved in, the water cycle (for example, evaporation of falling raindrops or secondary evaporation) means that with each careful study, students will learn more and more about the nuances of the cycle. Notably, in this figure, groundwater is treated not as an isolated system, but is shown clearly as having connections to the water cycle. The association of groundwater with the other components of the water cycle is usually a neglected aspect in textbooks.

Alternative Visual 2 (Figure 8) presents a more concrete depiction of the water cycle, relating our daily experiences with the entire cycle. This kind of a visual is suitable for the primary classes.

In place of the customary abstractness that characterises explanations of the water cycle, this figure presents a narrative, which is concrete and clear. The visual depicts the journey of the water molecule, its movement through humans, through plants, through animals, as well as through centres of human habitation and agricultural fields. In the visual, the cycle repeats itself several times, unlike the depiction in other unidirectional water cycle visuals. The winding path, depicted through dashes, takes the water molecule around the scene, inviting the eye to follow its curvy path (private communication, Dr Kim Kastens, researcher on visualisation in the geosciences). To enhance interactivity, verbal labels are to be added by the students, and the addition of a story with sound effects is also suggested in the accompanying Teacher's Book.[2]

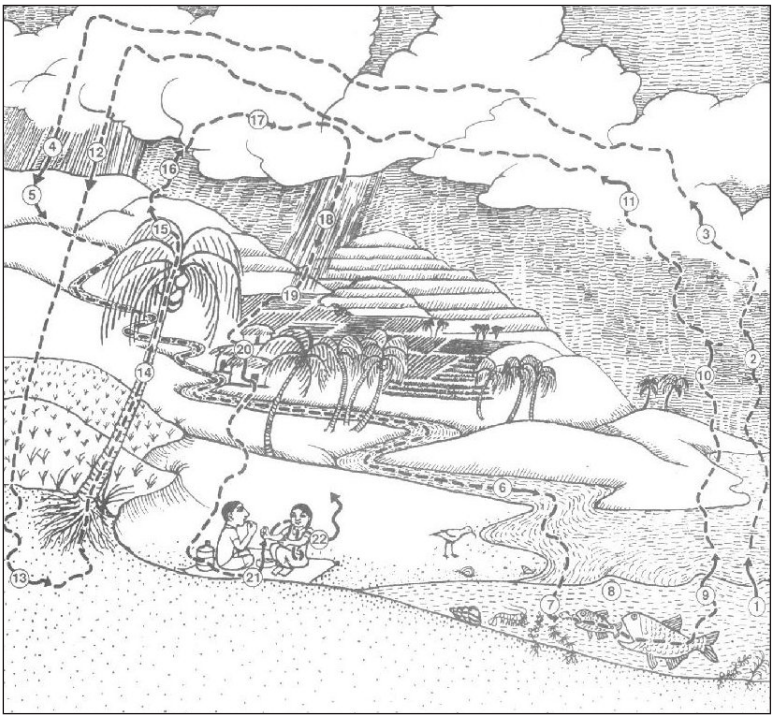

Figure 8. Alternative Water Cycle, Visual 2

Source: Small Science Class 4; Artist: Karen Haydock.

Conclusions and Implications

Visuals are an inseparable part of science textbooks. Both text and visuals in textbooks carry valuable information. However, the pedagogical role of visuals is often obscured by their role in making the books immediately attractive. An attractive visual may play a motivational role, as distinct from a pedagogical role; in this regard, recall Harp and Mayer's (1997) distinction between 'emotional' and 'cognitive' interest. While visuals are usually thought to be more important for younger children, they have a role to play in reaching out to readers of all ages. In terms of the comprehension of concepts, the more complex the text, the more likely it is that pictures will be helpful.

The organisation and sequencing of visuals is an important tool for tuning the content and pedagogy for students at different learning levels. With a balanced and thoughtful approach, the direct and indirect references to visuals may be organised so as to deal effectively with the content and to make learning more impactful. Factors like the connection of visuals with the text and the use of labels need more attention in our textbooks. Visuals that schematise the main elements or factors help effectively in communicating the content and the processes involved in the depiction of a system. Use of visuals for the organisation, interpretation and transformation of ideas needs to be exploited instead of a reliance on simple depictive or representational visuals. When more complex visuals are designed, the need for labels will be felt naturally. The interactive aspect of visuals will also then come into prominence. A possible mode of interactivity could be through a story, which meshes quite naturally with the concept of a 'cycle'.

The water cycle is central to human life activities, and it deserves an important place in school learning. In Indian schools, textbooks are the most relied upon resource used by teachers and students, and the good design of textbooks can have a multiplicative impact on learning. Analyses of school textbooks and comparisons between them provided insights into the pedagogy of the water cycle at the school level and helped in understanding the place of visuals in textbooks.

One of the motivations for the study was to provide the authors and designers of textbooks with a set of criteria that contribute to the analytical strength of good design and layout. This will help to make authors and designers more aware of the pedagogic function of a variety of visuals and of the placement of text and visuals in relation to the textbook as a whole.

The analysis has helped in providing an overview of the development of the concept of the water cycle in the textbooks through the school years, and also in identifying some of the problems in its treatment. It is seen that the use of visuals that bring to learning not just the prior knowledge of the student, but that also relate to their daily life activities and that are interactive, will ensure more effective learning and greater understanding. Two examples of such visuals have been discussed to elaborate this particular role of visuals. We hope that the analysis of the water cycle will not only help in identifying significant issues of representing and teaching content but will also serve as a model for investigating other systems in school textbooks.

Appendix A

List of NCERT Science Textbooks Examined in this Study (Classes 3–10)

- *Looking Around: Environmental Studies*—Textbook for Class 3, NCERT, 2006.
- *Environmental Studies: Looking Around*—Textbook for Class 4, NCERT, 2006.
- *Environmental Studies: Looking Around*—Textbook for Class 5, NCERT, 2008.
- *Science*—Textbook for Class 6, NCERT, 2006.
- *Science*—Textbook for Class 7, NCERT, 2006.
- *Science*—Textbook for Class 8, NCERT, 2008.
- *Science*—Textbook for Class 9, NCERT, 2006.
- *Science*—Textbook for Class 10, NCERT, 2006.

Appendix B

List of MSB Science Textbooks in This Study (Classes 3–10)

- *General Science, Book One*—Textbook for Class 3, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2008.
- *General Science, Book Two*—Textbook for Class 4, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2009.
- *General Science, Book Three*—Textbook for Class 5, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2006.
- *General Science, Book Four*—Textbook for Class 6, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2007.
- *General Science, Book Five*—Textbook for Class 7, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2008.
- *General Science, Book Six*—Textbook for Class 8, Maharashtra State Bureau of Textbook Production and Curriculum Research, 2009.
- *Science and Technology, Parts One and Two*—Textbook for Class 9, Maharashtra State Board of Secondary and Higher Secondary Education, 2006.
- *Science and Technology, Parts One and Two*—Textbook for Class 10, Maharashtra State Board of Secondary and Higher Secondary Education, 2006.

Notes

1. An earlier version of this article was presented at the Second People's Education Conference, held at the HBCSE, TIFR, Mumbai, in October 2009.
2. See http://coglab.hbcse.tifr.res.in/teacher-resources/multimedia-resources/water-cycle-english, for an audio version of the water cycle story.

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