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ABSTRACT

A comprehensive view of science and technology in curricular reforms and materials is needed to promote public understanding and participation in science issues. This paper presents the results of an analysis of the treatment of the nature of science and technology in science curricular materials in India. Textbook sections on the conceptions of mechanics are the basis for this analysis. A contextualized curriculum for schools is offered as a more productive approach to learning and exploring science concepts, processes, and science-and-technology-issues. The controversial Sardar Sarovar Hydroelectric Project in India is used as an exemplary case that can further this effort. It is concluded that a contextualized curriculum is potentially quite powerful for addressing the nature of science and technology in school curricula and materials. Contains 100 references. (Author)

Contextualized Science for Teaching Science and Technology

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Abstract

A comprehensive view of science and technology in curricular reforms and materials is needed to promote public understanding and participation in science issues. This paper presents the results of an analysis of the treatment of the nature of science and technology in science curricular materials in India. Textbook sections on the conceptions of mechanics are the basis for this analysis. A contextualized curriculum for schools is offered as a more productive approach to learning and exploring science concepts, processes, and science-and technology-issues. The controversial Sardar Sarovar Hydro-Electric Project in India is used as an exemplary case that can further this effort. The paper concludes that a contextualized curriculum is potentially quite powerful for addressing the nature of science and technology in school curricula and materials.

Introduction

Since the 1960s, science educators have increasingly emphasized the need for a comprehensive view of science and technology in curricular reforms and materials (Duschl, 1990; Fayard, 1991; Gallagher, 1991; Klopfer & Cooley, 1963; Nielsen, 1993; NSTS, 1996; Solomon & Aikenhead, 1994; Yager, 1996; Ziman, 1980). There is widespread agreement that a more holistic approach to science education will better promote general scientific literacy and greater public participation in science issues. Three inter-related aims that have emerged to help students and teachers gain a holistic view of the nature of science and technology are:

A1 The presentation of ideas, concepts, principles, and theories of science.

A2 The presentation of the processes of science: how ideas, concepts, and theories are developed. Processes of scientific inquiry incorporate both the generation and testing of knowledge in a specific context.

A3 The presentation of science, technology, and society issues.

These aims have been addressed through curriculum development projects such as the *National Science Curriculum* in England, *Biological Science Curriculum Study* (BSCS), *American Project 2061*, and the *National Science Education Standards* in the U.S. For example, BSCS selected six themes that any curriculum, unit, or activity must incorporate (BSCS, 1992):

- Science is a way of explaining the world.
- Technology is a way of adapting to the world.
- Science and technology are activities that involve human values.
- The social, cultural, and environmental contexts within which they occur influence the conduct and content of science and technology.
- Science and technology influence the social, cultural, and environmental contexts within which they occur.
- Science and technology and their interrelationship have changed over time.

In India, too, people participatory movements like *Kerala Sastra Parishad* have underlined the significance of a comprehensive view of science and technology to promote scientific and cultural literacy (Zachariah & Sooryamoorthy, 1994). With these comprehensive aims and concerns in mind, this paper follows an examination of current Indian National Council of Educational Research and Training (NCERT) science curriculum materials.

In many Indian science classrooms, the NCERT science textbooks are the only instructional tool available; therefore, the quality of these state prescribed science textbooks should be a major policy concern (Kumar, 1988). Textbooks determine the acceptable approach for science teaching by providing tasks, questions, problems, and other information (Gunstone & White, 1988). This paper presents the results of an analysis of the treatment of the nature of science and technology in current grade IV-X NCERT science textbooks. It also recommends the development of an alternate conceptual framework for the science curriculum. The first part of this paper comments on the development of conceptions of *mechanics* through the methods and strategies for the topics of *force, work, and energy*. This is followed by an interpretation of the values and assumptions on the nature of science and technology expressed through the treatment of these topics. The second part of this paper reviews contextualized curriculum for schools, followed by discussion of a case pertinent to practical decision-making on energy. The paper concludes that contextual investigation addresses each of the three major aims (A1, A2 and A3) for the school science curriculum.

Policy makers have complained that there is a lack of decision-making among students, and existing practices turn out unqualified, passive, unskilled students (and teachers) from schools and colleges in India (Kumar, 1988; Weiner, 1996). Furthermore, the prevailing practice of rote memorization promotes passivity among students, which ensures control and discipline in classrooms, but also deskills teachers. Projects such as the Hoshingabad Science Teaching Program in village schools have aimed at testing the feasibility of contextualizing the learning of science to the environment (Mukund, 1988). The results of these projects have been positive (see Mukund, 1988; Rampal, 1992). Educators from other parts of the world have also shared similar views (Lubben & Campbell,1996; Nganunu, 1988; Ogunnuyi, 1988; Robson, 1992; Swift, 1992; Yakuba, 1992). Lubben & Campbell (1996) have had positive experiences using contextualized lessons on circuit electricity, air, and respiratory systems with students in Swaziland, and Ramsden (1992) also shared the usefulness of contextulizing materials in his work with children in the UK. Contextualized curriculum is a good way to teach students about the nature of science and technology. However, quality school curriculum materials require appropriate methods and strategies in the treatment of subject matter.

Approach to Text Analysis

Most studies aim only at identifying generalized views on the nature of science and technology; they do not address how these views play out in the treatment of specific subject matter. In this study, the stated philosophical objectives in the teacher handbooks are examined primarily through energy themes within the topics of *force, work, and energy*, although the analysis was not limited to these. Topics on *force, work, and energy* were chosen because they constitute a significant portion of content across the different grade level textbooks. Each textbook chapter under examination was treated as a unit. To discern the methods and strategies used in the development of concepts, the researchers devised taxonomies for concept and question analyses (see appendix A). For concept analysis, each chapter on *force, work, and energy* was divided into its key conceptual idea (s) and components. The researcher recorded the strategies for each concept or component idea (appendix A). Concept mapping was used to help organize the data.

In the question analysis, all questions and problems on the topics *force, work, and energy* were identified under the strategy of assessment (those appearing in the prose as well as the end of the chapter assessment sections). Analysis was directed only at the nature of questioning since the source of answers reveals the nature of science implicit in the assessment. Each question was classified by identifying its source of answer (see appendix B). The sources of answers were compiled in a table of frequency counts (appendix B). Two researchers chose and analyzed a random sample of data to ensure inter-coder validity and reliability.

In addition to identifying methods and strategies for concept development, the researchers also analyzed the nature of science and technology implicit in these science textbooks. In relation to this, the researchers' concern extends to identify the gap which can possibly appear between the intentions of curriculum developers and the actual development of science curriculum materials. Each of the three aims (A1, A2 and A3) are explicitly addressed in the NCERT teacher handbooks. For example, the *Environmental Studies Teacher's Guide for Class III* lists two major objectives on the nature of science: 1. "It is important for the learner to assimilate the methods of scientific enquiry, commonly referred to as 'science processes': observing, classifying, measuring, recording, experimenting, hypothesizing, communicating and infering" (p. 1). 2. "The environment provides the themes (and not abstractions and generalizations of science) in which the relevant scientific principals are sought and elaborated" (p. 2). "Environment is a stimulus that comprises all the physical and social factors known and unknown which directly or indirectly affect his living and working conditions......the child should be trained to visualize time and space through the study of environment" (p. 1- 3). Similarly, *Teaching of Science in Secondary Schools* suggests "Chalk and talk method is not consistent with the nature of science....... You have to practise and use a variety of activities which are relevant for learning" (p. 4). Does the presentation of science in the textbooks support the objectives in the teacher handbooks?

Results of Text Analysis

Concept and Question analyses

The grade IV-X NCERT science textbooks use a spiral method for the treatment of content, introducing topics on physical science, life science, and earth science at each grade level. In the early grades (I, II and III), the textbooks mostly employ a phenomenological approach to ask students to explore the world around them. Formal concepts are not introduced until grades IV-V. Topics on *force, work, and energy* and science and technology themes first appear as full chapter topics in the grade V science textbook.

The primary strategy in the treatment of concepts on *force, work, and energy* is to put forth the names and concepts that describe the motion of objects, kinds of energy, and its transformations and so forth. Many concepts are introduced without being accounted for, or explored, through student investigations (see appendix A). This approach is merely confirmatory in nature (later in this paper, we will review the arguments against this traditional approach to curriculum). The same approach applies to the nature of questioning in these texts (see appendix B):

- Overall, there is a low percentage of questions (total 11%) that make any reference to activities.
- There is a high percentage of questions (total 58%) whose answers are *explicitly* given in the text itself.
- Answers to a high percentage of end of the chapter questions (72%) are *explicitly* given in the prose section. The purpose of end of chapter questions is merely to identify, name, or recall the factual material presented in the preceding sections.

Although the texts do present some activities in the development of concepts, laws, or principles on *force, work, and energy*, the questions or problems at the end of each chapter make no reference to any activity or investigation. Students are only assessed for predetermined answers provided in chapter readings, offering little incentive for students to apply or explore ideas.

The textbooks offer an abundance of conceptual information and very few activities (see appendix A). When activities are suggested, they aim at mere verification of a concept, law, or theory; they are less likely to generate curiosity and engage students to explore, explain, and evaluate their ideas. It may be noted that the practical work suggested in the "Things To Do" sections of grade IV and V science textbooks may be too generalized for the student: e.g. "Find out how a wrist-watch works?" (Grade IV, p. 104).

Nature of Science in Textbooks

Many researchers have pointed out that a confirmatory approach prevails in school science textbooks (see, e.g., Elliat & Nagel, 1987; Stake & Easley, 1978). The following quotes from the Grade VI and Grade V science textbooks illustrate this confirmatory approach (Grade VI, p. 151):

"*What* is energy?"

> If you work in your field or school for a long time you feel tired. Similarly, when you play for a long time you feel tired. How do you know that you are tired? Your ability to work is reduced. The ability to do work is called energy. It means that when you are tired you have less energy. The question now arises: Why is your energy reduced? Obviously, it is reduced because you did some work. It means you use energy to do work. When you say that you are feeling energetic today, what do you mean by this? You perhaps mean to say that you could run a long distance or play a lot or do a lot of work. Thus you see that work and energy are related.

The next quote, an activity from the Grade V science textbook, asks the student to fill a bottle with water and then suck the water through a straw. While closing one end of straw with a finger tip, the student is asked to remove the straw from his/her mouth and observe the level of water inside the straw (Grade V, p. 78):

> Why does the water not flow down? Now release your finger gently. Again observe. The water flows down as drops. How does it happen? Note these points.

> Air constantly exerts pressure on all surfaces. This air pressure is also there on the surface of water in the container. It is also on the inside and outside of the straw. When the air pressure is same, both inside the straw and outside on the water surface in the container, the level of water remains the same. But as you suck, air is taken out from the inside of the straw. The empty space thus created is then filled up by water. This happens because the air pressure is reduced inside the straw causing the water to rush in. As a result, the level of water inside the straw rises. When the upper end of the straw is closed, there is very little air inside it. The pressure of the air outside is more than that inside the straw. This prevents water from flowing out. When the upper end of the straw is left open, air rushes into the straw, thereby pushing down the water at the original level. If you release the upper end of the straw gently, the air pressure inside the straw increases and the liquid starts flowing out drop by drop.
>
> The activity given above shows how air pressure helps to push down or lift the liquid up the straw.

These examples are illustrations of confirmation through inductive-empiricism. The implicit nature of this activity in the Grade V textbook is that an understanding of air pressure results from a summary of student experiences with sucking water through a straw. The reader is led by the capillary action of a chain of inductive inferences, a 'rhetoric of conclusions' (Schwab, 1978). There is only one logical correct interpretation, one correct answer to the problem. Encouraging this kind of reasoning may lead to narrow-mindedness and the misconception that scientific laws and theories can be deduced from observational data, whereas in reality explanations mostly follow from conjectures. Furthermore, the authors employ a rigidly formal language which may not be appropriate for school level readers.

Results of analysis also show that the nature of science and technology expressed through energy themes conforms to a decontextualized, traditional framework for curriculum development (see fig.1). Within this framework, the NCERT textbooks introduce the student to the precise meaning of concepts, laws, or theories, but often fail to justify their major claims through any means. For example, under what conditions are specific sources of energy renewable? When and why should we treat nuclear energy as an alternate source of energy? The following quotes from narrative and assessment sections of the texts are representative of statements on energy fuels:

Grade V, chapter 11, p. 92

> Q. Hydroelectric power stations should be preferred to the thermal power stations because: a) they produce no pollution b) they produce more energy than the thermal power stations c) they help to save precious natural resources d) all of these

Grade VI, unit 11, p. 160

> Water, wind, sunlight and biomass are called the renewable sources of energy, since they can be used again and again. Moreover, they are freely available and do not pollute the environment. Efforts are being made to use to the maximum the energy available from them

Grade VII, chapter15, p. 232-234

> Alternative sources of energy: hydel energy; geo-thermal energy; tidal energy; Nuclear energy
>
> Alternative energy sources are renewable sources of energy.

The statements that "Water, wind, sunlight and biomass ....are freely available", and "do not pollute the environment", and "all alternative sources are renweable" follow traditional *deductive-nomological* and *inductive* models of logical positivism:

> In a *deductive* model the truth of the premises forces the truth of the conclusions:
> Renewable sources 'can be used again and again'. (*Law*)
> Hydel-energy water can be used again and again. (*Initial condition*)
> Hydel energy is a renewable source. (*Final conclusion*)
>
> In an *inductive* model, some finite set of experiences leads like capillary action to broader generalizations or universals.

The influence of positivism is like 'a dead horse with a vicious kick'! It would be fair for the textbook authors to state that hydro-electric energy is renewable in controlled laboratory experiments. However, this does not lead to the claim that the interchange of mechanical energies is ecologically acceptable under any circumstances. Numerous controversial dam projects in India clearly demonstrate that hydroelectric energy can not be viewed as exploitable in all circumstances (the Sardar Sarovar Hydro-Electric Project in the state of Gujarat is a famous case in point which will appear later in this paper). Contrary to the textbook claims, water can not be axiomatized as a renewable source of electricity with no environmental costs whatsoever. All alternate technologies involve direct and indirect costs which are inseparable from their effects in a complex system of interacting variables. Hydro-electric energy, for example, involves the cost of rehabilitating dam oustees (social), the cost for treatment of diseases (health costs), cost of the loss of forest or wild life (environmental), and multidimensional effects that can not be assigned a single monetary index (Zutshi & Bhandari, 1994).

A positivistic approach to alternate technologies does not address the issue that energy choices and concerns are always context specific and involve the values, preferences, assessment, and judgment of individuals and societies (Tatum, 1995). Within such a comprehensive context, "A simple logical account ..... often gives way to the inconsistencies and uncertainities of empiricism"(Nye, 1993; p. 282). Therefore, curriculum should acknowledge multiple solutions and representations. Students should be encouraged to seek contextual explanations and answers to problems, not a uniform, final word that could be blazoned on a T-shirt. A universal treatment of science offers simplistic solutions; students, however, need to understand science in its complex personal, social, and contextual dimensions.

The positivistic view undermines the second and third aims (A2 and A3) of school science curriculum, thereby presenting theory and practice, basic and applied, as opposites. Science and technology function solely as tools for human gain. A grade V science textbook reveals an essentially anthropocentric, instrumental view (Chapter 15, p. 118-119):

> Everything changes. Nothing remains static either in nature or in human affairs. Man's activities and thinking have also been changing for thousands of years. When we say, that we have made progress since the beginning of history, we mean that we have changed for the better. Progress involved change. With the progress in science and technology, we have now achieved greater control over nature. We will continue our search for knowledge. We will investigate natural phenomenon. Having understood then, we would like to control then further. Thus science would

progress. But this progress should be accompanied with wisdom It should be used that the world becomes a better place to live in.

The text presumes here that 'control over nature' through change and experimentation is desirable. This assertion is given as an unquestionable "fact". Yet the history of science and technology is not necessarily filled with wholly beneficial enterprise. Since 1947, for example, 30 million people in India have been displaced by technological decisions related to building dams, mines, and power plants (Katiyar, 1993). This fact refutes a linear, simplistic treatment of science and technology. Even if one accepts the anthropocentric assumption of this textbook, tempering it with an unqualified statement like "progress should be accompanied with wisdom" is not enough. Where does this wisdom come from? What is the nature of it? How can students gain this wisdom unless they explore questions on the role, value, and consequences of technology and the characteristics, limits, and possibilities of good technological solutions?

The lack of emphasis on pedagogical strategies that can help students make sensible choices is not limited only to the treatment of energy themes. In the presentation of methods for the prevention of certain diseases, the student is advised to "spray insecticide such as DDT in your house regularly" (Grade V, p. 61). Later there is a statement on environmental pollution that "the dead bodies of insects may contain traces of DDT"(Grade V, p.118). What is the student supposed to make of these two statements?. What action should the student take and what is the lesson? Use of poison in homes is not an attractive option, but the textbooks do no more than mention the sinister features of DDT. They do not include, for example, the way DDT passes from one organism to another through all the links of the food chains (For example, see Rachel Carson's discussion on *Elixirs of Death* in *Silent Spring*, 1962).

Rather than making an instrumentalist "choice" for the readers, curriculum materials can help students learn how to analyze the pros and cons of each decision. Most philosophers agree that the symbiotic nature of science and technology shapes our ways of living and the world we live in. The commonly entrenched idea that technology is a neutral tool, employable for good or evil depending solely upon the user's intentions, has been discredited (Casey, 1992). The notion of the "technological fix" suggested in the following proposition has been debased:

> If only we could learn the actual mechanisms by which they (plants transform energy) do this and copy it, we would be able to solve our energy problems! (Grade VII, chapter 10, p. 89)

A "technological fix" assumes that technological innovations will solve our social problems(Tatum, 1995). In his book *Energy Possibilities*, Jesse Tatum views the "technological fix" to energy problems as a combination of two traditional approaches: 1. The *engineering response,* which seeks new innovations such as the development of fusion energy systems, safe and environmentally benign breeder reactors, and so forth. 2. The *economic response,* which relies on objective market behavior to indicate the most cost effective solutions. Both of these approaches undermine the role of public participation in the making of energy choices and exclude the values, goals, and objectives of the individual and the society (Tatum, 1995). The technological fix also implies that the solutions to social problems are found only by professional scientists and experts, leaving little incentive for a lay person (the student in this case) to define, plan, and solve problems. Unless students are encouraged to develop their capacities for decision making the goals of scientific literacy and public involvement in science issues will remain elusive.

Just as the "technological fix" may foster ideas that limit *who* should make decisions, the advocacy for prescribed scientific procedure may create misconceptions on *how* knowledge is created and *how* decisions are made. The NCERT textbooks advocate a prescribed scientific procedure (Grade VI, p. 7):

> The Scientific method consists of the following steps: (i) Observation, (ii) Gathering basic information, (iii) Identifying the problem,(iv) Thinking about the probable causes, (v) Testing each of the probable causes through keen observation and experimentation, (vi) Finding out the result and drawing conclusions, (vii) Correcting ideas, whenever necessary.

This is an example of scientific method which has come under serious criticism from science educators (see, e.g., Hodson, 1992; Kauffman, 1989). There is no doubt that scientists do make observations to test their hypotheses and may revise them in light of evidence. This is, however, an unimaginative way of describing the activities of scientists (Kauffman, 1989). Curriculum materials that prescribe scientific method with a series of discrete steps suffer from three major problems(see also Driver and Millar, 1988): First, historians, philosophers, and sociologists disagree whether such a method exists (Feyerabend, 1993). Second, scientific inquiry involves more than following axiomatic rules; there are tacit, affective components of inquiry and doing science. Third, the method presented in the NCERT textbooks promotes a static view of skills, whereas observation is a dynamic entity that changes with the background knowledge of the student and is different from perception (Shapere, 1988). Most philosophers agree that every process skill, including observing, identifying, classifying, and hypothesizing requires a theoretical viewpoint (Kuhn, 1962). The approach found in the NCERT textbooks potentially dichotomizes observation from theory as if children can be imprinted with scientific concepts. Most importantly for curriculum, a prescribed method does not address the comprehensive, contextual nature of science and technology.

Even though the broader aims on the nature of science and technology are advocated in the teacher handbooks, these aims are not necessarily played out in the treatment of subject matter. There is a gap between handbook objectives and development of conceptions on energy themes. What emerges from the NCERT textbook analysis is science in its product form, which is a science that gives prime emphasis to its established concepts, laws, and theories. Both the concept development and questioning manifest this decontextualized form. Very few activities ask students to generate and test knowledge by applying it to new contextual situations (appendix A). The methods and strategies used in NCERT textbooks substitute quantification for qualitative richness and may not provide experiences which can help develop an understanding of the nature of science and technology, the crucial differences among abstract concepts like momentum, energy, degradation of energy, conservation, and so forth (Driver and Millar, 1986; Holmon, 1986; Niederrer, 1992).

The Significance of Context

Science is a way of explaining the world; technology is a way of adapting to the world; both influence each other in a symbiotic manner (BSCS, 1992). The distinction between them is crucial for understanding the comprehensive nature of "science and technology". Contextualized curriculum materials, teaching techniques, and instructional activities may better promote an integrated view of analysis that involves both science and technology. Rather than presenting a simplistic view of scientific methodology, a contextualized approach can introduce students to the complex decision-making strategies needed to solve day-to-day problems.

The traditional, decontextualized approach supports the premise that students in the early grade levels need to be given some content knowledge of the body of facts, concepts, laws, and theories of science before they can deal with problems that involve scientific solutions. There are three major arguments against this product form which insists on prescribed answers and explanations (fig.1): Firstly, when science learning begins with closed definitions of concepts and laws of science, then "right" answers and conclusions are sought. Teaching science becomes synonymous to training students to inhale scientific concepts with no reference to the prior knowledge and experiences of students. Students learn to view science as separate from everyday activities (Neiderrer, 1992; Reif and Larkin, 1991).

Secondly, the product form of science potentially rejects and stigmatizes the contextual, personal narratives of students and teachers as non-scientific. It contends that personal narrative lacks the legitimacy and precision of the theories and laws of science. Thirdly, the traditional approach is constrained by the limitations of empiricism or positivism. The empiricist view regards learning as a function shaped by a bundle of immediate, pure experiences in which the identity and the variety of learners are insignificant. The positivist stance positions the learner in a world far from the influence of social and physical contexts, which are considered unimportant. In either case, learning is reduced to individual factors such as motivation and IQ (Lave, 1992, 93). All too often, students give up science before it starts getting interesting (fig.1).

Figure 1

Traditional approach to curriculum

Concepts, laws or theories (A1)

(What we know?)

↓

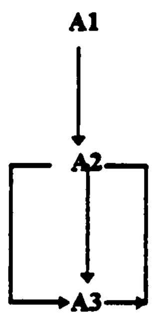
Scientific inquiry (A2)

(How we know it?)

↓

Applying to a contextual situation (A3)

(Why we have to know it?)



There is limited motivating and affective appeal in this design. The approach has an inverted cone effect; very few students will ever move down from A1 to A2 to A3 to experience 'why they have to know it?'

In this traditional approach, concepts and laws (A1) are a prerequisite to the more interesting aspects (A3) of science.

Contextualized approach to curriculum

Contextual situations or tasks (A3)

(Why we have to know it?)

↓

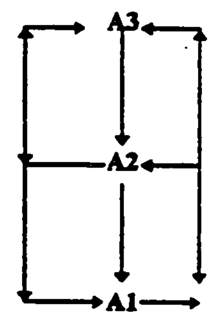
Scientific inquiry (A2)

(How we know it?)

↓

Concepts, laws or theories (A1)

(What we know?)



Teaching begins with providing students a reason for learning science. The science classroom is a forum where they can speak out their questions and concerns. The learning of science is compatible with the concerns and interests of students. Students learn concepts, laws and theories through contextual situations. They do not have to wait (and drop out!) before science gets interesting. Integration of the everyday domain with the scientific domain is more likely.

Contextualizing science does not imply a giving up of reason in favor of subjective irrationalism, or a sacrifice of rigor or demand for evidence. On the contrary, science in context illuminates the theoretical practices of science and technology. Context justifies and gives meaning to theory by demonstrating it in specific situations. Additionally, context and activity should be understood as flexible and changing rather than discrete and deterministic entities (Lave, 1993). When students take part in activities, their thought processes are engaged in the content *and* the context of the problem (Rogoff, 1984, p. 3-4):

> The context includes the problem's physical and conceptual structure as well as the purpose of the activity and the social milieu in which it is embedded......context is the integral aspect of cognitive events, not a nuisance variable .

This contention is supported by the developments in the fields of HPS and cognition during the last few decades, which clearly show that problem-solving is strongly influenced by social and cultural factors. The traditional approach to science curriculum tends to replace intuitive knowledge of the world with formal problem-solving procedures, thus ignoring the prior knowledge and experiences of students and teachers. In contrast, a contextualized approach recognizes the socio-cultural dimensions of problem-solving and makes it easier for students to connect with their prior experiences. This encourages students to articulate or construct meanings in specific situations. It welcomes improvisation and open-endedness, acknowledges ambiguity, and gives voice to the subjective and social experiences of students. As Solomon (1983) suggests, the job of science education is to help students learn how to find solutions to problems in different contexts. This is a different proposition than simply replacing faulty prior conceptions with formal scientific ones.

Research in psychology also supports giving emphasis to both content and context in the teaching of procedures (Chi et. al., 1982; Rowell & Dawson, 1989). By general agreement, teaching can be improved by providing exercises for problem-solving (procedural knowledge) in specific contexts.

How can curriculum provide a context? Martin & Brower (1991) are persuasive in advocating that the school science curriculum materials should incorporate a program of activities organized around contextual bodies:

> When one leafs through any high school physics textbook the contextulessness of the material presented is easily apparent. Most textbooks portray science in a highly convergent, rational manner that overwhelms the reader with a claim of authority and truth.........By implications, such texts convey the message that the context of the inquiry is seldom essential to the inquiry itself. yet, paradoxically,

> one of the goals of the pedagogy is to draw the content of the lesson into the life-world of the student and to accomplish this, context must be provided (p. 707; cited from Stinner, 1996, p. 247).

Curriculum materials can include practical work to aid students in developing both the declarative and procedural types of knowledge and skills. Simple enquiry activities help to develop skills and concepts; investigations provide an opportunity to apply these concepts and skills in new contexts (Duggan & Gott, 1995). Students can begin with activities that capture their interest and then elaborate and evaluate their results for deeper understanding. Affective components contribute significantly to these investigations (Toh, 1991) and have a positive impact on student learning.

Curriculum materials should include activities and investigations based on areas of broad consensus, or conceptual conflict (e.g. predict-observe-explain experiments as proposed by White & Gunstone (1988)), and debatable issues of science and technology (e.g the use of case studies on science and technology-based controversies will be discussed later in this paper). Since learning involves the construction of knowledge through practical work, students can refine and reformulate the possibilities by directly participating in this construction. When the curriculum emphasizes variety in the practical work, students have the opportunity to take on a more creative role.

Questions in science textbooks normally draw upon specialized scientific knowledge, far removed from the everyday concerns of students. If science education aims to promote public knowledge and participation in science issues, then textbooks should incorporate questions on context specific issues and problems. For example, in regard to the textbook topics reviewed for this paper, the text could ask: What potential benefits and troubles do large scale hydroelectric projects bring to society? How can an understanding of the various sources of energy help us make better choices for the kind of life we would like to live? Since abstract questions are difficult to answer (Rowell & Dawson, 1985), contextual questions can help students seek solutions to situational problems, rather than reasoning about abstract science through the rules of logic.

Significantly, in most current science curricula, problem-solving is largely an algorithmic procedure (Larkin, 1980). Textbooks provide students with numerous algorithmic problems like 'how many joules of energy are consumed using 9KW of power in 2 minutes'?. These problems involve symbolic manipulations and introduce students to symbolisms and conventions that may have little relevance to the world outside the science classroom. Students tend to believe that problem solving is a technical activity which involves a prescribed, logical method to reach pre-determined answers. The solutions to these problems do not involve the components of creativity and flexibility that must enter in the solutions to every day problems (e.g. Rowell & Dawson, 1989). Questioning and assessment need to address these deficiencies of standard curriculum materials. They could, for example, be directed towards the criticism and commentary of findings from practical work.

R.S.Castro & A.M.P. De Carvalho (1995) have used history based activities and lectures to teach about heat and temperature. Students were asked to seek answers through the help of history. As Castro & Carvalho have argued (p.68):

> Using the history of scientific knowledge is, above all, trying to transform the cold, dissertive, impersonal, static scientific jargon (when it is presented as a finished product), into a narrative, descriptive, sequenced language capable of interrelations that had been obscure, and therefore much nearer to students' cognitive skills.

Since history examines problems and events within specific contexts, it enlivens the teaching of science and technology as a wonderful, multifaceted human activity constructed through life stories and unique circumstances (Cohen, 1993; Kipnis, 1996; Kuhn, 1962; Jenkins, 1989; Jung, 1994). History introduces students to the rich interconnections between science and other fields, revealing the stability and established facts of science as well as the flux and inaccuracies. History provides students with the "tactics and strategies of science" (Jenkins, 1989) and enhances their understanding of the modification, revision, rejection, and restatement of a particular idea, concept, or law. Curriculum materials can be designed to explore historical documents and case studies, which can help students examine controversial issues and understand conceptual shifts in knowledge. Science becomes a dynamic, living enterprise with knowledge that is disciplined, yet flexible and transferable (Jung, 1994). Science teaching within a historical context introduces interdisciplinary relationships between science, technology, and society which can spur students to explore alternate possibilities and grapple with the misfits or their misunderstandings on the nature of science and technology.

Using themes from popular culture is another way to provide context. Stinner (1980) has used a well known TV character the *Bionic Man* to provide a context for teaching problems on kinematics and dynamics. Students critically examine the physical feats of the *Bionic Man*. They come to understand Newton's laws of motion and energy conservation by analyzing the stunts of the *Bionic man* (Stinner, 1980; p. 806):

> TV's Bionic Man can jump 20m high and stop a car at 70 KM/h just by sticking out his foot, and an elephant that takes him on in a tug of war comes out with egg on its face. Why can't we all perform such feats, and why don't his shoes catch fire?.........I ask my students to perform the calculations for each situation and to answer the questions. They then try to identify situations which they think are possible and those that they think are impossible. They are expected to be ready to support their claims

Practical work which could expand upon energy themes in NCERT curriculum materials across the various grade levels could be based upon:

- Historical case studies or vignettes, controversies, and/or other historical or technological investigations (e.g. investigation on factors that shaped the development of early knowledge about photosynthesis, theories of Van Helmont, Saussure, Priestley and Hutton, and other factors such as funding resources, interests of researchers, and occasional luck that guided the research, see NSES, 1996). These should employ a wide range of ordinary human language and narratives (Sutton,1996).
- Domestic energy practices (e.g. explorations of local industrial practices on energy. see also Driver & Miller, 1986)
- T.V. programs, library materials, local newspaper articles. Instructional materials can be designed to help students and teachers build upon local resources and conditions.

Contextualizing science, however, requires the coordination of numerous factors: It involves devising and using new curriculum materials and instructional approaches, alterations in present pedagogical theories and assumptions, and, ultimately, acceptance by students, teachers, and parents who may view contextualized science as inferior. In India, science which is oriented toward practical application is often called *pichada vigyan* or backward science (Mukund, 1988; also, Putsoa, 1992). The difficulty of curriculum changes demonstrates the success of decontextualized science as the dominant public perception of science. However, changes in current Indian curriculum materials will also enhance the already existing initiatives for teacher training.

Contextualizing science would necessitate corresponding changes in the methods of assessment and examination systems. In the present Indian system, student failure is attributed either to lack of teacher training or the incapacities of the student. Considering the rampant practice of copying and cheating in India (with the occasional help from parents !), the value of the prevailing system of examination and assessment is definitely in question. Assessment is the means through which the student legitimizes and articulates knowledge of concepts, laws, and theories (Kvale, 1991). We need to ask whether the existing system compliments the objectives of science curriculum described in the teacher handbooks. It may require an overhauling!

Investigating Controversy to Articulate Science

While educators have put forth the aims of science teaching, researchers the world over have identified the lack of understanding of the second and third aims (A2, A3) among both teachers and students. Driver et al. (1996) suggests that many British pupils have very little or no understanding of the social and contextual aspects of scientific practices. For example, these pupils thought that controversy is settled merely by gathering more hard facts. Gallagher and his collegues did a study on teacher understanding of the nature of science and found that the participant teachers (who all had long experience with *Project Physics Course*) were unable to articulate a deeper understanding of science (Gallagher, 1991). The teachers "failed to articulate an understanding of the processes by which scientists formulate new knowledge, or the controversies among philosophers of science about those processes" (Gallagher, 1991, p. 127). In an effort to move beyond a positivistic characterization of science and address aims 2 and 3, teachers and students may find controversies a particularly rich and useful addition to their science classrooms.

A controversy is a "disputation on matter of opinion which may exist over a longer period of time and divides groups of people" (Brante et. al., 1993, p. 181). Very few studies have explicitly addressed how the investigation of local or global controversies would help students to resolve issues of science-based conflict through practical reasoning (Geddis, 1991; Riss, 1991; Ziman, 1980). Ziman suggests that ".......they (controversial issues) can not be shut out of the classrooms or seminar just because they must not be taught in the dogmatic style of established science itself" (Ziman, 1980, p. 104). Gaddis (1991) makes suggestions for using controversial issues for improving the quality of classroom discourse. He suggests that we pay attention to the intellectual independence of students, uncover how particular knowledge claims may serve the interests of different groups, promote inquiry, multiplicity, and an intellectual context that measures the success of students to interpret, speculate, judge, and integrate their ideas. The last part of this paper will suggest how students can use a case study of an energy based controversy to learn about science and technology and gain experience in practical and difficult decision-making. The investigation is discussed primarily with higher grade level students in mind.

Although no single pedagogical approach is adequate for developing all learning outcomes in science, a historical case-study organized around a specific scientific and technological issue or problem may help students develop skills for historical inquiry and the action needed to solve day-to-day problems. One such case-study could be organized around the controversy over the Sardar Sarovar Project (SSP) in the western state of Gujarat in India. Due to the ubiquity and low environmental impact of hydro-power compared with highly polluting fossil fuel, hydro-power will remain a critical source of energy in developing countries like India (Moreira & Poole; 1993; Reddy, 1990; Sinha, 1992; Winshafter & Denver, 1991). The SSP shows us that the major benefits of hydro power become uncertain when geological constraints and social and environmental factors are considered. Investigation exposes students to different views on hydro power, the views of proponents who are primarily from the middle class and opponents who include *Adivasis* (tribal) families displaced by the dam construction. Their basic positions are expressed in the following quotes:

> "We have concluded for ourselves that this dam is not a development project according to our concept of development and our priorities."(Madhu Pathkar, a key figure among the opponents of Sardar Sarovar Project in Sataur, 1991, p. 10)

> "Why should anyone oppose when tribal culture(s) change? A culture based on lower level of technology and quality of life is bound to give way to a culture with superior technology and higher quality of life. This is what we call development" (Vidyut Joshi, a proponent of Sardar Sarovar Project in Fisher Ed. *Towards Sustainable Development*, 1995, p. 33).

These quotes indicate the profound social, environmental, political, and ethical dimensions of this science and technology based controversy. "One of the key aspects of the local, national and global debates over Narmada is the array of actors. ...Dam proponents and opponents seem sincere in their commitment to goals of sustainable development and social justice, but what they mean by these terms differs"(Fisher in *Towards Sustainable Development*? 1995, p.8; see also TIFR, 1993).

While investigating a controversy like SSP, some students may view SSP as a clash between a teleological world (e.g. to know a river is to know its purpose) and a world in which the instrumental, "neutral' view of science serves the political interests of those who control the means of production. Others may argue that the benefits of such projects for the nation are greater than the potential risks and sacrifices which are incurred. They might say that the resettlement of dam displaced people is one way to break the cyclical pattern of population growth, environmental degradation, and poverty. Still others may argue that only decentralized, alternate technologies that redefine 'poverty as a shortage of *biomass* rather than a shortage of cash' (Sattaur, 1990; see also Dasgupta, 1995; Johnsson, 1993) can potentially benefit the poor trapped in the vicious cycle of poverty. Each viewpoint expresses the personal values of an individual as an investor, consumer, and a member of a social group (Stern & Aronson, 1984). The divergent points of view help the student to understand that what we do is profoundly affected by what we perceive and understand. Practical aspects of the investigation can involve students in evaluation of such factors as how hydro-electric energy is conditioned by topography, river flow, climate, ecology, and land use as well as scale and design of the hydro-plant, and why these factors are essential for utilization of this energy source. The situation offers schools an excellent opportunity to help students understand the complex and important interaction between science, technology, and society in a specific context.

Investigating any science or technology-based controversy like SSP is *historical*, since students learn the kinds of applications scientific laws have had for daily life, and how their meanings and conceptions can change with time. Science students need the skills of a historian to analyze complex human interactions, to weigh the evidence and arguments of each faction (Mendelsohn, 1987). Investigation is *contextual*; students need to know the comparative costs of their day-to-day decisions; the consequences of a decision relative to the consequences of the alternatives. Students learn that their daily 'practical life' requires continual reinterpretation, in the light of their own immediate concerns and the dominating problems of society (Layton, 1973).

This kind of practical involvement in making difficult and controversial choices on energy means they are more likely to identify the problem, conduct investigation, and formulate and revise explanations. Most importantly, they learn to recognize and analyze their own presumptions and alternate explanations. Students can learn to interpret, evaluate, and understand their own narrative of inquiry by utilizing the processes of scientific inquiry. The science classroom becomes a forum to help develop informed attitudes and interests in science and technology practices.

Latour and Woolgar's *Laboratory Life* (1979) contains a discussion of the social construction of knowledge in science laboratories which carries important pedagogical implications for scientific inquiry. They discuss five types of statements: Type 1 statements are those which are mere conjectures or speculations; 'One day, fusion will solve all our energy problems'. Type 2 statements offer tentative suggestions; 'Water through this river can be used to generate electricity'. Type 3 statements specify the conditions under which scientific assertions may be valid; 'water is renewable for *small* dams'. Type 4 statements are prototypes of scientific assertions; ' The potential energy of the dam water is proportional to the height of the dam'. Removing the modality *small* changes the Type 3 statements to Type 4. Type 4 statements constitute accepted knowledge. 'Water and biogas are renewable energy sources' is another example of this type. Type 5 are the statements which nobody questions; for example, the meaning of "renewability" or "time" are normally taken for granted. These concepts are rarely featured in classroom discussions since traditional teaching practices and textbooks never question them.

Latour and Woolgar's definitions can be useful in helping students to understand, construct, and deconstruct the factual information of science. As philosophical critics, students and teachers can discuss what is "between the lines" of the story, which includes the possible meanings that emerge from official knowledge and alternate explanations. With, for example, SSP controversy in mind, students can take opposing positions on technology choices in the construction phase of analysis. They may speculate with their own intuitive ideas and interpretations of the issues. At this stage, there are no accepted facts but only conjectures or speculations (type 1 statements). As students negotiate and debate the controversial issues with their own tentative statements, they may reach conclusions. It should be emphasized that the prime purpose is not to find the correct solution, but to develop a sense of the most 'prudent and efficient balance of forces' (Engelhardt & Caplan, 1987). Students learn that closure of controversy through force is unwanted and that closure through consensus may be an unattainable ideal. As students strive for 'part fair and part correct' solutions (Engelhardt & Caplan, 1987), they gain insight into the human condition and learn to choose among multiple interpretations. Significantly, students are exposed to how their own theoretical viewpoints shape the inquiry process.

Once students learn first hand how a theoretical perspective shapes the process of investigation, pedagogy becomes theory-oriented, not fact-centered. This is an important distinction. Facts are different from theories; even a discarded theory is still a theory whereas facts, once rejected, cease to be facts (Shapin & Schaffer, 1989, p. 23). This does not imply that pedagogy is theory-centered. Unlike the teaching of science in its product form, students learn the actual processes in science and technological practices. Students learn the context, background, understanding of the options available to different factions, and the solutions chosen. This process of moving from type 1 to type 5 statements constitutes a social construction of reality as a result of the settling of controversy. As Latour and Woolgar (1979) summarize it (p. 180-182):

> It is because controversy settles, that a statement splits into an entity and a statement about an entity; such a split never precedes the resolution of controversy....Once controversy is settled, reality is taken to be the cause of this settlement; but while controversy is still raging, reality is the consequence of debate.

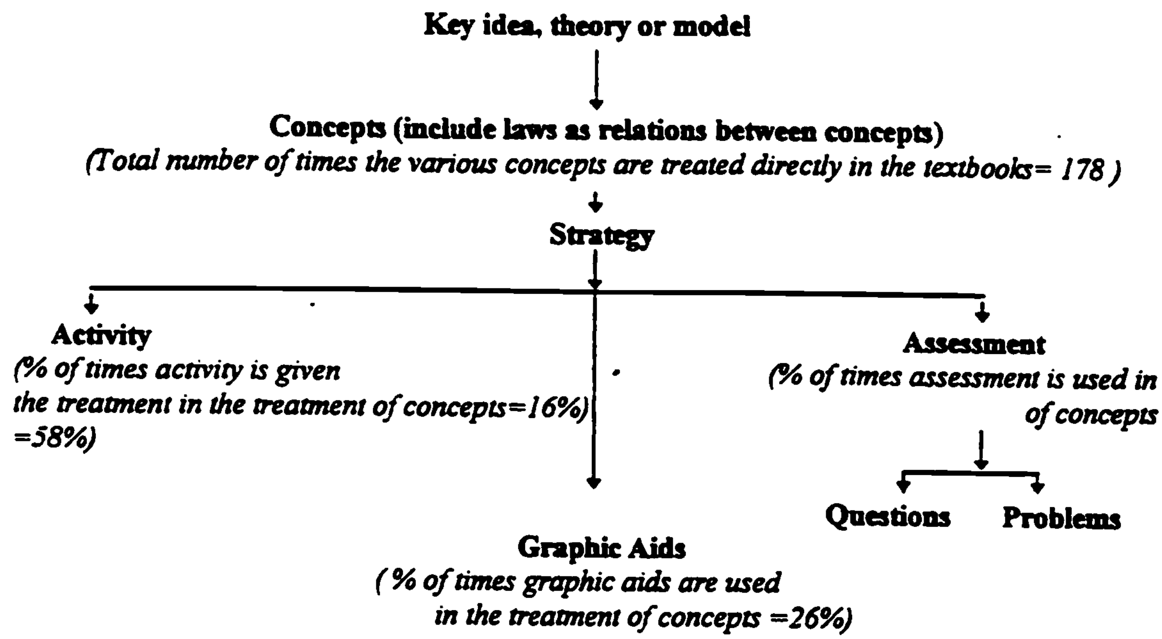
The process may help students to learn how a simple reality of statements corresponding to facts may dissolve in the incommensurable views expressed through controversy. The understanding of how controversy acts and how it is settled clearly shows that what we often take for granted is not necessarily an unquestionable assumption. Students often expect explanations in the terms of abstract science; they would be challenged to explore multiple interpretations of evidence and work for conflict resolution. Using an open forum, students develop attitudes to cope with the informed and uninformed criticism of peers. They learn that controversy is contained within larger socio-political dimensions and that these dimensions have relevance to their decisions.

Practical decision making in the SSP investigation will ask students to select and control variables, interpret results, and draw conclusions for the use of different alternate technologies. For example, present researchers on alternate technologies strongly recommend micro-hydro-dams and wind-energy as good renewable energy sources; large scale dams are not recommended (Grubb, 1990). How do researchers arrive at such recommendations? Investigation could be designed to assist students to make similar decisions based on cost-benefit analyses of hydro-electric energy compared with other alternate technologies. Students can compare energy sources like hydro-electricity, natural gas, kerosene, charcoal, fuel wood, dung etc. These could be compared for personal fuel preference, relative energy consumption, and comparative costs. In an application of bioenergy for household cooking, direct and indirect costs of simple cooking stoves that need less fuel and emit fewer airborne particulates could be contrasted with costs of hydro-electric energy, including disturbance of life-patterns, environmental damage, air pollution, and health problems. Similarly, costs of hydro-electric energy could be compared with the three-pot traditional mud stove used with fuel wood, crop stubble, and cow dung, and with a modified mud stove with a chimney (e.g. Johansson, 1993).

Controversies like SSP that remain unsettled to date introduce students to the urgency of concerns related to science, technology, and society issues. Contextualized case studies can engage students in practical decision making; students learn science by working with it. If classrooms are a focal point of activity, it would be a good real world experience for the students. Students are not merely supplied with official knowledge; they would see themselves as producers of new knowledge. They would feel that they are part of the curriculum and their activities are valuable to their society "here and now" (Posch, 1993; see also Rubba & Wiesenmayer, 1988).

School science curriculum materials can help students and teachers build on their prior knowledge and experiences to articulate science. The articulation of knowledge is the essential 'intermediary between an abstract science and practical action' (Layton et. al., 1993, p. 129). The contextualized approach advocated in this paper underlines the nature of science and technology, where both historical narrative and imminent laws are essential for a scientific understanding.

Appendix A



Concept total (178) is the total number of concepts times the number of times concepts are treated across the grade IV-X level textbooks.

Activity is used to confirm, explain, explore or apply a concept, law or theory presented in the textbook. These include investigations, demonstrations, laboratory activities, thought experiments or any other investigation.

Graphic aids include graphs, tables, charts, pictures or any other illustration used in the treatment of concepts in the textbooks.

Assessment includes problems (90) and questions (385).

Appendix B Results

Source of Answer in questioning

		Source of Answer				
Source	**Total number of questions**	***Prose 1***	***Prose 2***	***Graphic***	***Activity***	***Not given***
Chapter readings	189	3%	40%	4%	22%	31%
End of Chapter	196	72%	0%	1%	0%	27%
TOTAL	385	38%	20%	2%	11%	29%

Source of Answer to the Question

Prose 1	Answer follows the question and is explicitly given in the text.
Prose 2	Answer precedes the question and is explicitly given in the text.
Graphic	Answer is only derivable from the graphs, tables or pictures
Activity	Answer is derivable from the activity presented in the text. This type includes all questions that make some reference to an activity or an investigation.
Not given	Answer is not given in the text and is not derivable from the above sources

The above taxonomy was applied to all types: "YES or NO", "TRUE OR FALSE", multiple choice and explanatory questions.

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