Technical Report

A short course on Energy & Environment for middle school students and a study of students' ideas on the topic

Saurav Shome and Chitra Natarajan

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
Mumbai 400 088

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Inquiries:

Publication cell
Homi Bhabha Centre for Science education (TIFR)
V. N. Purav Marg, Mankhurd,
Mumbai 400 088
Fax: 25566803
hbcpub@hbcse.tifr.res.in

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Several errors have been corrected through the several drafts of this report. However, we are sure errors still remain. We appreciate your positive criticism for the improvement of the report.

HBCSE (Mumbai) Saurav Shome and Chitra Natarajan
May 2009

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A. Introduction

The environment of an organism is the sum of all biotic and abiotic components, including energy that surround it. All the components in the environment interact continually in a non-linear way. The biotic components include humans. As human populations are found almost all over the surface of the earth, our environment is the earth itself. However, humans among all living species, have the greatest potential to alter their surroundings. Humans have traversed a long journey of evolution – over 300,000 years, which was first biological, and then largely cultural. Hence, the human environment includes cultural artefacts and their organisations. These add complexity to the human-environment interactions. The dynamics of culture also makes it more challenging to predict the trajectory of environmental conditions based either on the past or present.

A.1 Humans and the environment

People's interest in and attitude towards the environment are affected by the extended time spent outdoors, parents' attitude, education, involvement in environmental organizations, and the loss of a valued place. A single exposure to any of these elements can allow people to feel connected to the environment and committed to protecting it (Chawla, 1999). Direct childhood experiences of nature is a key factor in adult attitudes towards the environment (Milton, Cleveland, & Bennett, 1995).

Interestingly, providing information is not sufficient for creating environmental knowledge. Much of it depends on how the information is presented (Young & Witter, 1994). Besides, existing alternative conceptions may be barriers to assimilating new information into knowledge (Driver, Squires, Rushworth, & Wood- Robinson, 1994).

People's environmental concerns tend to be egoistic, social-altruistic, or biospheric/ biocentric (Schultz, 2001). These categories shape people's environmental attitude, and are indicative of their value orientation, and different reasons for their environmental concerns (Schlutz & Zelezny, 1999). Simply providing more information or even more knowledge about environment may not alter environmental attitudes and does not lead to environmentally responsible behaviour (Kollmuss & Agyeman, 2002).

Environmentally responsible behaviour is influenced by multiple factors like locus of control, sense of responsibility, knowledge, and attitude etc. (Newhouse, 1990). The relationship between attitude and behaviour is strong when the attitude has been developed through direct experience (Milton, Cleveland, & Bennett, 1995). Through their meta-analysis of environmental behavioural research, Hines, Hungerford, & Tomera (1987) found that individuals who have knowledge about environmental issues or knowledge about how to take action on those issues are more likely to engage in environmentally responsible behaviour.

A.2 Environmental education (EE)

Environmental Education (EE) has been an important issue at the global level for at least close to four decades. Educators and environmentalists the world over have repeatedly pointed out that any solution to the environmental crisis will require that environmental awareness and understanding are deeply rooted in the education of all people at all levels (UN, 1973; UNESCO/UNEP, 1978; UN Division for Sustainable Development, n.d.). As spelt out in Agenda 21, a major landmark in environmental action that resulted from the Earth Summit 1992 (UN Division for Sustainable Development, n.d.), "Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues… It is also critical for achieving environmental and ethical awareness, values and attitudes, skills and behaviour consistent with sustainable development and for effective public participation in decision-making" (Chapter 36, section 36.3).

The road to the Agenda 21 was paved over a long period. The Stockholm Conference 1972 (UN, 1973) recommendations formed the foundation and framework for a cooperative effort in international EE. The 'Tbilisi Declaration' of educators provided further guidelines for EE (UNESCO/UNEP, 1978). In recent times, there appears to be a shift of focus in environmental studies, from an ecological understanding towards social science (Palmer, 1998). Though the new aspects are welcome, it is necessary to emphasise ecological understanding when dealing with environmental issues.

In India, EE has been made a school subject by a policy initiative by the government following a Supreme Court directive to do so (NCERT, 1981).

A.2.1 Goals and Objectives of EE

There is considerable agreement regarding the general nature of EE (NCERT, 1981). 'Tbilisi Declaration' (UNESCO/UNEP, 1978) provides the goals and objectives of EE. The goals of EE are:

- to foster a clear awareness of, and concern about, economic, social, political and ecological interdependence in urban and rural areas;
- to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment; and
- to create new patterns of behaviour of individuals, groups and society as a whole towards the environment.

The objectives of EE in the 'Tbilisi Declaration' are categorized as follows:

Awareness: to help social groups and individuals acquire an awareness of and sensitivity to the total environment and its allied problems.

Knowledge: to help social groups and individual gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems.

Attitudes: to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.

Skills: to help social groups and individuals acquire the skill for identifying and solving environmental problems.

Participation: to provide social groups and individuals with an opportunity to be actively involved at all levels in working towards the resolution of environmental problems.

One of the broader long-term goals of EE is to form an environmentally literate citizenry, who can actively participate in solving environmental problems (Roth, 1992).

The NGO Forum at the Earth Summit 1992 (UN Division for Sustainable Development, n.d.) provided guidelines for EE as follows:

- EE must involve a holistic approach and thus an interdisciplinary focus in the relation between human beings, nature and the universe.
- EE must stimulate solidarity, equality and respect for human rights involving democratic strategies and an open climate of cultural interchange.
- EE should treat critical global issues, their causes and interrelationships in a systemic approach and within their social and historical context. Fundamental issues in relation to development and the environment, such as population, health, peace, human rights, democracy, hunger, degradation of flora and fauna, should be perceived in this manner.

A.2.2 The EE curriculum

The Discussion Guide for UNESCO Training Seminars on EE (Wilke, Peyton, & Hungerford, 1987) has suggested two models for EE curricula: the Interdisciplinary (single subject), or infused model and the Multidisciplinary or infusion model. The curriculum development goals are organized into four levels. Those goals encompass the ecological foundation, issue awareness, investigation and evaluation, and issue resolution (Ramsey, Hungerford, & Volk, 1991).

Level I is the ‘knowledge level’ that focuses on ecological concepts, and provides knowledge that can help make ecologically sound environmental decisions. The specific concepts to be included are left to the judgement of curriculum developers.

Level II is also the ‘knowledge level’, but focuses on information from an ecological perspective about aspects of human behaviour and cultural activities (religious, economic,

political, social etc.) that influence the environment. This level intends to develop an awareness of the link between individual and collective human actions, human quality of life and the quality of the environment. It emphasises the resolution of environmental issues through investigation, evaluation, values clarification, decision making and finally, citizenship action.

Level III is a 'skill level' that focuses on skills needed for issue investigation, evaluation and values clarification.

Level IV is an 'environmental action level' (training for application) that focuses on those processes that are important for citizenship action (participation). This level seeks to help achieving and maintaining a dynamic balance between the quality of life and the quality of the environment.

In principle EE is contextualised in the natural and built environments, the technological and social environments, including economic, political, cultural, historical, moral, aesthetic aspects (CEE, 1999). Environmental education needs to include the appreciation and beauty of the natural world but also, the economic, political, and social issues involved in our decision making process. We need to be aware of information and facts in order to make informed decisions. People cause the environmental problem so it is a social problem (Volk, 2003). Engelson (1986, as cited in Sa'di, 1997) suggested that an EE program needs to be action-oriented, continuous, experimental, future-oriented, globally oriented, holistic, interdisciplinary, issue-oriented, and neutral.

One of the central components of EE is information about how ecosystems naturally function and the problems that are threatening the well-being of all life. Information needs to address all aspects of environmental issues (be neutral), preferably through direct environmental contact, and stimulate a sense of responsibility and personal control (Newhouse, 1990). Thus, information needs to be coupled with action strategies, which may be illustrated through role models. While, changes in knowledge and attitudes towards the environment are important goals of EE, its goal is to effect behaviours that will lead to sustainable environments (Leeming, Dwyer, Porter, & Cobern, 1993). One of the strategies that helps this is discussing and solving local environmental problems (Schaefer, 1992).

Environmental education in early schooling should not only be on par with reading, writing, and arithmetic, it should be an integral part of all courses (Gigliotti, 1990). An effective EE needs to be a learner-centred and activity based approach for exploring the environment, encouraging learners in the development of attitudes and qualities like self-esteem, rational outlook, curiosity, spirit of enquiry, objectivity, and the courage to ask questions, as well as creativity, initiative and value appreciation for truth and aesthetic sensibility. The pedagogic strategies need to promote logical and independent thinking, skills of observation, reasoning, analysis, interpretation, problem-solving and decision making in real life situation for improving everyday living and environmental conditions (NCERT, 1988).

To address environmental knowledge without reference to the attitudes and values held by student will limit the extent to which such knowledge is translated into action. To address environmental attitude and values without providing an accurate and relevant knowledge base will limit the power and effectiveness with which attitudes/values are applied (Ballantyne & Packer, 1996).

Baba Dioum, a Senegalese environmentalist, stated in a meeting at New Delhi, 1968 (Valenti & Tavana, 2005):

In the end we will conserve only what we love.
We love only what we understand.
We will understand only what we are taught.

A.2.3 Role of the teacher in EE

Good environmental education requires teachers to move beyond their role as a script reader to learner, thinker, facilitator, problem solver, leader, follower, observer and communicator (Volk, 2003). Environmental educators need to supply information of a very practical nature, addressing the role of individual. Environment includes the psychological environment created by relationships with teachers and peers (Milton, Cleveland, & Bennett, 1995).

Children and young people are influenced by adults' attitudes. Wilson (1993) explains the role of a teacher in early childhood instruction as follows:

a) Through my actions and words, I demonstrate a sense of wonder and respect for the natural world.
b) I involve children in frequent nature-related learning experiences, focusing on activities which are pleasant and memorable.
c) I provide opportunities for children to be actively involved in the learning experiences, with attention to safety and comfort.
d) I show a sincere and active interest in children's new understanding and discoveries about the natural world.
e) I emphasis "sharing and doing" versus "teaching" in introducing children to the wonders of the natural world.
f) I focus on qualities and experiences versus labels in my questions, discussions, and activities related to the natural world.
g) I introduce a variety of both indoor and outdoor nature-related activities, with attention to the social context.
h) I look for pro-nature characteristics in choosing children's literature.
i) I provide a variety of opportunities for children to experience the nature and care of living things.
j) I know and model ecologically sound environmental behaviours.
k) I share information with families and invite their involvement in nature appreciation activities.

l) I work toward enhancing my own understanding and appreciation of the natural world.

If teachers set themselves up as example, students can form a respect towards mutual existence, self-respect, and a democratic and harmonious society (Kastenholz & Erdmann, 1994).

A.2.4 Pedagogic strategies

Outdoor education complements and expands classroom instruction (Kenney, Militana, & Donohue, 2003). Environmental education programs in the wilderness was found to build self-esteem, increase the feeling of personal adequacy and worth, and bring about changes in participants' interpersonal skill (Priest, 1986). Lisowski & Disinger (1991) found that field-based instructions helped students understand ecological concepts. Meaningful learning takes place when students can link and correlate what is learned inside school with what they experience outside school (Driver, Squires, Rushworth, & Wood- Robinson, 1994). Environmental magazines in the classroom can act as an inside-outside bridge (Chipman & Brody, 1993).

Buchan (1991) pointed to the usefulness of vacation school program of taking students to a University in developing understanding of high school students. Participation in outdoor activities can generate knowledge about issues, empathy towards environment and a willingness to protect the environment (Palmberg & Kuru, 2000). A study showed that active participation of students in environmental issues led to significant changes in their attitude and they were more likely to take action on such issues (Dresner & Gill, 1994).

Bardwell (1991) showed the usefulness of narrating success stories to motivate students in an EE classroom. Seeing adults unable to solve environmental problems, generates anonymity and passivity in children. Seeing urban activities that are largely destructive to the environment, strengthen their position of passivity (Dresner & Gill, 1994). In nature camps, on the other hand, a feeling of connection with nature transforms participants' attitude of domination to a desire to live with nature (Talbot & Kaplan, 1986). However, the benefit of short-term programs is also short-lived if follow up interactions are not properly planned (Milton, Cleveland, & Bennett, 1995).

Environmental problem solving needs not just scientific knowledge, but also depends significantly on the moral ethics of the concerned society (Stevenson, 1993). Students who are familiar with or witness environmental changes due to human impact become environmentally sensitive (Volk, 2003).

Students can be encouraged to volunteer for environmental monitoring or other related issues, through which they may be sensitised about environmental and sustainability issues (Fleming, 2003) or even can be a part of community based participatory research work (Rao, Arcury, & Quandt, 2004). Students contributing to their community feel a sense of

pride. This has been shown to help them take risks in all academic areas. They become more comfortable in communicating with peers and adults (Volk, 2003).

The basic pedagogic strategy in EE is to make teaching-learning holistic, and incorporate all the possible modes of education under one ongoing program.

A.2.5 Complexity of EE in Indian schools: A proposed model

India has wide variations in bio-geographical regions. India has the following major regions:

Lowland rain forest
Degraded rain forest
Mountain rain forest
Lowland monsoon forest
Degraded monsoon forest
Mangroves
Non-forest
Freshwater marsh
Estuaries, coastal wetlands
Tank regions
Wetland complexes

Besides the bio-geological variations that contribute to lives of humans, India is also home to a large number of languages, religions, and other cultural diversities. Over and above these, there are also socio-economic differences. These diversities contribute to differing life styles as well as world views among the people, especially in relation to human and nature. In the light of these vast diversities, a uniform environmental educational program and material is not applicable in our country. EE in existing conventional teaching system will not be fruitful (CEE, 1999).

How then should EE be incorporated in meaningful ways to Indian students? This field work project is a small effort in addressing this question. A possible immersion model of environmental education is suggested in Appendix A. This was earlier presented at two conferences (Shome and Natarajan, 2007a; Shome and Natarajan, 2007b).

The model considers environmental education as a process that makes multidisciplinary linkages (infusion) as well as an interdisciplinary subject (infused). It requires the teacher, school administrators, and all stakeholders to be involved in creating a physical and social environment in which students learn. The implementation of the model will require the teacher to adopt practical environment friendly ways of living, access information on environmental phenomena and understand the nature of human interactions, and be motivated to address environmental issues in a free-thinking inclusive class. The model has several essential components:

- Books that are largely self-learning and activity-based with content that moves from the local to the global. Issues should be addressed in all subjects within a grade and progressively related across different grades.
- Multiple modes of communication need to be encouraged through use of audio and video materials, charts, diagrams, paintings and posters, which even students can make, structured interactions in oral (dialogues, debates, presentations) and written modes, mimes and gestures, dramas, dances and skits.

- Tours and visits can be arranged to museums, zoos, places of historical and cultural interest, national parks, reserve forests and sanctuary and disaster affected areas, with a plan to sensitise students.
- Response to local issues followed by national and global ones need to organised in terms of suitable action at the local and global levels. Forming local clubs with shared aims will facilitate and strengthen environmental action.

A.2.6 Ideas about environment and energy in the NCERT textbooks

This is a brief analysis of the content related to energy and environment studied by students, who are currently in Class VIII and had followed the NCERT textbooks from Class V to VIII.

Class V

In Class V, the science textbooks were titled “Environmental Studies.” It had six Units. Unit I had a lesson on “Parts of Plants and their Functions”. The lessons in Unit III were “Interdependence in environment,” “Natural calamities,” and “Means of transport and communication - their impact”. Unit IV had “Force, Work and Energy,” “Simple machines,” and the “Microscope”.

The lesson on plants (Unit I) dealt only with terrestrial plants. Photosynthesis was the process of making food by leaves of plants in the presence of sunlight with the help of chlorophyll. It said, “Stomata also help the plants by giving out oxygen and taking in carbon dioxide from the environment for making food” (p. 33). In the lesson on “Interdependence in environment,” there was a reference to “all living beings need land, water and air to survive” (p. 91). On the same page, there was also a reference to “some (living beings) live on land whereas some live in water.” These statements may have posed confusing situations and contradictions, which were not clarified in the textbook.

The lesson included statements like, “the living beings on earth like humans, animals, and plants are called biotic components of the environment,” (p. 92) and phrases like, “...hunt birds and wild animals” (p. 95). The examples of animals given in the lesson were deer, rabbit, tiger, lion. The food dependence in the environment was given as a linear food chain. In the lesson on “Force, Work and Energy”, there was a statement, “to perform any activity we need energy” (p. 128), while there was another that said, “energy is the ability to do work” (p. 129). All given examples of energy use were associated with motion. The textbook also stated that for humans, food is the source of energy and for vehicles, it is petroleum and coal.

Class VI

Class VI book dealt with fewer issues relevant to environment and energy. There was content on food and sources of food, components of food, etc. (mainly human centred), a

lesson about fibre and fabric, a lesson on getting to know plants, one on the living organisms and their surroundings, light, shadows and reflections, electricity and circuits, fun with magnets, water, air around us, and solid waste management.

Class VII

The class VII book deals with nutrition in plants, nutrition in animals, soil, weather, climate and adaptations of animals to climate, winds, storms and cyclone, respiration in organisms, transportation in animals and plants, reproduction in plants, water: a precious resource, forests: our lifeline and waste water story. In chapter 1, it is written “humans and animals are directly or indirectly dependent on plants” (p. 1). “Plants are the only organisms that can prepare food for themselves by using water, carbon dioxide and minerals” (*ibid.*). “The synthesis of food in plants occurs in leaves” (*ibid.*). Later it is mentioned that “chlorophyll, sunlight, carbon dioxide and water are necessary to carry out the process of photosynthesis” (p. 2). “The solar energy is captured by the leaves and stored in the plant in the form of food” (*ibid.*).

In the chapter of heat, 'heat is depicted as transferable'. In turn heat energy which can be transferred, the idea which is not much different from the idea of caloric. In the chapter of acids, bases and salts the short introduction of acid rain is given. Similarly in the chapter of physical and chemical changes, Ozone layer is introduced as a protective shield against ultraviolet radiation from sun.

In the chapter of respiration in organisms, respiration is introduced as releaser of stored energy from food. “The air we breathe in is transported to all parts of the body and ultimately to each cell. In the cells, oxygen in the air helps in the breakdown of food” (p. 108).

In the chapter Forest: our lifeline, when it is mentioned about birds not mentioned particular bird but as a common noun. For example, in page 207, “they got excited on hearing a sudden sound of birds and some noise...”, while name of animals, like monkey, boar, bison, jackals, porcupine, elephants in the same paragraph. In page 210, name of butterflies mentioned but not in context of types of animal. Next paragraph of same page writes “they came across numerous insects, spiders, squirrels, ants and various other small animals...”. In page 212, the trends repeated by “an army of tiny insects, millipedes, ants and beetle on them”. In the same page it is written, “the dead animals become food for vultures, crows, jackals and insects...The plants release oxygen through the process of photosynthesis. The plants help to provide oxygen for animal respiration.”

In page 212, formation of cloud has been connected with transpiration by plants. Again it says, “...that the forest is not just home to plants and animals. Many people also live in the forest”.

In page 211 a food chain is shown in linear form as below:

Grass --------> insects --------> frog ---------> snake ---------> eagle

It is mentioned, there are many food chains in the forest and they are linked. If one food chain is disturbed, other will be affected. It is explicitly mentioned that “if we remove one component, say trees, all other components would be affected” (p. 211).

Class VIII

Class VIII books deals with Crop production and management, micro-organisms: friend and foe, synthetic fibres and plastics, materials: metals and non-metals, coal and petroleum, combustion and flame, conservation of plants and animals, cell – structure and functions, reproduction in animals, reaching the age of adolescence, force and pressure, friction, sound, chemical effects of electric current, some natural phenomenon, light, stars and the solar system, pollution of air and water. In the first page of the book it is mentioned that “animals including humans can not make their own food”.

A.3 Students' ideas about Energy and Environment

The following sections briefly describe some of the studies reported on students' ideas about issues and topics in energy, environment and those that link the two. These include concepts of (i) energy, (ii) ecosystem like food chains and energy production through photosynthesis, (iii) matter and energy flows through food chains, as well as (iv) greenhouse effect, global warming, ozone hole.

A.3.1 Concepts about energy

The word energy frequently occurs in everyday talk even of lay people, and is perceived as a non-conserved quantity. For instance, we see water at high temperature gradually cool down to room temperature, without perceptible heating of the surroundings. Therefore, we conclude energy is “used up” without being converted to anything else; energy disappears or is lost.

A familiar experience is of a vehicle coming to a stop when its fuel is exhausted. Therefore, all practical purposes the energy is lost with the exhaustion of fuel. Most lay persons do not link the movement of the vehicle to manifestation of energy. For them energy exists in the fuel only. We also use the term energy conservation in daily conversation. As we know energy (more precisely sum of mass and energy) is a conserved quantity, there is no meaning in saying conserving energy. What we are looking for is the conserving high grade energy sources which are used for or having potential in providing usable mechanical energy.

Energy is deemed one of the most important and yet one of the most difficult topics of secondary school science. Watts (1983) reports that energy is identified only when there is an outward display of activity. Movement of any kind is often given as a reason for energy being involved (Stylianidou, Ormerod, & Ogborn, 2002). Students as well as adults take 'life world knowledge' (Solomon, 1987) for granted. One such knowledge is 'plants feed from the soil' (Leach, Driver, Scott, & Wood-Robinson, 1995).

Students face difficulties in applying the law of energy conservation in a biological context. They also have trouble in differentiating between available and unavailable energy for the living body. Both students and teachers hold the notion of vitalistic energy and force as part of the biological conceptions (Barak, Gorodetsky, & Chipman, 1997).

The concepts pupils hold is summarised by Gilbert and Watts (1983, as cited in Trumper, 1997), as follows:

- energy is to do with living and moving things,
- energy makes things work, and
- energy changes from one form to another.

The list of the most popular and persistent pupils' alternative conceptual frameworks about energy as provided by Gilbert and Pope (1986, as cited in Trumper, 1997) as follows:

1. Anthropocentric: energy is associated with human beings,
2. Depository: some objects have energy and expend it,
3. Ingredient: energy is a dormant ingredient within objects, released by a trigger,
4. Activity: energy is an obvious activity,
5. Product: energy is a by-product of a situation,
6. Functional: energy is seen as a very general kind of fuel associated with making life comfortable, and
7. Flow-transfer: energy is seen as a type of fluid transferred in certain processes.

According to Kruger, Palacio, & Summers (1992, as cited in Trumper, 1997), even teachers' difficulties in understanding concepts of energy are like following:

- Most of the teachers showed a lack of ability to differentiate between force and energy.
- Many teachers did not understand the notion of gravitational potential energy and associated energy mostly with motion.
- A substantial number of teachers' responses contradicted the principle of conservation of energy.
- Many teacher saw energy as a quasi-material entity.
- Most of the teachers had a vitalistic view of energy.

A.3.2 Concepts about ecosystem

Students hold many misconceptions about concepts of ecosystem and the nature of interrelatedness in ecosystem. Students tend to reason about individuals and miss the effect of population. They tend to reason locally and miss the larger picture. For instance, students think that a change in one population will only affect a population, which has a direct predator-prey relation with itself (Grotzer & Baska, 2003).

Photosynthesis

Understanding photosynthesis, respiration, and energy allocation at the organism level is key to understanding issues of energy flow, food supplies, and other ecological principles. In a study by Ozay and Oztas (2003) among secondary students, about half claimed that respiration of plants happens only during the night. In another study (Barman, Stein, McNair, & Barman, 2006), students of a similar age thought that plants "breathed" carbon dioxide.

Understanding photosynthesis, cycling of matter, and flow of energy as shown in Figure 1, is considered as the fundamental to gain understanding and insight of ecology (Carlsson, 2002). Ecological issues and environmental problems in general, must be tackled in an open, multi-variable, and interdisciplinary context, rather than a mechanistic and reductionist way, in order to be more fully understood (*ibid.*).

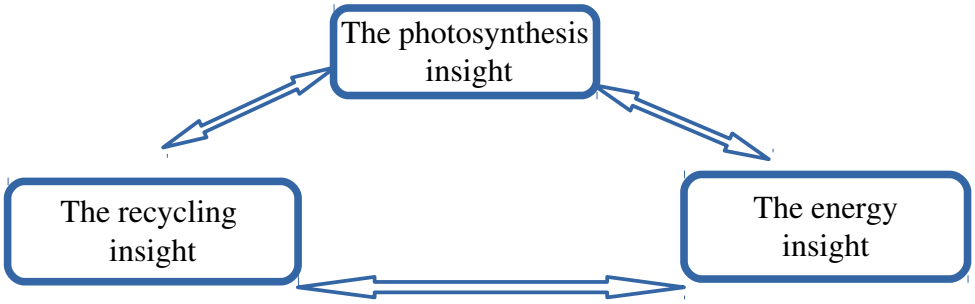


Figure 1: The relation between three essential insights of the ecosystem (adapted from Carlsson, 2002)

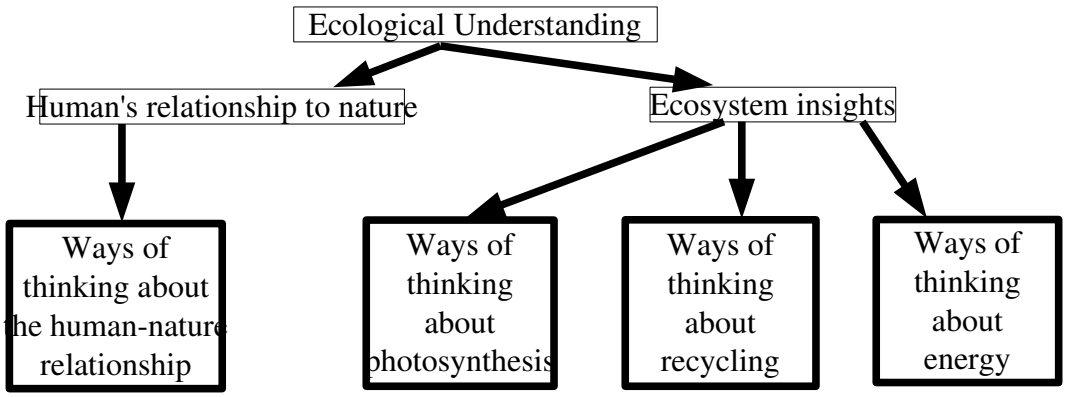


Figure 2: Conceptual framework for the study of ecological understanding adapted from Carlsson (2002)

Food Relationships, Energy and Material Flow

Students hold the misconceptions on food chain like 'a change in one population will not be passed along several different pathways of a food web', 'a change in one population will only affect another population if the two are related as predator-prey', 'a population located higher in a given food chain with in a food web is a predator of all populations located below it in the chain', 'a change in the size of a prey population has no influence on its predator's population', 'if the size of one population in a food web is altered, all other populations will be altered in the same way', and 'a change in the population of a first-order consumer will not affect one or more producer populations'. Students generally omit the discussion of energy flow through food chain. Most students do not understand the concept of energy flow through a food chain and food web (Barman, Griffiths, & Okebukola,1995).

Global Warming, Greenhouse Effect and Ozone Hole

Students, age 13 – 16 years, have difficulty in understanding of explanation of greenhouse effect and the ozone-layer depletion. Sometimes global warming is considered as the consequence of depletion of ozone layer. Sometimes students might face difficulty due to double meaning of words (Osterlind, 2005).

One of the studies (Leighton & Bisanz, 2003) with secondary school students found that more students knew the term ozone layer than the term ozone hole. Some students had misconceptions about the nature of ozone hole, which they thought of as a physical hole like a puncture, tear or opening. Students are unable to visualize a gradual depletion.

B. Method

B.1 Objectives

The broad aim of the study carried out by conducting an 8-day course on Energy and Environment for middle school students was to explore their understanding of environment, energy and the relation between the two. The camp was structured to answer the following questions:

1. What ideas do students hold about what constitutes their environment?
2. Middle school students have studied taxonomic classification of living beings as animals and plants and about food webs. What common animals and plants do students fail to classify and how do they connect them in food relations?
3. What ideas do students hold about forms of energy?
4. What understanding do middle school students have about photosynthesis and respiration in plants and their role in the environment?
5. What ideas about the environment, energy and their relation to society are represented by students in their posters on these topics, in science fiction writing and discussion of futuristic situations, and during role play on choice of a power plant for a small town/ village?

Besides exploring students' ideas, conceptual enrichment on environment, energy and its relationship to everyday living was provided to students during the course in the form of lectures, discussions and activities.

B.2 Participants

Forty students of Class VIII from three English medium schools voluntarily participated in the course. Announcements of the course for the students of class VIII were sent to each school. The students participated voluntarily. Guardian's written consent was taken before allowing participants to attend the course. Participants' profile is given below:

Table 1: Students' (Participants') profile

S. No.	Category	No. of students in morning session				No. of students in afternoon session	Total
		School 1	School 2	School 3	Total	School 1	
1	Male	0	10	3	13	17	30
2	Female	2	4	4	10	0	10
3	Total	2	14	10	23	17	40
4	Mean age of males	---	---	---	13.2	13	13.1
5	Mean age of females	---	---	---	12.8	---	12.8
6	Mean of total	---	---	---	13	13	13

B.3 Course organisation, structure, and data

Since a relatively large number of students had volunteered to participate in the workshop, we conducted the workshop in two sessions: Morning session from 10:30 am to 1:00 pm and an Afternoon session from 3:00 pm to 5:30 pm.

Eight morning sessions were conducted over 12 days. The same number of afternoon sessions were conducted over 13 days. Each session constituted four periods of about 30 minutes each with a break in between. After five consecutive days there was an interval of two days. The course schedule is given in Appendix B. The summary of the course is given in Appendix C. The sessions were structured to include a variety of activities:

- Responding to Activity Sheets,
- Participation in interactive lectures and group and class discussions,
- Drawing (context map),
- Writing (science fiction),
- Presentations,
- Conducting experiments (photosynthesis),
- Conducting surveys, plotting graphs of data,
- Poster making and putting up an exhibition,
- Role play in a drama, and
- Generating a draft report of recommendations for a village power options.

In the course there were several interactive lectures and group and class discussions. They served to explore students' ideas, discuss students' responses to concept questions in activity sheets, prepare students for activities and enrich their content knowledge. There were four structured lecture sessions on: environment, forms of energy and conversion of energy, photosynthesis, and sources of energy.

Data was collected in the form of students' responses to questionnaires and activity sheets, and students' productions of context maps, posters, reports, essays and other writings, survey tables and graphs, etc. Data was also available through video recordings of whole class discussions, audio recordings of structured presentations, researcher's observations and notes. Activities like drawing context maps, writing on fictional situations, and presentations are discussed in the Analysis Section.

B.4 Activity sheets

Three Activity Sheets – one each on environment, energy, and photosynthesis – were given to students. The questions in the Activity Sheets were based on a preliminary understanding of some of the misconceptions relating to the three topics. The primary and secondary science textbooks up to Class VIII (NCERT) were surveyed and ideas about students' misconceptions were gathered from the literature survey and from researchers' own experiences. The questions in the Sheets were of different kinds: multiple choice, true/false,

and those requiring open ended short answers, one word or even drawing diagrams. It was found that students were able to finish their writing task within the stipulated period.

Though the questions were developed with inputs from the second author, an expert in the area, several questions did not conform to the wording and format required of good diagnostic questions. The first author has since learnt from the experience, which will be outlined and discussed towards the end of this report. This report is limited to the analysis of those multiple choice and true/false questions that have been validated in terms of content and wording.

B.5 Photosynthesis experiments

Two sets of 3 experiments on photosynthesis were prepared: evidence of release of oxygen during photosynthesis (Experiment A); effect of absence of sunlight on photosynthesis (Experiment B); and effect of absence of carbon dioxide on photosynthesis. The activity sheet for the experiment is given in Appendix D. Only one of the experiments was successfully completed. The other two experiments could not be completed because of insufficient time for students to monitor and follow up. However, both the results and the incomplete experiments were discussed in class, perhaps not very satisfactorily.

B.6 Energy use over time

Students carried out 3 activities to study energy use over time and space: current energy audit of their own homes (survey sheet in Appendix E); energy used during three generational times – the students', their parents' and grandparents' times (survey sheet in Appendix E); and energy used during different periods of human civilization (response sheet given Appendix F).

Students were given an imaginary situation, where they had to shift to Mars to live for a long while. They could carry only a very limited number of electrical appliances. They had to list the appliances they wish to carry according to the priority, the most essential one being first on the list. The situation and four examples of lists by students are given in Appendix G. The lists indicate a total alienation of students from their basic needs.

The questionnaire and activity sheet responses are analysed semi-quantitatively, while the data from posters, essays, classroom discussions, etc. are qualitatively discussed. The interactions during the sessions are detailed along with the relevant analysis.

In the introductory session the workshop structure and events were elaborated what would be done and what was expected of them. The workshop aimed to expose students to concepts of energy and environment. The students were asked to form groups of four members. The groups were identified as Group A, B etc. Each student was given an identification code that included the following: the school no. (1, 2 or 3), male or female (M

or F), Group (A, B, C etc.), Sr. no. in participant list (two separate list prepared for morning and afternoon sessions), session (M for morning and A for afternoon)

Id Code = (School No.)(Male/Female)(Group)(Sr. No. in Participant list)(Morning/Afternoon)

A code 1FB16M meant that the student was from School 1, was a female (F), belonged to Group B and her serial number in the list of participants was 16 in the Morning session.

Students had to write this number on all the sheets used by them. The students were asked to use given sheets of paper for all their paper work and preserve these in their Group's folder. Tasks were assigned either to individuals or to groups. Students were clearly told each time whether the given task was to be done individually or by the group as a whole. Even in group tasks, individuals could do their rough work and make a fair copy for the group. This enabled us to trace the contributions of individuals to group tasks.

C. Analysis and discussion

The analysis is reported here on two main themes: Environment and Energy. Under the Environment theme, students' ideas about the environment, ecological concepts like food (energy) dependence of organisms and the material world and specifically humans in relation to the environment were studied. Under the Energy theme, students' responses were qualitatively studied in the several activities, which gave students a variety of opportunities to express their ideas on the topic.

C.1 Environment

The following activities were carried out as part of the discussions on the environment with an aim to understand students' ideas about some aspects of the environment related to food and energy flow and to give students occasions to express themselves on the theme. The strategies used were:

1. Activity Sheet on Environment,
2. Context map on Humans and Environment,
3. Photosynthesis:
   (a) Activity Sheet,
   (b) Whole class discussion on photosynthesis, and
   (c) Activity on Photosynthesis.

C.1.1 Activity sheet on Environment

The Activity sheet (given in Appendix H) had 9 questions: 5 multiple choice or True/False options; and 4 open ended questions, where students were encouraged to write their ideas. Responses to three of the questions were related to students' ideas about animals and the ecological concept of food chain and web. These are discussed below.

What is an animal?

In one question, students were given names of a few animals and a plant and asked to circle all options that they thought were not animals. The question is given in Box-1. This question sought to probe students' conception of animals. It is to be noted that these students from Class V have been studying about animals and plants and their distinctions for at least three years. The number of students, who thought an item or a combination of items was not an animal, is given in Table 2.

Box-1: Environment Activity Sheet, Question 2

Q. Which of the following living beings are not animals? (Circle your choices)
a) Tiger b) Fox c) Palm tree d) Spider e) Whale f) Bat g) Human h) Fish

The list of items consisted of 7 animals and one tree, which was the only non animal. It is heartening to note that all students (sum of S. No. 1 to 6 in the table) thought that the Palm tree was not an animal. Surprisingly 28 of the 37 students (almost three fourths) thought one or more items other than the Palm tree were not animals. Most students (38%) chose only one item other than the Palm tree to be not an animal. Only one student chose 5 other items as not animals.

Table 2: Students' responses to the question, "Which is not an animal?" in Environment Activity Sheet.

S. No.	Item	Frequency of students' choice as not animal (%), N = 37
1	Only Palm tree	9 (24)
2	Palm tree + 1 other	14 (38)
3	Palm tree + 2 other	5 (14)
4	Palm tree + 3 other	5 (14)
5	Palm tree + 4 other	3 (8)
6	Palm tree + 5 other	1 (3)
7	Bat	18 (48)
8	Fish	12 (32)
9	Whale	11 (29)
10	Spider	9 (24)
11	Human	6 (16)
12	Tiger	0 (0)
13	Fox	0 (0)

Another interesting aspect of students' responses is that all thought that Tiger and Fox were animals. The words animal, brute, beast are all synonymously used for ferocious animals, and are hence typically considered animals. This is reflected in the students' choices.

On the other hand, almost half the students considered Bat as not an animal. This may have two possible causes. Students may have difficulty classifying it as an animal or bird and hence classified it as not an animal. Alternately, it is possible that students may have associated the word with its other commonly understood meaning, namely, the cricket bat. This cannot be ruled out as students were not interviewed on this aspect.

Fish, Whale, and Spider were considered by lesser number of students – from a third to a fourth of all students. It is noteworthy that 6 students did not consider humans as animals. This is understandable if we recollect that animal is a derogatory term used to scold humans. Students are told not to behave like animals. This appears to be interpreted by some as humans not being animals. Besides, textbooks, especially in primary and upper primary classes, mention 'human and animal', rather than 'humans and other animals' or 'animals including humans'.

Textbooks also mostly refer to terrestrial wild animals by individual species like lion, tiger, fox, etc. while they refer to whole class of birds, insects, fish or a common name for a large number of species, like snakes. Paraskevopoulos, Padeliadu, & Zafiropoulos (1998), in a study on fifth and sixth grade students of Greece, found that most mentioned animals were pets or domesticated animals. They mentioned no birds other than chicken and pigeon. Fish, reptiles, insects, amphibians, molluscs, and worms were totally ignored. In another study by Chunawala, Apte, Natarajan, & Ramadas (1996), where students were asked to name an animal they most liked and one they most disliked, they mostly mentioned mammals, followed by birds, while there were fewer references to reptiles and they rarely mentioned fish.

Ecology concept: Food chain

Students' understanding on food chains was explored through a few questions, two of which are analysed below. Textbooks of Class VI onwards have references to food chains and explanations about them. Grass, insect, frog and snake have been connected in a food chain was shown in textbook of Class VII. One question relating these organisms was posed as given in Box-2. The students were expected to recognise that one of the items would not appear in any food dependency chains that they could think of. In fact students were taught that in general microbes form a part of all food chains, and help complete the cycles of matter through the environment. They were introduced as decomposers and role of microbes in decaying the dead plants and animals to humus, which are nutrients for plants.

Box-2: Environment Activity Sheet, Question 7

Which of the following are not there in any food chain? Circle your choices. a) Grass b) Snake c) Moon light d) Grasshoppers e) Microbes

The frequency of students' responses is given in Table 3. Moon light was not a part of the food chain in any student's response. This agrees with the fact that moon has not been referred to in any of biology chapters of school textbooks.

Table 3: Students' responses to the question, "Which is not in any food chain?" in Environment Activity Sheet.

S. No.	Item	No. of students responding as "not in a food chain" (%) N = 37
1	Moon light	37 (100)
2	Microbes	5 (14)
3	Grasshoppers	2 (5)
4	Grass	0 (0)
5	Snake	0 (0)

Interestingly, grass and snake have been considered as part of a food chain by all students. Only 2 of the 37 students thought that grasshopper was not part of the food chain. It is also heartening to note that microbes were thought to be part of the food chain by 32 students.

In textbooks and everyday understandings food chain, the transition of food from inorganic to organic is always emphasised introducing the importance of green plants, while the transition of food from organic to inorganic substances, in which microbes play a major role, is rarely mentioned. Even when microbes are said to help in the decay of organic matter, and in converting the organic matter into food for plants, this process is not treated as being a part of the food cycle.

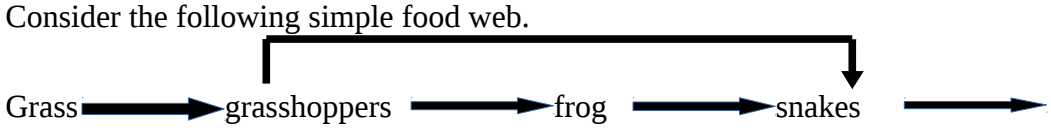
Interestingly, the 2 students, who thought grasshopper was not a part of the food chain, chose microbes to be part of the food chain. One of the reasons for students not choosing grasshoppers in the food chain may arise from the textbook connections of grasshoppers as prey to frogs and not snakes. Hence, they may not have included it in a particular food chain, which they perceived among the organisms given in the question. This ambiguity may be partially resolved from students' responses to Question 8 discussed below.

In another question on the same concept, a part of a simple food web was given as shown in Box-3. To form the web, first a linear food chain is constructed and the grasshoppers in it have been connected by an arrow to snakes, which are farther away in the chain. Textbook of Class VII states that “if any one food chain is disturbed, it affects other food chains,” (p. 211) and that “if we remove one component, say trees, all other components will be affected” (*ibid.*). Food relationships have been always represented in Class VII and earlier textbooks as unique predator–prey linear relationships. Despite such statements, the representation of food relationships always in terms of chains constrains the visualization of the interdependences in food relationships, and their role in the flow of matter and energy through organisms.

In the question, students were told of a change in the population of one organism in the web and asked to choose one or more from among 4 effects: either one or more of the other three organisms in the chain or neither.

Box-3: Environment Activity Sheet, Question 8

Consider the following simple food web.



If there is a change in the frog population, which of the following will be true? Circle your choice or choices.

a) amount of grass will change, b) grasshoppers population will change,
c) snake population will change, and d) none of the above populations will change.

The frequency of different combinations of responses from students has been shown in Table 3. Only one student among 37 did not attempted this question. Only a fifth (19 %) of the students recognised that the entire food chain was mutually dependent and hence chose all the other three components. It is seen that most students do not perceive that variation in the population of one organism of a food chain, affects other organisms as well and to some extent, the food web. None of the students chose only grass and snake populations as changing. It appears that students perceive change as proceeding from the immediate relations to farther ones. So, if grass population changes so does the grasshopper populations, though the argument is not the other way around.

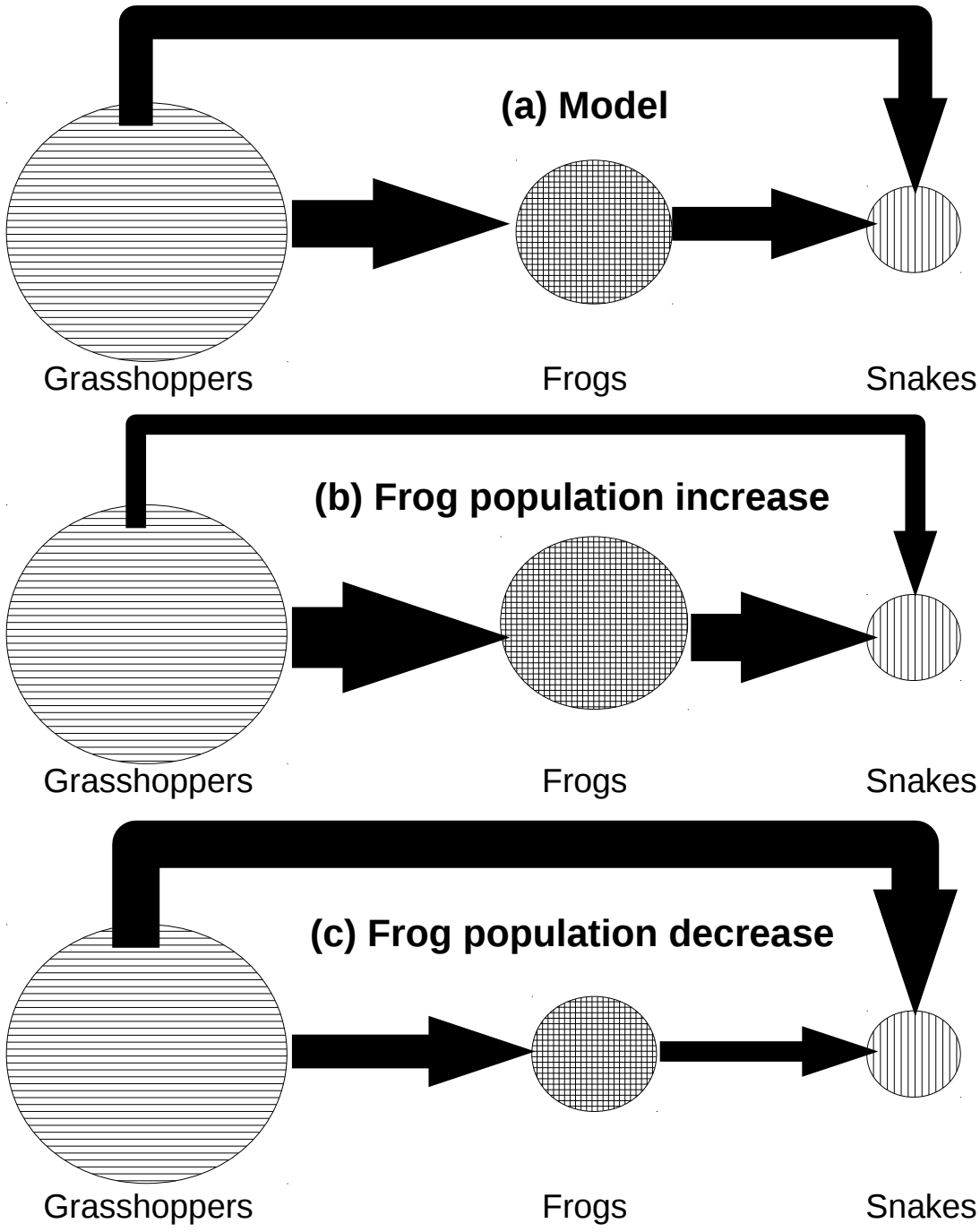
Table 4: Students' responses to the question 8, in Environment Activity Sheet

S. No.	Students' choice/ choices	No. of students (%) N= 36
1	Only “Grasshoppers...”	8(22)
2	Only “Snake...”	4(11)
3	Only “Grass...”	1(3)
4	Only “Grasshoppers...” and “Snake...”	7(19)
5	Only “Grass...” and “Grasshoppers...”	4(11)
6	Only “Grass...” and “Snake...”	0 (0)
7	All 3: grasshoppers, snakes, grass	7(19)
8	Only “None..."	5(14)

Over a fifth (8 students, 22%) thought that only the prey population, namely grasshoppers, will change, but just half the number (4 students, 11%) thought that only the population of the predator, namely snake, will change. This may indicate that some students consider change in populations of only prey (grasshoppers), while others focus only on the predator (snake) population. Besides, this focus appears to be asymmetrical, with more students focusing only on change in prey populations. In fact, a third of the students seem to have focused on the prey population if we also consider those who chose both grasshoppers and grass populations to change.

Responses of a fifth of the students (7, 19%) showed symmetrical and nearest neighbour (or direct relationship) ideas about predator-prey relationships. That is, they thought that only grasshoppers and snake populations change. Such recourse to focusing on immediately neighbouring organisms to the one changing, or a first order change, is seen in other responses as well. We propose that students think of frog population change in terms of a decrease in its population. These may lead to arguments that show either an increase or decrease in the population of grasshoppers. One argument may be that as the frog population decreases grasshoppers have only one predator, that is the snakes. Hence grasshoppers population may increase. Another suggestion is that students argue that snakes eat more grasshoppers in when the frog population decreases. Hence the grasshoppers population will decrease.

Figure 3: Diagram of a possible "no change" model showing (a) initial flow of food in the food web, (b) effect of an increase in frog population and (c) effect of a decrease in frog population



However, these arguments are invalid to explain the consequences of increase in frog populations. We do not know if students even considered such an option. It is also unclear why one student thought that only the amount of grass will change.

It is interesting that 5 students (14%) though that the other components of the chain will be unaffected by the change in frog population. It is possible that they do not perceive the food chain as a dependence of populations of organisms.

Textbooks mention “components” and “effects on components” in food chains and do not discuss what are the effects on populations of components. While most students have made the connection between effects on components and change in population of those organisms, perhaps, a few did not.

This “no change” response may also arise if the students adopted another model of food chain. If the frog population decreases, the flow of food in the web continues, with the snakes eating an additional share of grasshoppers that frogs ate to make up for the missing frogs. Hence, there will be no change in the populations. The flow of food in the web continues unchanged even if the frog population increases, with the snakes eating fewer grasshoppers, which the frogs can then eat. The snakes can eat additional share of frogs to make up for the grasshopper. This is shown diagrammatically in Figure 4.

Global climate change

Textbooks of Classes VI to VIII make references to global warming, greenhouse effect, and ozone hole. These issues are also discussed in several print and audiovisual media, which may not be accessible to students. One of the questions in the Activity Sheet asked students whether they had heard of each of the terms global warming and greenhouse effect. Students' response in the affirmative indicated that all students had heard of both the terms. Another question asked students to write, “How is global warming related to greenhouse effect?” Close to one third of the students were able to correctly relate global warming to greenhouse effect. However, only a few were able to define greenhouse effect and global warming and explain their meanings correctly. Two typical correct responses to this question are given in Box-4 along with four examples of wrong responses.

Even those students, who correctly stated that global warming was a consequence of greenhouse effect, made errors while elaborating their conceptions of the two phenomena. For example, some wrote that greenhouse effect is a phenomenon recently occurring on earth due to the anthropogenic pollution. They did not perceive that greenhouse effect has been essential to maintain a warm liveable earth. Interestingly, some student even wrote about a few consequences of global warming. Some wrote that greenhouse gases absorbed the light and heat coming directly from sun. Their responses did not indicate that they knew about the earth heating by its atmosphere trapping infra-red radiations from earth.

Students who gave incorrect responses possibly had different alternative models regarding global warming and greenhouse effect. Some students think gases like CO_2 deplete the ozone layer, which is called greenhouse effect. Through the region depleted in ozone, more ultraviolet rays (from sun) enter the atmosphere causing global warming. Some students' ideas of global warming and greenhouse effect needs further probing. Their responses consist of inconsistent and erroneous statements as in item 5 in Box-4.

Several students wrote the literal meaning of “global”, “warming”, and “greenhouse effect”

and even to some extent the factors responsible for the phenomena, though they made errors while trying to give the causes of either global warming or greenhouse effect.

Several of the confusions in causal connection between greenhouse effect and global warming arise from students' association of greenhouse with plants. One student wrote “Global warming is caused due to the excess pollution caused by humans. This increases carbon dioxide which causes greenhouse effect.” The response seems to suggest a confusion between cause and effect. It is unclear whether “This” in the second statement refers to pollution or global warming and needs to be probed further. Thus the human connection in environmental phenomena is a complex area that students struggle to understand.

Box-4: Examples of correct and incorrect responses in relating global warming to greenhouse effect.

Correct ideas about greenhouse effect and global warming	
1	The increase in the greenhouse gases, specially carbon dioxide traps the heat rays reflected by Earth and thus the temperature rises in the atmosphere. This is how greenhouse effect is related to global warming.
2	The greenhouse effect is the effect which is caused by some gases that have capacity to absorb heat increasing the temperature on earth is called global warming. So the greenhouse effect and global warming are related because due to greenhouse effect global warming is caused.
Errors in understanding greenhouse effect and global warming	
3	Global warming is related to greenhouse effect by the gas which is used in the green house effect. The gas (carbon dioxide) is also a part of the global warming.
4	Greenhouse effect is formed by gases like CO_2. These gases deplete the ozone layer allowing ultraviolet rays of the sun to enter the earth. Because of these rays, there is a rise in temperature which is nothing, but global warming.
5	Global warming is the air we pass out that is carbon dioxide. Carbon dioxide is taken by plant and trees. Plants and trees converted carbon dioxide into oxygen. In greenhouse effect the plants are kept.
6	The global warming is related to greenhouse effect because greenhouse is a place where plants are kept in safe and that's why...

C.1.2 Context map on “Humans and Environment”

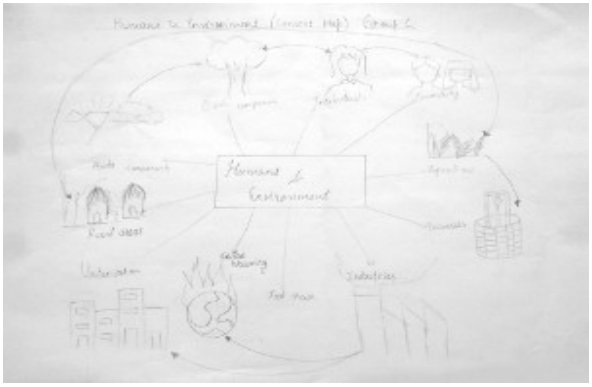
More than an hour was devoted to probing students' understanding of the relation between humans and environment. Discussions in the whole class showed that most students were aware of the constituents of the environment and the interdependence between these constituents and humans. In fact some students explicitly mentioned that we humans were “part of the environment.”

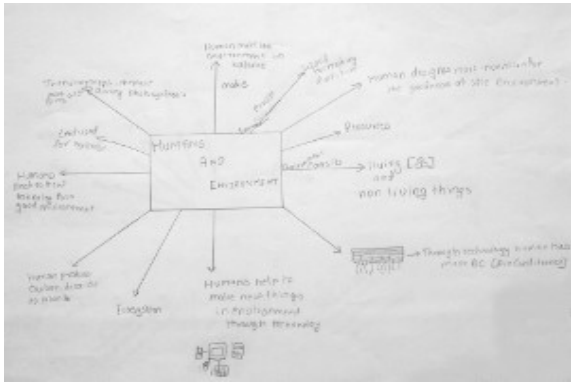
Discussion issues included early large scale modification of the environment in the form of agriculture, domestication of animals, and use energy sources alternative to human muscle power. The discussion also touched upon the issues of recent environmental problems, sustainability of human lifestyles, and human intervention in natural cycles. An interesting misconception that students held was that all plants breathe in CO_2, and that too only at night. Another idea that posed a problem was in thinking of plants as 'producers'. Some thought plants were producers because they give us humans many things what we can use.

These and other ideas were represented by students in a context map. Typical context map showing the complex interconnections and one that has fewer interconnections are shown in Figure 4 (a) and Figure 4 (b) respectively.

Each of the 11 groups made one context map. All the context maps had terms like biotic and abiotic, pollution, industry, globalisation, deforestation, etc. While most context maps had both pictorial presentations and verbal descriptions, some had more of one and less of the other. It is encouraging that more than half of the context maps referred to negative human interventions in the environment and a few of their consequences: e.g. pollution and global warming, globalisation, mining, deforestation, etc. However, these terms, which were all connected to the central term (Humans and Environment), were not interlinked among them.

Figure 4: Context maps on “Humans and Environment” showing (a) complex interconnections between components and several pictures (image at the left), and (b) no interconnections and fewer pictures.





There could be at least two possible reasons for this: students were not familiar with the drawing of context maps, and they had a limited understanding of the highly multidimensional and complex issues involved in the theme. The students did not link even

those terms that they had verbally described together. There is a need to probe this further.

C.1.3 Photosynthesis

There have been several studies on students ideas about photosynthesis. As part of the course, three strategies were used to probe students' ideas: an activity sheet on the topic followed by a whole class discussion as well as a set of three activities to study the effect of sunlight and carbon dioxide on photosynthesis and to see evidence of oxygen as a by-product of photosynthesis in aquatic plants (Appendix D).

C.1.4 Activity sheet on Photosynthesis

The students responded in about 30 minutes to an Activity Sheet on photosynthesis comprising of 6 questions (given in Appendix I): 1 true/false followed by justification, 2 multiple choice type and 3 open ended questions. The questions addressed (a) the material and energy requirement for the process, (b) factors affecting survival of plants, and (c) aspects of photosynthesis like its locale on plants, and time of occurrence relative to respiration. Analysis of three of the questions is reported here.

Material and energy requirements for photosynthesis

A question probed students' understanding of whether water, soil, sunlight and carbon dioxide are needed for photosynthesis. The question listed these items and asked students to choose one or more items that were “unimportant”. Though students are familiar with sunlight, oxygen, water and carbon dioxide being associated with photosynthesis even from Class IV and V, students in Class VIII are still unsure of the components of the environment that take part in the process. Students' responses are listed in Table 5 in terms of the item or combination of items that students chose and the frequency of students, who chose it.

Table 5: Students' response on Photosynthesis Activity Sheet, Question 4

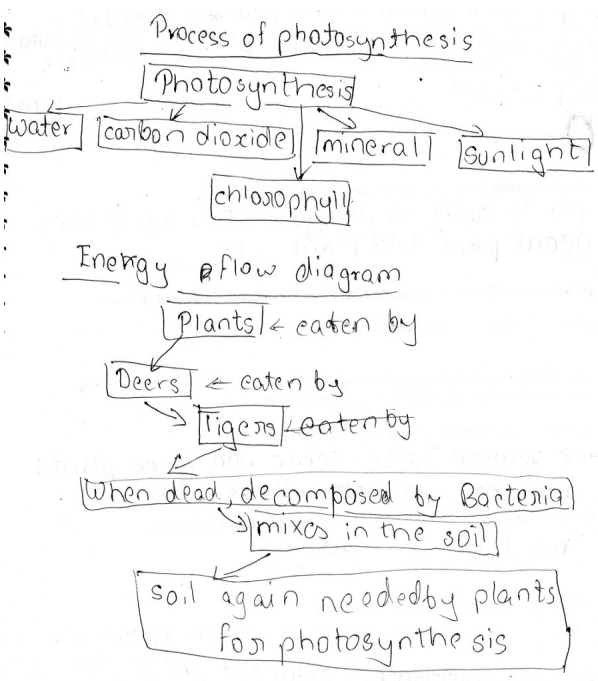
S. No.	Item or combination of Items selected as unimportant	No. of students (%) N=37
1	Only Soil	25 (68%)
2	Only Carbon dioxide	2 (5%)
3	Water, Sunlight, Carbon dioxide	3 (8%)
4	Soil, Sunlight, Carbon dioxide	1 (3%)
5	None are unimportant	5 (14%)
6	All are unimportant	1 (3%)

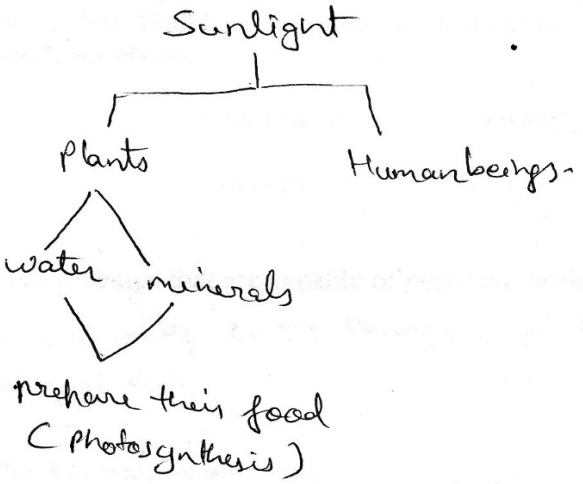
Two third of the students (68%) responded correctly that only soil is unimportant for photosynthesis. Of the remaining one third, almost half chose none of the items, implying that none of the given items were unimportant.

Ten of the students (S. No. 2 + 3 + 5), who did not choose Soil, perhaps considered soil as important for photosynthesis. Five of these students are unambiguous about its importance. However, combinations of items in S. No. 2, 3, and 6 suggest that students may have misinterpreted the question. They probably read the word “unimportant” as “important”.

A strong evidence for this possibility came from one student, who circled all the options (S. No. 6). This implies that this student considers that all are unimportant. This is contradictory to this student's response to another question asking for a neat diagram to show the role of photosynthesis in the energy flow in the environment shown in Figure 5. The student has clearly indicated the role of water, sunlight and carbon dioxide. Other students whose response included water, sunlight, and carbon dioxide as unimportant may have been similarly misled. Of the two students, who wrote carbon dioxide as unimportant, one omitted carbon dioxide from the diagram in the question discussed above (Figure 6).

Figure 5 (on left): A student's diagram on photosynthesis showing important aspects, including soil (ref. response pattern S. No. 6 in Table 8). Figure 6: A student's diagram on photosynthesis showing few aspects.





In most textbooks, in describing photosynthesis soil is referred in the context of minerals and water. How mineral plays a role in photosynthesis is ignored in the textbooks. Therefore the students those who had considered soil is important for photosynthesis might have thought of soil as source of minerals and water.

Another question listed 5 statements and asked students to mark each of them as True or False and write one sentence in support of their response. The statements were aimed at understanding students ideas on photosynthesis and plant respiration. Students had been taught photosynthesis from Classes IV to VIII. Textbooks do not refer to plant respiration apart from respiration of living beings.

The frequency of True response to each statement is presented in Table 6. This is analysed here. Students' explanations are qualitatively referred to infer about their level of understanding. For instance, in several cases students marked the statement correctly but their explanation was incorrect.

Table 6: Students' response on Photosynthesis Activity Sheet, Question 5

S. No.	Statements	No. of students marking "True" (%) N = 37
1	Photosynthesis takes place only in green plants	15 (41)
2	During photosynthesis plants take in carbon dioxide and give out oxygen	37 (100)
3	Photosynthesis only takes place in leaves	15 (41)
4	All plants are capable of photosynthesis	18 (49)
5	Photosynthesis takes place only during the day and respiration only at night	29 (78)

It is heartening to note that all the 37 students correctly responded to the second statement "During photosynthesis plants take in carbon dioxide and give out oxygen". But their explanations were varied. One of the students wrote, "The(y) plants need(s) carbon dioxide and photosynthesis helps to release energy only with oxygen." It appears from the response that there is an idea of releasing energy in photosynthesis.

Some students hold that during photosynthesis carbon dioxide is converted to oxygen. This seems like a direct input-transformation-output model of the phenomenon. Carbon dioxide, which is taken in by plants as input is transformed to oxygen, which is given out. Some students even correctly wrote the chemical reaction of photosynthesis.

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + O_2$$

One of the most prevalent misconceptions is that respirations in plants happens only in the night, when photosynthesis cannot happen. One of the statements (No. 5) was posed to explore this aspect. Close to four fifth (78 %) of the students considered the statement of exclusive times for photosynthesis and respiration as True. They possibly had one of the following models:

1. Respiration takes place at night in place of photosynthesis. Some explained that it was not possible to have both processes at the same time. This was also explained in terms of the "climate" being suitable for photosynthesis during day and for respiration at night.

2. Plants use CO_2 both for photosynthesis and respiration. Since the plants have worked hard during the day using the CO_2 around them, and at night they cannot do so, the CO_2 concentration increases at night, which they use up in respiring.
3. Some may have been misled by the first part of the statement, which is True.

Some of the students who thought that both processes can happen simultaneously wrote that plants gave out oxygen during respiration.

Close to half the number of students thought that all plants are capable of photosynthesis. Several students thought that insectivorous plants, saprophytic plants, and parasitic plants were not capable of photosynthesis. Some students thought that there were plants that did not have chlorophyll, and hence were not capable of photosynthesis. This relates to the responses to the first statement about photosynthesis taking place only in green plants, which about 40% of the students say is True. Most students think (a) that photosynthesis happens only in leaves, and (b) that only green leaves are capable of it.

It is interesting that there is very low correlation (Coeff = – 0.14) between students' responses to the two statements, one about green plants and the other about all plants. In a consistent model with adequate experience of different colours in plants, a high negative correlation may be expected. Students, who thought of all plants being capable of photosynthesis also thought of all plants having green colour either in leaves or other parts. Thus green colour does seem to be strongly associated with photosynthesis.

This is consistent with a mixed response for the statement (No. 3) about the location on the plant that photosynthesis occurs, where 41% agree that it happens only in leaves. They explain that the leaves are the “kitchen” or “factory” of the plants, and chlorophyll, as seen in the explanations of the statements discussed earlier, is present only in leaves.

Students, who disagreed with the statement either gave the correct explanation or gave a function/causal/tautological relation as “food is required by whole (parts) of the plant”.

Factors affecting survival of plants

One of the questions was complementary to the earlier question on constituents of photosynthesis (What is unimportant...?). Seven constituents were given as items and students were asked to choose those items that they felt were as essential to plants' survival as oxygen is for human survival. The question is given in Box-5.

The question aimed to probe students' ideas of plant's survival needs and students' ability to perceive an underlying unity in plants and animal physiological processes. Table 7 lists the frequency of students who chose each of the items. Note that students could choose as many items as they wished as essential for plants' survival.

Box-5: Photosynthesis Activity Sheet, Question 2

We, humans cannot stay alive for more than 5 to 6 minutes without oxygen. Oxygen is essential for our life. Which of the following will cause similar survival problems for plants? Circle your choice(s). (a) oxygen (b) hydrogen (c) water (d) carbon dioxide (e) sunlight (f) minerals (g) soil

Existing literature frequently mentions students misconception on plant respiration and alternative conceptions regarding plant nutrition. Plants need to respire as do animals, and transform the complex compound (food) to simple compounds and release the chemical energy. This energy in turn is used in all physiological processes. Plants maintains a balance of various components in the plants' body and cells through the cycling of water from surroundings (soil, aquifers, air) through its cells back to the surroundings. Hence water is another essential component for the survival of plants as satisfying the need for transportation of all nutrients. Absence of photosynthesis will not create severe survival problem.

Table 7: Students' response on Photosynthesis Activity Sheet, Question 2

S. No.	Item	No. (%) of students N= 37
1	Oxygen	13 (35)
2	Hydrogen	6 (16)
3	Water	28 (76)
4	Carbon dioxide	28 (76)
5	Sunlight	22 (59)
6	Minerals	15 (41)
7	Soil	23 (62)

The largest proportion of students (28, 76% each) felt that water and carbon dioxide was essential for the survival of plants. It may have been due to the great importance given in the textbooks to photosynthesis. The large frequency responses for Sunlight and Soil as survival needs confirm this. This also follows from the discussion on an earlier question, where a large proportion of students thought soil was important for photosynthesis.

C.2 Energy

Energy, which was another main theme of the course, was discussed in several sessions and through a variety of strategies:

1. Activity Sheet on energy,

2. Essay on “A world without energy”,
3. Whole class discussion on energy,
4. Poster on “Human civilization; 500 years from now”, and
5. Role play on energy options for a small village.

The observations within each, and analysis of students' ideas are reported below. The whole class discussion was initiated both before making a poster and before role play. These were aimed at preparing students for making the poster and for the role play respectively.

C.2.1 Activity sheet on Energy

The students were given an Activity Sheet on Energy having 15 questions, which they had to complete in 30 minutes (Appendix J). The Activity sheet had 1 multiple choice question, 1 true/false and the rest were open ended questions, where students were encouraged to write their ideas. The quantitative analysis of students' responses to the two objective questions (multiple choice and true/false) and a qualitative analysis of the general nature of students' responses to the open ended questions will be reported here.

Ideas about reflection

The multiple choice question shown in Box-6 explored students' ideas about reflection of light from different kinds of surfaces in the context of environment and energy. Reflection is dealt with in Class VII science textbooks. All surfaces reflect sunlight to a greater or lesser extent. The question aimed to see which surfaces students perceive as reflecting sunlight. Everyday experiences tell us that several surfaces scatter light, that is, there is little or no regular reflection. Students could choose as many options as they thought could reflect sunlight. The frequency of students' responses to several combinations of items in the multiple choice question are given in Table 8. 38 students responded to the question.

Box-6: Energy Activity Sheet, Question 6

Which of the following can reflect sunlight? (Circle your choices)
(a) Mirror (b) Water surface (c) Black stone (d) Leaf (e) All of these

Only 5 of the 38 students felt that all the given surfaces reflected sunlight. We can only see objects because they reflect some light. But this is not perceived by most as reflection of light. How an object is visible is not explained in textbooks, which miss the opportunity to establish the idea of object visibility while discussing reflection.

Reflection is associated with formation of an image. From daily life experiences, and reinforced by textbooks, objects that can reflect light on to a screen, are considered reflectors. NCERT science textbook of Class VII uses examples of mirror and water surface

as 'reflector'. Mirror, of course, is a familiar example of 'reflector' in many textbooks. Some understanding associated with a reflector is that one can see the image or which can form image is a reflector. Mirror and Water surface both has this property. This may explain why the largest numbers of students selected mirror (97%) and water surface (66%) as reflecting sunlight. Two students, besides the 5 who chose all, even chose black stone.

Besides those who chose all surfaces, three students thought leaf reflected sunlight. Perhaps they thought of shiny leaves. This idea must be related in some way to their idea of photosynthesis and needs to be probed further.

Table 8: Students' responses to the Question 6, Energy Activity Sheet

S. No.	Item	No. of students, (%) N=38
1	Mirror	37 (97)
2	Water surface	25 (66)
3	Black stone	7 (18)
4	Leaf	8 (21)
5	All	5 (13)

Energy issues

One question, with 6 sets of statements about energy, was aimed at exploring students' ideas about energy sources in relation to the environment and human society: “Which of the following statements are correct? Circle your choice or choices of correct statements.” These issues are not discussed in textbooks up to Class VIII. Nor were these issues discussed with the participants before administering the Activity Sheet. We also did not probe the source of students' knowledge about these issues.

However, the terms and concepts used in the statements are used in the textbooks as well. The aim of this question was less to explore misconceptions and more to help bring these issues into the classroom discussions.

One major problem with the way the statements are framed makes students' responses to this question ambiguous. Most statements include more than one aspect. Besides some items have multiple statements. Hence, it is unclear to which aspect the students are responding. The items and the frequency of students' positive response to each are given in Table 9.

Most of the students (84%) have marked as correct the combination of statements in item 3 about shortage of energy and the connection between reduced energy demand and lifestyles. Such ideas are often publicised in the audiovisual media. Some textbooks refer to the “energy crisis” and discuss judicious use of energy. It would be interesting to probe which part of the statements in this item 16% of the students did not find correct.

Table 9: No. and % of students responding as "correct" to the items in Question 15, Energy Activity Sheet

Item No.	Statement	Choice as correct	
		No. (N=38)	%
1	Society, which uses more energy, is more developed.	13	34
2	Finding more energy sources and building new energy plants is the only way to meet the increasing energy demand.	21	55
3	Today in most of the countries we are experiencing shortage of energy. We can reduce energy demand by changing our individual life styles.	32	84
4	Nuclear energy is a clean energy. It is pollution-free during electricity production.	15	40
5	Nuclear energy produces no safety or waste problem before, during or after production.	14	37
6	Biogas uses methane gas from bio-wastes and releases carbon dioxide and water vapour. All three are greenhouse gases. Therefore we should stop using biogas.	12	32

Though a large proportion of students agreed that there was a need to reduce energy demand, more than half (55%) still felt that "Finding more energy sources and building new energy plants is the only way to meet the increasing energy demand." Agreeing with the statement that individual's lifestyle can reduce energy demand is consistent with agreeing that there is a concurrent need to meet increasing demand.

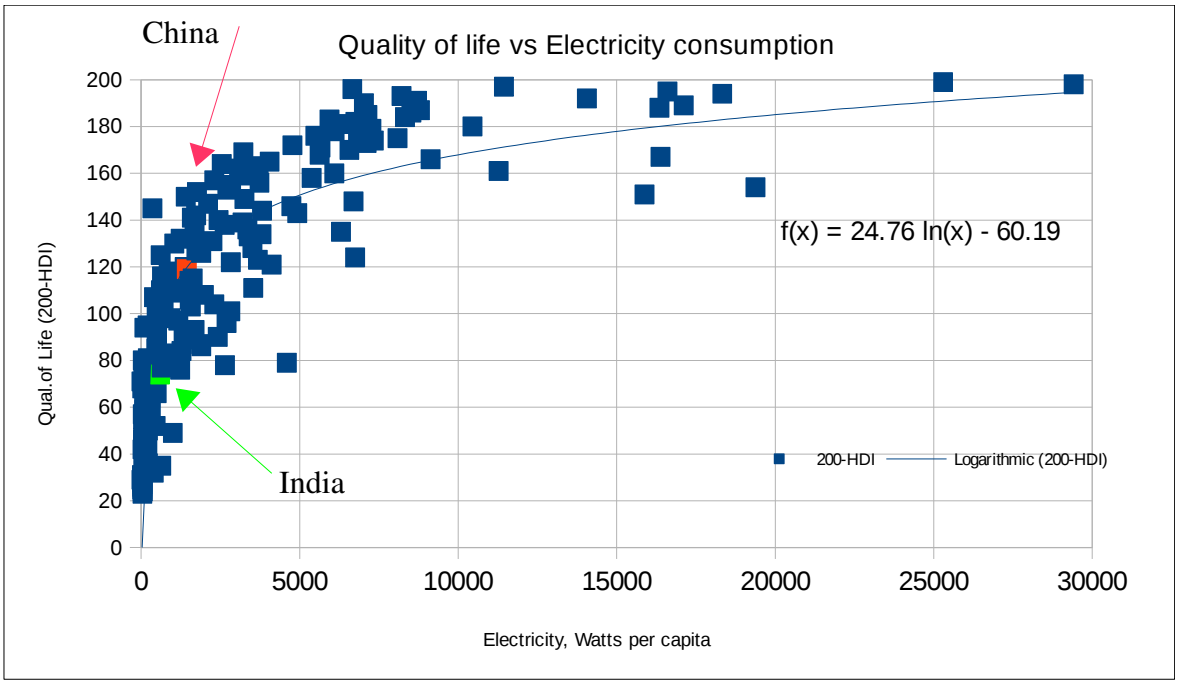
In the context of the pattern of responses to the above statements, it is interesting that only a third of the students (34%) agree that "Society, which uses more energy, is more developed." If this were correct, why do we need to meet increasing demands? It would be interesting to probe how students make these connections. Plotting a graph of a measure of quality of life (e.g. human development index = HDI) as a function of per capita energy consumption shows that at least for relatively low per capita energy consumption, as in India, quality of life is likely to improve with increasing consumption. This is shown in the plot in Figure 7.

The plot also indicates the inefficiency of energy use in India as compared to China confirming the discussion in the last paragraph.

The two items on nuclear energy had positive statements about it, while the one item on bio-energy had negative statements about bio-energy. Regarding both these issues, students gave mixed responses – about 12 to 15% agreeing with statements in an item. However, that more than half (61% and 63%) of the students disagreed with the positive statements about nuclear energy, while a similar proportion (68%) disagreed with the negative statement about bio-energy shows some overall consistency in students' responses. However, since there were multiple statements in each item and we are unsure about students' understanding

of these issues, we may not be able to conclude much. Besides, individual students disagreed with one item on nuclear energy and disagreed with another.

Figure 7: Quality of life as indicated by HDI increases steeply with increasing per capita energy consumption and saturates at high energy consumption.



C.2.2 Essay on "A world without energy"

The second strategy used to probe students' ideas was essay writing. Students have vivid and varied imaginations, for which there are few outlets in normal science classrooms. Students need to be given opportunities to articulate, defend and explain their ideas within the social context of the classroom (Solomon, 1987, Halliday and Martin 1993 as in Prain & Hand 1996). They need to refine understandings through open-ended questions, creative writing, explanations and classroom dialogue (Glasson & Lalik 1993 as in Prain & Hand 1996).

Asking students to write about fictional situations has several advantages. It helps students to overcome the fear of authority in traditional classrooms, and express their own thoughts and ideas. Several students are found to be non-participatory in traditional classroom interactions, due to a variety of reasons, including inability to reproduce verbatim from textbooks or notes, and fear of peer reactions. This can be avoided through essay writing on imaginary situations. Students are better able to articulate their ideas in their own words in such situations and therefore reveal their conceptual understanding of issues discussed. These writings reveal the world-views and conceptual models that students use to explain natural and other phenomena and processes.

It has been discussed for long in literature that students hold both the classroom science and

their own conceptual models simultaneously. Some students can successfully accommodate classroom science for use only in classroom, while outside classroom they revert to their alternative explanatory models.

Essay writing about imaginary contexts may be used to diagnose students alternative conceptions. Students can be provided the time and context to resolve cognitive conflicts. In classroom discussions either students are not given sufficient time and opportunities to articulate their ideas or are addressed in an unsatisfactory manner. While writing, students can be given time to discover the inconsistencies in their arguments or models. Besides, once written, they can more easily track their thoughts and amend them.

In the essay writing session, students were asked to imagine a world without energy. Each had to write an essay and the group had to consolidate the ideas into one essay. The group dynamics as the students went about writing and selecting the essays for presentation as well as the format of presentations are given below.

Group dynamics in collaborative writing

Very interesting observations made in the students' collaborative work strategy. It was found that group members first made a consensus to approve or dis-approve the individual member's opinion expressed in their respective writing. Then some of the groups adopted a strategy to underline the important sentences of the individual's writings and then edited it in a fresh sheet of paper for presentation.

Some of the groups discovered that one of the writings of their respective group members was encompassing most of the issues mentioned by other members and therefore they compromised the situation by selecting the best one by either a few editing or kept afresh for presentation. Another interesting observation was made during writing the presentation as group task. One or two members of most of the groups took leading role in sharing ideas and in convincing other members about own thoughts. Most of the passive members took the task of writing as their friends dictated their ideas.

In some cases it was found that all the essays were reviewed by the group members and one essay as written was selected for presentation. In a few cases it was found that the authors of the essays did not make the presentations of their writing but the groups selected one of their members to present.

Presentation of the essay

One member from each group read out the essay, which was followed by questions and comments from other group members and researchers. Other members of the presenting group responded to some of the queries. Researchers moderated the proceedings.

Students' ideas about the imaginary world

The situation posed an unresolvable conflict especially for the students of the morning session. How can there be a world without energy that they were supposed to write about? Several groups found a compromise in the situation by considering world with increasing scarcity of energy or sudden disappearance of all energy sources. Many said that our survival or even coming into existence was not possible without energy. According to one group, “if there is no energy we cannot (ful)fill our stomach, we cannot breath(e), we will not survive.”

After one of the presentations, students were asked to find the potential energy of a vehicle parked at a underground parking place. The students were now confused because they had already stated earlier that potential energy is zero at ground level. One student responded that the accounting of potential energy starts from some lowest point. There were no responses to the question of where was the lowest point?

The afternoon batch of students focused on the issue of energy and peace. They also did not refer to the biological requirement of energy in their writings or presentation. However, on questioning specifically about it, they seemed to know.

C.2.3 Semi-structured whole class session on energy

The difficulty in defining energy is due to its nature. Energy cannot be seen and can be measured only during transfer. Energy is usually expressed in terms of the units of works it performs; thus, a common definition is that energy is the ability to do work. However, essential aspects of the energy concept are usually based on quantities, that is first and second law of thermodynamics (Liu & McKeough, 2005).

“The most common usage of the word energy in English is in the realm of literature. English dictionaries, from 1599 on, define this as “force or vigour of expression.” From the 1650s, it also has had the meaning of “exercise of power” (Trumper & Gorsky, 1993).

The whole class session addressed definition of energy, forms of energy, conversion of energy, an idea of first and second laws of thermodynamics. The researcher posed questions to the whole class, and several students responded with intermittent clarifications by the researcher. The specific questions followed students' responses and are given below.

1. What do you mean by energy?
2. Explain the terms power, force, work, pressure?
3. What are the various forms of energy?
4. Is it possible to convert one form of energy to another form?
5. When we lift a stone to a certain height from the ground, what forms of energy does

the stone have? There was a discussion on the amount of work done to lift the stone to a height being equal to the potential energy gained by the stone at that height.

6. When we release the stone from a height what will be the energy of the falling stone at different heights from the ground?
7. When the stone was at a certain height it had potential energy. What can you say about energy transformation, while the stone is falling?
8. When the stone touches the ground what will be the stone's energy? What will happen to the kinetic energy it had before touching the ground? (In response to students' answer that it will become sound energy.) Will entire kinetic energy transformed to sound energy?

Students' ideas about energy

Students' typical responses to the questions, “What do you mean by energy?” and “What do you mean by work?” are listed in Table 10. Students spontaneously used terms like 'power' and 'force' as synonyms of 'energy'. Moreover, students were not able to define the term power. A few students defined force as 'a push or pull'. As is already known in literature, students represented energy with some scientific vocabulary which has entirely different meaning in the realm of physics. In summary, according to students, force = power = energy. Though energy is a very abstract concept and difficult to define, it is not desirable to define energy in such a conceptually inconsistent manner. For some students 'power' is equivalent to 'ability to perform work'.

Table 10: Students' typical responses to 2 questions on energy

S. No.	Students' responses on	
	“What do you mean by energy?”	“What do you mean by work?
1	Energy is power	Work is equal to distance/mass
2	Energy gives us the ability to perform work	Work is equal to distance x force
3	A source to perform work	Work is equal to distance x power
4	Capability of doing something is energy	Work is any physical activity performed by a body, sitting idle is not work because it is not productive/useful.
5	Energy is the force applied on anything	
6	Energy is used when force is applied	
7	Sometimes without energy force could be there	
8	Energy plays a vital role to give power of a body to work	

The students were basically confused with all the terms used by themselves for energy in terms of choosing the appropriate one. When the students were asked about force they defined force as pressure applied on a object. To define force the researcher asked the students whether they knew Newton's first law of motion and asked to state it. Most of the morning session students stated the law of inertia correctly. Researcher then defined force in

terms of the first law of motion. The afternoon batch students could define force as push or pull. Some said, “when an object is in motion there is a force acting on the object”, or “force is required to move a(n) object”. However, these students did not recollect Newton's first law of motion. Students were asked to name various forms of energy and their responses were listed on board and is shown in Table 11.

Morning session students mentioned 15 types of energy, whereas in the afternoon session students referred to 23 types of energy. Twelve forms of energy were common to both the sessions; 3 forms, light, sound and electrical energy were mentioned only by the morning session students; afternoon session students mentioned 11 forms of energy different from those in the morning session.

Some of the forms of energy mentioned were actually sources of energy, like solar, gravitational or tidal, while some others were forms like light, sound, and electrostatic. Some of the terms mentioned are associated with forces: e.g. electrostatic, magnetic, gravitational, and even repulsive, and frictional.

The mix of energy words given by the students of afternoon session are interesting for further probing on students' ideas about forms of energy. They mentioned bio-energy, which they said would include energy from biogas or biomass as well as energy required for biological activity which comes from the living body itself. Do students' ideas of bio-energy link to the concept of “vitalism”? The link, if any, may need to be explored further.

Table 11: Forms of energy as mentioned by the students of morning and afternoon sessions

	Morning session	**Afternoon session**
Different in the two sessions	Sound, Light, Electrical	Static, Electrostatic, Magnetic, Physical, Repulsive, Gravitational, Frictional, Freeze, Ubiquitous, Bio-energy, Genetic energy
Common to both sessions	Solar, Geothermal, Tidal, Wind, Kinetic, Potential, Mechanical, Nuclear, Hydel, Chemical, Heat, Thermal	

Students, who mentioned “static energy” were referring to “the energy in a static body”. Some students adopted two forms of energy in the contexts of heat and cold, and they mentioned heat and freeze energy. Perhaps, students think in terms of the caloric, or of heat as material flow. Students said that so much genetic material (genes) is transferred and transported in the cell, it involves genetic energy.

C.2.4 Poster: Human civilization 500 years from now

Students were asked to imagine the energy scenario of human civilization 500 years from now. Each group had to make a poster depicting the scenario they visualised using the given

materials: pencils, sharpeners, paper cutters, scissors, coloured pencils, coloured papers, glue, scale, a chart paper and 2-3 blank A4 sheets of paper for rough work.

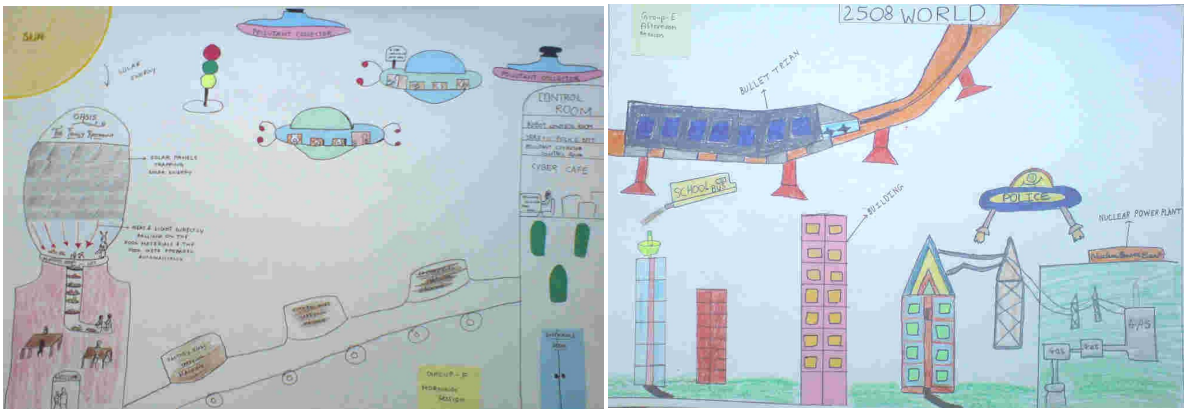
There were 11 posters made by 6 morning groups and 5 afternoon groups. One of the afternoon groups was absent on the day. The following aspects of the posters were noted and are described in this section.

1. General comments on the posters including what was most and least prominently depicted as well as environmental sustainability in energy use shown in the posters.
2. Number and nature of objects shown in the posters were categorised as: structures without explicit indication of energy needs; ideas about energy, which could be structures or objects indicating energy source, transmission or use and sources of energy; transport on air, land and water; natural objects; and human figures. This is followed by a discussion of students' ideas related to energy as seen from their posters and categories of energy sources.
3. Conceptual content and conformity with known physical laws: whether there was clarity in the concepts on energy depicted and to what extent the ideas shown conformed with known physical laws.

General comments: High rise buildings and air transportation

A reliance on non-conventional energy sources is reflected in all the posters. Most posters emphasised solar energy as the most promising alternative energy source of the future (see Figure 8a). A general trend in the posters showed high rise buildings and transportation as seen in the listings in Table 8. Most speculated that the space above ground would be the only mode of future transportation. While some posters as in Figure 8a depict only small vehicles (for nuclear family), others depicted only large vehicles as in Figure 8b (for public transport).

Figure 8: (a) Poster to left shows high rise structures, solar energy, small flying vehicles, robotic systems, and (b) Poster to right shows some greenery besides high rise structures, public transport, and nuclear power plant.



One poster showed reduced energy requirements of a vehicle by modifying its shape and using “anti-gravity coating”. One poster indicated a revolution in transportation by depicting a pair of jet shoes that help the wearers move over water. One of the posters showed 2

pollution collectors floating in the air (Figure 8a). It also showed a cyber cafe in where a person is reading mail from Mars on a computer. Six of the 11 posters showed human or cartoon figures. Only one poster was incomplete in terms of drawing and colouring.

How green were the posters?

The posters address the issue of 'energy crisis' (scarcity of fossil fuel) by showing multiple renewable energy sources. They emphasise energy production, and ignore issues of efficient distribution. Efficiency of use was shown in the context of vehicles. In fact, none of the posters referred to reduced energy demand in daily lives or use of biomass as an alternative energy source. Village context was not depicted in any of the posters. Greenery, which was depicted only in some posters, was mostly grass cover, not woodland or forest.

Number and nature of objects

Students depicted a variety of ideas and objects in their posters. The objects are broadly classified in six categories listed in Table 12 and given below. Students' ideas about energy and energy sources are discussed below in greater detail.

i. Structure: This refers to drawing of any structure without explicit indication of needing energy for its sustenance or use; for example, a residential or office building.
ii. Ideas related to energy.
iii. Structures/ objects indicating energy source/ transmission or use: The structure was drawn along with depictions that indicate energy transmission or use. Examples are message sending tower, air conditioner, computer, and other electronic instruments with electrical cords, antennae, etc.
iv. Production of power by power plants, energy converters, etc.
v. Transport: This category includes land, air or space and water transportation vehicles.
vi. Natural objects: Sun and Mars, water bodies, trees, etc. are categorised as natural objects.
vii. Human figure.

Table 12: Objects depicted by students in the posters

S. No.	Category	No. of drawings	Objects in category (No. of posters)
1	Structure	8	High rise buildings (6), Restaurant building, Over-bridge
2	Ideas related to energy: (a) Structures/ objects indicating energy source/ transmission or use	9 14	(a) Transmission tower (2), Industries emitting smoke (2), Floating traffic signal, Belt carrying energy source (fuel), Air conditioner, Computer, Pollutant collector, (b) Nuclear power plant (3), (Dish!) Antenna (3), Solar energy converters (4), Wind mill,

	(b) Producers of power		Hydel power generation tower, Multi-purpose energy producer, Speed breaker as turbine
3	Transport (a) Air (b) Water (c) Land	 13 1 3	(a) Satellite (3), Rocket, UFO, Advanced flying vehicle, Aeroplane with solar batteries, Aerodynamic anti-gravity vehicle with solar panel, Sky bus, School bus with jet, Flying police vehicle, Vehicle with propeller, Rocket on launching pad, (b) Ship, (c) Vehicle with solar panel, Bullet train, Vehicle alone
4	Natural objects	22	Sun (5), Mars (2), Earth (3), Greenery and trees (5), water body looks like ocean (3), Cloud (2), Part of a water body, Water body
5	Human figure	26	Human figure (3), Cartoon humans (1), Human figure with jet shoe (1)

Ideas related to energy

This section gives a summary of students' ideas about the future scenario of energy as depicted in their posters. Their ideas have been categorised in Table 13.

Table 13: Ideas about energy sources and vehicular use reflected in the posters

Ideas reflected in poster	No. of posters
Green energy sources: Renewable energy sources like solar, hydel, tidal, wind, reduction/avoidance of global warming	9
Innovative energy use/ saving in transport: Vehicle with coating of anti-gravity, changing shape of vehicle to reduce air resistance, Sky bus with jet on suspended metallic track, hot and burning jet used for propulsion over water, sky buses with jet, flying cars, future school in home	9
Nuclear energy (3), unknown fuels (2)	5
Vehicles with solar panel, solar batteries, etc.	5
Innovative energy sources: Water converted to energy, jet shoes for humans to move over water, turbine attached with speed breaker, “Multi-purpose energy producer”	4

Most of the posters (9) depicted renewable energy sources as future options, one poster had an ambiguous fuel, and one poster depicted nuclear energy and an ambiguous fuel. Two of the 9 which had renewable sources also included nuclear energy.

Most of the posters depicted some possibilities of efficient energy use, especially in transport: either by changing shapes of vehicles or showing additional red coloured jets. But the fuel used for the jet was not mentioned in any of the posters. One poster speculated that "future school will be in house," which is an noteworthy way of reducing energy demand for transport and structure. It may be interesting to ask, what then would we learn about the world around us – both natural and technological?

One poster constructed a "Multi-purpose energy producer" in which one windmill-like structure was shown to harness a variety of renewable energy sources besides the wind, viz. solar, hydroelectric, and tidal. One poster depicted a turbine in speed breaker to harness energy. One poster speculated that in the future energy would only come from water which would be converted to energy, different from the hydroelectricity, though the group that made the poster could not tell how the conversion would happen. They thought of something similar to electrolysis.

Categories of energy sources

Most of the posters showed centralised power generation. Only one poster showed a distribution of power generation around the globe. Students' understanding of technological aspects of energy production is worth probing. Students' preferences for depiction of specific energy sources in the posters is listed in Table 14. Most of the posters (8) showed solar energy as one of the future energy sources, as seen in Figure 8a. Five of these showed only solar energy. Hydroelectric power appeared in 3 posters, with one exclusively showing this source. Tidal and nuclear energy were found in 3 posters each. Possibilities of harnessing wind energy was shown in two posters. One had an innovative idea of harnessing energy from speed breaker with a turbine.

Table 14: Energy sources by category

Future energy source	No. of posters
Solar	8
Tidal	3
Nuclear	3
Hydel	3
Wind	2
Energy from speed breaker	1

Concepts not in conformity with physical laws

One group showed a red coloured jet emitted vertically downward by the shoes worn by a person elevated from the surface and striking the surface of water. How a vertical jet is supposed to help in the horizontal movement of the person was unclear.

According to a group, energy was directly obtained from water, though they could not explain how that could happen. When questioned during their poster exhibition, they suggested that water has some energy which can be transfered to places when required. One poster showed electricity from a turbine connected to a speed breaker. The same group also showed an antenna for receiving energy from the sun.

C.2.5 A power-plant for Shaktipur

This section discusses the literature on the use of role play in teaching-learning, with emphasis on debates in role play. This is followed by an outline of the context provided to the students for the role play and the inputs given, a list of activities carried out as part of role play. The section ends with interesting findings about students' decisions about energy and influence of researcher's intervention on students' decision making.

Role play

Classroom teaching-learning may not be sufficient to enhance the students' ability to understand and act in the world outside the classroom. On the other hand it may not be practical for students to participate in all social decision making. However, the purpose may be served to some extent by involving students in mock decision making exercises by simulating real social contexts in the classroom. In doing so, the social aspects of the situations as well as the content level required of students have to be taken into account (Simonneaux, 2002). The context could provide an opportunity for students to express themselves, sort out their biases, negotiate ideas, etc.

According to Bridges (1979, in Gayford, 1993) the purpose of discussion of controversial issues would be (a) sharing perspectives between members of the group, (b) reaching an understanding, (c) making a choice, and (d) finding a rational resolution for differing points of view. According to Simonneaux (2001, 2002), while using role play as a pedagogic tool, the teacher must first help students identify the criteria and information which support a point of view, theirs' as well as those held by others, so that they can treat the issue as problematic.

Role play and debate

The role play may be a debate or could involve a debate. During arguments, students are in situations of inter or intra subjective conflict (Simonneaux, 2001). According to Bender and Leone (1981 as in Proulx, 2004) “...to have a good grasp on your own view point you must understand the arguments of those with whom you disagree. It is said that those who do not completely understand their adversaries point of view do not fully understand their own” (p. 27). Hence, during and after the role play, teachers also need to help students identify their emotional stance as well as the arguments used by scientists, popularizers, teachers, other students and by themselves, together with their validity and the stages involved in reaching a decision (Simonneaux, 2002).

After the role play, teachers have the opportunity to discuss and deal with the misconceptions revealed by students. Students may encounter complex situations needing multidimensional thinking (Barker, 1986 as in Eisen & Stavy, 1993).

Role play involving a debate on energy issues

There are several pedagogic advantages of involving students in a role play that includes a debate on energy issues within a described social context. These are listed below.

(a) Students understand that making decisions can be complex when there are important social issues involving economic, ethical and other aspects.

(b) Students need to attribute advantages and disadvantages for different energy sources.

(c) Students need to both descriptive and normative discourse in a discussion, where the former is about describing facts and the latter about evaluating them.

(d) Students need to express their ideas and defend them, critique other's ideas and viewpoints.

Outline of context: A power-plant for Shaktipur

An industrialising town called Shaktipur faces a crisis in electrical energy availability. The Chief Minister of the State (Trihar) has called for a meeting to form a consensus on the kind of power plant for Shaktipur. The context is detailed in a sheet given to students (Appendix K). The students were given a set of roles as listed in Table 15 below to be played out and asked to choose one among them. Every students was assigned a role, and hence would be a participant in the CM's meeting. Students were told about the characterisation of each role. Students were also given reading materials on energy, renewable and non-renewable sources, and advantages and disadvantages of obtaining power from some of these energy sources. The reference sources for the reading material is listed in (Appendix M). The students were even requested to come suitably dressed for the role they were to play. Each students had to be seated on an alloted seat with their (role) designation indicated on it.

Table 15: List of roles played by students of morning and afternoon sessions (fewer students)

Session	Roles played
Morning	Chief Minister; Minister for Energy; Minister for Industries and Mines; Industrialist; Environmentalist; Research Scientists working on different energy sources, like Coal, Nuclear, Solar, and Hydroelectricity; and observers from national organisations like HBCSE, AECS, CEE; and international ones like WHO, SACEP, UNDP, UNICEF
Afternoon	Chief Minister; Minister for Energy; Minister for Industries and Mines; Industrialist; Environmentalist; Research Scientists working on Coal, and Nuclear energy; Observer from AECS; Observers from international bodies WHO, UNICEF, Journalist

List of activities carried out by students

1. Chief minister (CM) explained the power shortage problem to the participants of the meeting.
2. CM asked for the views of those present based on their expertise, in the order of Ministers, followed by Industrialist, Scientists, and Environmentalists.
3. Discussions and clarifications among the members of the meeting.
4. Participants, facilitated by an intervention by the researcher, summarised the advantages and disadvantages of power-plants from different energy sources.
5. The participants with similar views came together to present their consolidated views and arrive at a decision facilitated by the researcher.

General comments on students' performance

Most students presented their stance in accordance with the role assigned to them. Some were less aware of the role they were playing, especially as students were not exposed to organisations like SACEP, WHO, UNESCO, etc. and their activities. Some of the students were too shy to express themselves.

In the morning session, there was in general broader and deeper discussion of the energy options and animated discussion by a larger proportion of the 19 students present than there was among the 13 students in the afternoon session. The CM of the morning session was rather pliable, and supported any group that could put forward a strong argument. Some interesting views expressed by the participants of the meeting (from either morning or afternoon sessions) is given in Table 16.

Table 16: Some interesting remarks by students during role play

Role	**Opinion**
Environmentalist	India has less Uranium and thorium; we need to import from other countries.
Research scientist nuclear	Nuclear energy is cheap and does not pollute air. There are radiation hazards, but can be controlled through proper safety measure.
Environmentalist	Due to dam construction farming land will be submerged.
Minister of Industries and mines (Morning)	Mining of Uranium is less costly and less hazardous (than coal). Government can create awareness in favour of Uranium mining.
Minister of Industries and Mines (Afternoon)	Nuclear power plant, gives a large amount of electricity, no emission of greenhouse gasses.
Observer from CEE	We have to reduce energy demand through efficient energy use.

Findings from Role Play

The role play pointed to some interesting aspects about students' options for energy sources for the Shaktipur power plant, and the factors that influenced their choices.

Options of energy sources

The role play resulted in choices among 6 energy sources for power plant: solar, wind, biomass, nuclear, hydroelectric, and coal. Participants of the meeting in the morning session supported five sources of energy, mostly a combination of solar energy with another renewable source, for the power plant. There were only 3 proposals for a nuclear power plant, that too along with a biomass plant. On the other hand, the meeting in the afternoon session largely focused on nuclear energy. This is indicated in Table 17. Members of morning session prescribed for combination of five sources to be used while members of afternoon session prescribed only three energy sources.

Factors influencing students' energy options

Most of the morning session participants were observed to have read both the given materials as well as other relevant materials that they had found. These were from schools that showed better academic performance than the school of the afternoon students. Not only did the morning students gather information on one option they supported, the participants also gave arguments against the sources that they were not supporting. This may have led to the greater variety of energy options among them as well as a preference for renewable energy sources. The afternoon participants had read some of the given reading materials. However, their representation showed that they had not understood the points. This may have contributed to the smaller number of choices, perhaps essentially based on their local context, since the students come from a colony of people working in an atomic energy establishment.

Table 17: Combination of energy sources chosen by morning and afternoon sessions for the Shaktipur power plant

Choice of energy source for power plant	**No. of students**	
	Morning session N=19	**Afternoon session N=13**
Solar and wind	8	-
Solar and biomass	6	-
Nuclear and Biomass	3	-
Solar and hydroelectric	2	-
Nuclear energy	-	10
Coal	-	2
Hydroelectricity	-	1

In the morning session, some participants changed their opinion both during the role play as well as after the intervention by researchers. However, in afternoon session, all participants stuck to their opinion till the end of the role play. Neither the argument by the peers nor by the researchers made any impact on their decisions.

The context of the role play assumes a prerequisite knowledge among its participants. Hence, if students are not provided with adequate content knowledge and given sufficient time and opportunities for preparation, the role play may not lead to meaningful decisions. In fact this situation reflects the general democratic discussions of issues in any forum. It was found that organising for and conducting a role play can involve a lot of time that may be difficult to allocate in regular school settings and would be challenging for teachers. However, the benefits it can have for average and above average students (in terms of examination score and knowledge they have) was evident in the discussions in the morning session. It would be interesting to study other contexts for the use of role play in Indian classrooms' settings.

D. Conclusions

The project work aimed to organise a workshop for students in which students' ideas on energy and environment would be explored through a variety of probes. There were a large number of activities carried out by students individually and in groups. However, only a few of these have been analysed and reported here. Students' responses to the variety of activities and questionnaires gave several evidences of students' correct ideas about the environment and energy. It also revealed students' alternative ideas in this area. These have been discussed in the earlier section. They are summarised below.

Humans and environment

It was encouraging to find that most of the students are aware of constituents of the environment and human-environment interrelationships. They are also aware of the scarcity of fossil fuel and the possible future crisis of energy sources. In a context mapping activity, several groups of students correctly related human intervention in environment with corresponding environmental problems. However, they have some misconceptions about the nature of the problems. For example all students had heard of the terms greenhouse effect and global warming, but only a few of them could give a valid explanation for the phenomenon.

Many students showed incomplete knowledge of the classification of living beings as plants and animals. It was found that more than half the students did not consider either fish or insects as animals. Almost a third did not think whale was an animal, while a sixth of the students did not consider humans as animals.

Photosynthesis and food relations

Most students knew about food chains. However, they did not appreciate the level of dependencies of organisms involved related by a food chain, and of the food chain as a whole. Most look for changes in parts of the food chain and fail to see that change at one point can affect all other parts of the chain.

Students knew about photosynthesis and most students were aware that it takes place in green parts of the plants. In fact, almost three-fifth of the students even knew that photosynthesis can take place in green parts of the plants other than leaves. Students knew of the inorganic components required for the photosynthesis, but most were unaware of their role in photosynthesis. Some students even mentioned that plants with leaves of colours other than green also possess the green chlorophyll.

Close to half of the students think that insectivorous plants and parasitic plants are not capable of photosynthesis, perhaps, by drawing an analogy of such plants with animals, as

they mentioned during discussions.

Most students thought the oxygen released in photosynthesis comes from the carbon dioxide that it uses up. Though students have been taught about photosynthesis as well as energy flow through food chain in nature, they are not exposed to photosynthesis as a process aiding energy flow in nature. This is reflected in their drawings, where students consider photosynthesis in terms of the input and output materials and sunlight - as a process of food preparation.

More than two thirds of the students thought that plants did not respire all the time, but only at night. Photosynthesis dominates textbook discussion on the physiological processes in plants. Perhaps, because of this students do not easily connect others like respiration and transport as important physiological processes in plants.

Energy

Students know to define energy as “the ability to perform work”. However, it does not help in introducing forms of energy other than the mechanical. Some students know about potential and kinetic energies of a body, but are unable to use it in simple contexts of bodies at rest or in motion. Some considered static, dynamic, frictional, and muscular as forms of energy. Students mentioned that energy was synonymous to power or force.

Energy is recognised an abstract concept and its introduction in secondary school science has been discussed in the literature. Introducing it within the complex context of the environment did not help in clarifying students' concepts. Besides unearthing the flaws in students' understanding, it may have added to their confusion. It may be useful to deal with all aspects of energy needed to discuss a particular context of environment and then connect it with the environment in a systematic manner. Only after that is a critical discussion on its socio-economic dimensions possible. Yet, this was attempted, and students showed considerable awareness of issues.

In response to questions in the activity sheet, most students felt that change of individual life styles can reduce energy demands. However, in their posters on future energy scenarios, students predominantly draw transportation, especially private vehicles. It appears that the message of public transportation being more environment friendly than private ones has not been understood by them. Besides, students drew more high rise buildings and robotic systems, but no forest or animals other than humans in their posters. In the activity sheet, a third of the students had responded that the society which uses more energy is more developed. This provides evidence that students do not connect their understanding of energy flow in nature with human energy use.

The essay writing on “A world without energy” revealed that students consider energy as a very basic constituent of the universe. Although students discussed the energy issue mostly

from an anthropocentric view. They concluded that a world without energy is impossible. Role play in the classroom can be an effective strategy to introduce students to democratic informed decision making. However, it needs time and effort to equip the students with the pre-requisites.

Learning from this engagement

We hope to be able to study the remaining questions of the activity sheets and students' responses to other activities. The study so far helped the first author gain insights into some issues of students' learning. These are listed below.

1. The broad nature of understanding of energy and environment among students of Class 8 in a specific Indian context from which the sample was taken.

2. A better understanding of the order of content and its level to be provided to students of Class 8.

3. An understanding of the nature of problems that a teacher-researcher may face in a classroom.

4. An understanding on what can go wrong while framing questions in an activity sheet. The activity sheets used in the current study were not content validated, piloted or checked for reliability. Some questions were compound sentences giving two different statements. Students may have been confused about responding to one or the other.

5. The experiments on photosynthesis, as well as activity on energy audit and energy trends done with students demanded more structured and informed approach than what we followed.

6. The work corroborates the first author's readings in the literature on students' conceptions of photosynthesis, plant and respiration, food chain and biological classification. It would be interesting to probe one or more of these in different Indian context.

Overall the study has opened up possibilities to carry out a number of more planned studies. The students' responses received from this exercise would help prepare design a better pedagogic intervention in future studies. Practicing teachers and researchers can try out some of the activities carried out in the project and share their learning to a larger community.

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Appendix A

Immersion Model of Environmental Education (Shome & Natarajan, 2007a, 2007b)

Appendix B

Course on Energy and Environment for Grade VIII Students

from School 1, 2 and 3

October 20 to 31, 2008

Schedule of Events

Date	Session I	Session II	Session III	Session IV
	3:00 pm – 3:30 pm	3:30 pm – 4:00 pm	4:30 pm – 5:00 pm	5:00 pm – 5:30 pm
20/10/08	Introduction to camp (SS)	Worksheet on Environment (SS)	Introduction to Environment (CN)	Humans & Environment (CM) (CN/SS)
21/10/08	Worksheet on energy (SS)	Imagine a world without energy... Writing (SS/AP)	Presentation & discussion (SS/AP/CN)	Presentation & discussion
22/10/08	Forms of energy, conversion, Energy links (SS)	Worksheet on Photosynthesis (SS/AP)	Introduction to Photosynthesis (AP)	Contd.
23/10/08	Activity on Photosynthesis (AP/SS)	Poster: Energy trends (handouts for diff era given to diff grps) (SS/AP)	Where I am consuming more? (SS/AP/CN)	Energy audit intro, give Worksheet for energy audit at home (SS)
24/10/08	Poster: Human civilization after 500 years (SS)	Poster	Poster	Poster & Supply of reading material (SS)
27/10/08	Sources of energy: renewable, non-renewable, biofuels economic criteria (SS)	Contd.	Contd.	Intro to “A power plant for Shaktipur” Role Play (come suitably dressed) (SS)
30/10/08	A power plant for Shaktipur: Role Play (SS/AP/CN)	Contd.	Contd.	Contd.
31/10/08	Discuss energy audit at home (SS/AP/CN)	Posters on energy audits at home and at HBCSE (SS/AP/CN)	Energy audit at HBCSE (SS/AP)	Contd.

An Exhibition of posters and photographs from the course will be held on Saturday, November 8, 2008 at HBCSE for the parents and teachers of participants.

SS – Saurav Shome
AP – Ankita Patel
CN – Prof. Chitra Natarajan

Contact: Mobile – 996xxxxxx6

Appendix C

Structure of Energy and Environment Course for middle school students

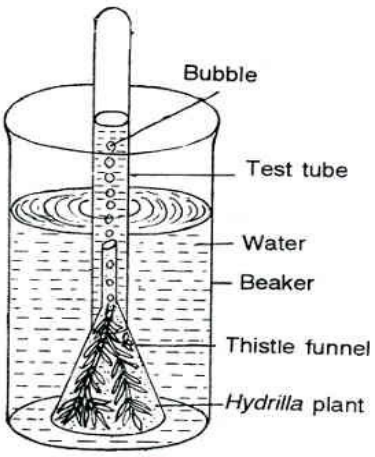
Day No. (No. of stdts)	Session I	Session II	Session III	Session IV
1 (37)	Intro to course, group formation (SS) {35 min}	Worksheet [I] on Environment (SS) {35 min}	Intro to environment and discussions (CN) {35 min}	Context map [G]: humans & environment (CN/ SS) {30 min}
2 (38)	Worksheet on energy [I] (SS) {30 min}	Science fiction essay writing: A world without energy... [I] (SS/AP) {37 min}	SF essay [G] Preparing write up for presentation (SS/AP/CN) {40 min}	Presentation [G] & discussion [C] {30 min}
3 (37)	Forms of energy, conversion, Energy links (SS) [C] {55 min}	Worksheet on Photosynthesis [I] (SS/AP) {30 min}	Introduction to Photosynthesis [C] (AP) {60 min}	Contd.
4 (36)	Activity on Photosysthesis [G] (AP/SS) {45 min}	Poster: Energy trends (handouts for diff era given to diff grps) [G] (SS/AP) {30 min}	Where I am consuming more? [I] (SS/AP/CN) {20 min}	Discussion on energy trend [C] (SS/AP/CN) {25 min}
5 (36)	Observation on the photosynthesis activity [G] (AP/SS) {30 min}	Poster: Human civilization; 500 years from now [G] (SS/AP/CN) {1 h 20 min}	Poster contd.	Poster contd. & Supply of reading material [G] (SS/AP/CN) {15 min}
6 (36)	Sources of energy: renewable, non-renewable, biofuels economic criteria [C] (SS) {1 h 40 min}	Contd.	Contd.	Intro to “A power plant for Shaktipur” Role Play (come suitably dressed) (SS)
7 (39)	A power plant for Shaktipur: Role Play [C] (SS/AP/CN) {1 h}	Contd.	Lecture on disadvantages of various power plant [C] (SS) {30 min}	Presentation of final draft report by students [G] (SS/AP) {40 min}
8 (37)	Discussion on energy trend and making posters [G] (SS/AP/CN) {1 h}	Contd.	Intro of energy audit and performing energy audit in HBCSE. [G] (SS/AP) {45 min}	Discussion on exhibition and giving assignments [C] (SS/AP) {20 min}

AP – Ankita Patel, CN – Chitra Natarajan, SS – Saurav Shome
I – Individual activity, G – Group activity

Appendix D

Photosynthesis Experiments Sheets

Experiment A: Releasing of oxygen from plants during photosynthesis



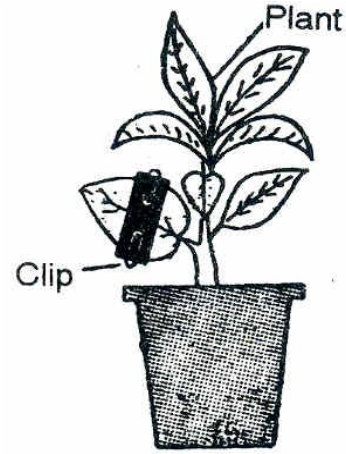
Requirements:
Hydrilla plant twigs, Beaker, Test tube, Funnel, and water

A few twigs of Hydrilla are kept under inverted funnel in a beaker filled with water (see picture).
The cut end of the twigs should face upwards. A test tube filled with water is placed upside down over the tube of the funnel. It will be partially immersed in beaker water.

Observations:

Conclusions:

Experiment B: Effect of sunlight on photosynthesis



Requirements:
Black paper, Paper clips, Alcohol , Iodine solution, Water and A potted plant with wide leaves

Procedure:
Keep the potted plant with wide leaves in a dark room for about a day or two and it is essential to water the plant earlier so as to force the plant to use its reserve of starch, and not allow its replacement by photosynthesis. Thus the plant will be destarched.

Then a part of a leaf is covered with black paper fixed by clips. This destarched plant is kept in light for a few hours.

Then pluck the leaf covered and perform the following steps.

Decolorizing the leaf

a) Place the leaf directly into boiling water until it becomes soft.
b) Transfer the leaf to a beaker of alcohol in a water bath set to about 70 °C.

The iodine test can now be performed.

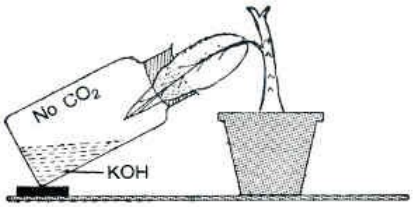
- Immerse the whole leaf briefly in cold water - tap water will do.
- Spread out the leaf in a plastic (Petri) dish.
- Add a few drops of iodine solution (I/KI), and wait a few minutes for colour to develop.

Observations:

Conclusions:

Experiment C: Effect of carbon dioxide on photosynthesis

Requirements:
A potted plant, A wide mouthed bottle, Caustic potash and
Split rubber cork/ aluminum foil



Procedure:
Keep a potted plant with wide leaves in dark room for about 24 - 48 hours and it is essential to water the plant earlier so as to force the plant to use its reserve of starch, and not allow its replacement by photosynthesis. Thus the plant will be destarched.

Fill a wide mouthed bottle, with the solution of caustic potash, 1/3 its volume.
Insert a half leaf of a destarched green leaf (potted plant) and fix inside the bottle with the help of split cork.
Leaf should not touch caustic potash solution.
The apparatus is kept in light for few hours.
Then pluck the leaf and perform the following steps.

Decolorizing the leaf

a) Place the leaf directly into a boiling water until it becomes soft.

b) Transfer the leaf to a beaker of alcohol (IMS) in a water bath set to 78 °C.

The iodine test is performed after killing the leaf in boiling water and decolourising with alcohol.

- Immerse the whole leaf briefly in cold water - tap water will do.
- Spread out the leaf in a plastic (Petri) dish.
- Add a few drops of iodine solution (I/KI), and wait a few minutes for colour to develop.

Observations:

Conclusions:

Appendix E

HBCSE Energy and Environment Course Oct 20-31, 2008
Activity Sheet on "How much do I consume?" - Home Energy Audit

Name of the student_____ Code _____

Fill up the values in the different cells below according to the instructions given in class.

Appliance	Average Wattage (W/hr)	Duration Used per day (in hours)	Duration Used per year (in hours)	Electricity Used per year (in kWh)
Microwave Oven	1300			
Mixie	300			
Toaster	1400			
Refrigerator	300			
Vaccum Cleaner	630			
Washing Machine	500			
Water Heater	2000			
Television	150			
Computer	150			
Electric Iron	1100			
Music System	100			
Hair dryer	600			
Air Conditioner	1500			
Fan (Ceiling)	50			
Grinder	300			
Flour Mill	800			
Radio	70			
Sewing Machine	75			
Electric Shaver	15			
Electric bulb(60W)	60			
Tube Lights	42			
Zero Watt Bulb	15			
Total				

We use several electrical appliances in everyday life today. Was it the same when your parents' and grandparents' were your age? It would be interesting to know. Consult with your parents and grand parents and complete the table for when they were your age. Mark 'Y' to represent 'Yes' and 'N' to represent 'No'

Appliances used	Used by me	Used by my parents	Used by my grandparents
Microwave Oven			
Mixie			
Toaster			
Refrigerator			
Vaccum Cleaner			
Washing Machine			
Water Heater			
Television			
Computer			
Electric Iron			
Music System			
Computer			
Hair dryer			
Air Conditioner			
Fan (Ceiling)			
Grinder			
Flour Mill			
Radio			
Sewing Machine			
Electric Shaver			
Electric bulb			
Tube Lights			
Zero Watt Bulb			

Use the energy values in the first table to compare your current consumption with that of your parents and grandparents, which you have tabulated above. Draw a bar graph of total electricity used (on Y axis) versus the categories – you, parents, grandparents.

Adapted from CEE (xx). Energy matters. Ahmedabad: CEE.

Appendix F

HBCSE Energy and Environment Course Oct 20-31, 2008
Survey sheet on Energy Use in different Periods

Name of the group_____ Time period of Energy used _____

Activity	Energy Used in Period	Energy Used Today
Travel		
Cool your home		
Light your home		
Make tools		
Grow food		
Cook food		
Store food		
Wash clothes		
Entertain yourself		

Tabulation of energy use trends

Discuss the energy trends from various groups' response and fill the table below. Comment on energy trends.

Type of Energy	1million BC	10,000 BC	3500 BC	600AD	1500 AD	2000 AD
Animal power						
Wind power						
Water power						
Muscular power						
Electricity						
Oil and natural gas						
Biomass						

Comment:

Adapted from CEE (xx). Energy matters. Ahmedabad: CEE.

Appendix G

HBCSE Energy and Environment Course Oct 20-31, 2008

Name of the group_____

What appliances do you need?

Consider a time when the number of people has increased beyond what earth can support, and some people being shifted from Earth to Mars. You are one of them. You are told that you will be provided food, shelter and other structural facilities. However, availability of electricity in Mars is limited. You can carry with you only ten electrical appliances. Please list the appliances that you most need according to your priority. You may have to cut off the low priority items from the list. Justify your choices.

Some typical responses of students

S. No.	Name of electrical appliances by four groups viz. A/A, C/A, C/M, F/M			
1	CFL or tube lights	Computer	Fridge	Microwave oven
2	Fans	Bulb	Laptop	Fridge
3	Fridge	Watch	Fan	Tube light
4	Telephone and Mobile	Air Conditioner	CFL	Fan
5	Washing machine	Switch board	Water purifier	Cell phone
6	Electric iron	Mobile	Television	Washing machine
7	Vacuum cleaner	Television	Heater	Iron
8	Computer	Refrigerator	Microwave	Heater/Geyser
9	Television	Microwave oven	Radio	Television
10	Geyser	Water boiler machine	Geyser	Computer

Adapted from CEE (xx). Energy matters. Ahmedabad: CEE.

Activity sheet supplied on Renewable energy source:

1. Natarajan Chitra (1997). *Activity based foundation course on Science, technology and society: Resources; Energy.* Mumbai, HBCSE.

Appendix H

HBCSE Environment & Energy Course, October 20-31, 2008

Activity Sheet on Environment (20/10/2008)

Name _____

Code _____

1. Define the following terms related to the environment:

(a) Species

(b) Food chain

(c) Producers

(d) Consumers

2. Which of the following living beings are not animals? (Circle your choices)

a) Tiger b) Fox c) Palm tree d) Spider

e) Whale f) Bat g) Human h) Fish

3. State whether the following statements are True or False by writing T or F against each.

(a) Several packaging resins and all plastics are petroleum products.

(b) Ozone holes are places in the upper atmosphere where the largest amount of ozone is found.

(c) The population of a species could have any size independent of its environment.

(d) The Earth is closer to the Sun in the summer than in the winter.

4. Answer the following questions:

(a) Draw a food chain.

(b) Waste is thrown away after animals and plants have used up the food consumed by them. What happens to this waste?

5. Have you heard the following terms? Circle 'Yes' or 'No'.

(a) Global warming (Yes/ No) (b) Greenhouse effect (Yes/ No)

6. How is global warming related to greenhouse effect?

7. Which of the following are not there in any food chain? Circle your choices.

(a) Grass (b) Snake (c) moon light (d) grass hopper

(e) microbes

8. Consider the following simple food web.

grass grass hoppers frog snakes

If there is a change in the frog population, which of the following will be true? Circle your choice or choices.

(a) amount of grass will change

(b) grasshoppers population will change

(c) snake population will change

(e) none of the above populations will change

9. What causes decay in the environment?

Appendix I

HBCSE Energy & Environment Course, October 20-31, 2008

Activity Sheet on Photosynthesis (22/10/2008)

Name:_____

Code:_____

1. How do plants get their food?

2. We, humans cannot stay alive for more than 5 to 6 minutes without oxygen. Oxygen is essential for our life. Which of the following will cause similar survival problems for plants? Circle your choice(s).

   (a) oxygen (b) hydrogen (c) water (d) carbon dioxide

   (e) sunlight (f) minerals (g) soil

3. List some living beings that are capable of photosynthesis.

4. Which of the following is/are unimportant for photosynthesis? Circle your choice(s).

   (a) water (b) soil (c) sunlight (d) carbon dioxide

5. State whether the statements given below are true or false by writing **T** or **F** against each statement. Write one sentence in support of your answer.

   10. Photosynthesis takes place only in green plants.

   11. During photosynthesis plants take in carbon dioxide and give out oxygen.

   12. Photosynthesis only takes place in the leaves.

13. All plants are capable of photosynthesis.

14. Photosynthesis takes place only during the day and respiration only at night.

6. Draw a neat schematic diagram to show the role of photosynthesis in the energy flow in the environment.

Appendix J

HBCSE Environment and Energy Course Oct 20-31, 2008

Activity Sheet on Energy (21/10/2008)

Name _____

Code _____

3. Write two sentences on what do you mean by energy.

4. Name five sources of energy?

5. Where do living organisms get their energy from?

6. List the different forms of energy?

7. A bus is parked at a bus stop. The driver climbs into his seat, starts the engine and drives the bus. Where does the energy for all this activity come from?

8. Which of the following can reflect sunlight? (Circle your choices)

(a) Mirror (b) Water Surface (c) Black Stone (d) Leaf (e) All of these

9. A ball falls from the fifth floor on a concrete ground. In each of the following cases,

write down the kind of energy the ball has.

a) the ball is at rest on fifth floor

b) the ball is falling freely towards the floor.

c) just as the ball hits the floor.

d) the ball is bouncing off the ground.

10. In thermal power plants petroleum or coal is burnt as fuel. Chemical energy from the fuel is converted to heat energy. The heat energy is used to produce electricity through some more energy conversion steps. Your friend claims she can get back from the electricity all the heat energy produced from the coal or petroleum by her newly invented technique. Do you think this is possible? Comment on her claim.

11. Write two differences between respiration and breathing.

12. What is meant by renewable and non-renewable energy sources?

13. Give three examples each of renewable and non-renewable energy sources.

(a) Renewable energy sources

(b) Nonrenewable energy sources.

14. Your friend comments that all sources of energy are actually just transformed solar energy. Do you think she is right? Explain in a couple of sentences.

15. We measure mass in kilogram, and length in meter. Similarly we use units to measure energy. Write the units used to measure energy.

16. Write the units in which our household electricity consumption is measured.

17. Which of the following statements are correct? Circle your choice or choices of correct statements.

(a) Society, which uses more energy, is more developed.

(b) Finding more energy sources and building new energy plants is the only way to meet the increasing energy demand.

(c) Today in most of the countries we are experiencing shortage of energy. We can reduce energy demand by changing our individual life styles.

(d) Nuclear energy is a clean energy. It is pollution-free during electricity production.

(e) Nuclear energy produces no safety or waste problem before, during or after production.

(f) Biogas uses methane gas from bio-wastes and releases carbon dioxide and water vapour. All three are greenhouse gases. Therefore we should stop using biogas.

Appendix K
HBCSE Energy & Environment Course, October 20-31, 2008
Role play

A power plant for Shaktipur: citizens' concern for a better future

The case of Shaktipur in brief

You are residents of a state Trihar, were Shaktipur is a growing industrial locality in the state. Shaktipur is enjoying a period of economic growth that most places can only dream about. Shaktipur has grown from a sleepy little rural locality to a booming place with plenty of jobs and high standards of living, reported in a local news paper few months ago.

Shaktipur luckily, has avoided problems like crime and pollution that plague many other communities during their boom periods. It has become a place where people want to live and where business want to come. As a result, the population has increased fivefold during the last 20 years. Yet electricity is produced in a power plant built in 1949 designed for a much smaller population. During the heat wave last summer, many air-conditioners, air coolers and refrigerators were turned on and power shortages occurred all over the place. It is feared that the situation will go worse in the future.

The chief minister of the state has called for a cabinet meeting with all members concerned, and she has also invited leading industrialists and research scientists from across the state, working on various aspects of energy, for technical assistance and clarifications. Through this meeting, she plans to decide on the type of energy source to depend on for generating further power for Shaktipur.

Your role:

Each of the group has given one or more slips of papers. Your role has been written in the slip. You consult with your team members and select a person who will present in the role play. We have the following roles: Chief Minister, Minister for Energy, Minister of Industries and Mines, Leading industrialists, Environmentalist; one each and five research scientists, One journalist, and a group of observers deputed from WHO, UNDP, UNICEF, HBCSE, CEE, and SACEP. Al the members in the group will responsible for preparing the presentation.

At the end the reporters and observers will read out their report which will be taken as the seminar outcome and further steps in this regard will be taken based on this report. The outcome of the report could be modelled and displayed in the exhibition.

Adapted from CEE (xx). Energy matters. Ahmedabad: CEE.

List of Reading Material for Role Play on Shaktipur Power plant

1. Page 2 – 9 from *Energy Matters – A school energy education guide*. (2000) Ahmedabad; CEE.
2. Page 73 – 85 from Bakhshi A. K. (1995). *Energy*. India: National Book Trust.

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Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
Mumbai 400 088