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Secondary students beliefs about, understandings of, and intentions to act regarding the greenhouse effect

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SECONDARY STUDENTS' BELIEFS ABOUT, UNDERSTANDINGS OF, AND INTENTIONS TO ACT REGARDING THE GREENHOUSE EFFECT

By

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USE OF THESIS

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

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Abstract

The greenhouse effect (GHE) is a concern to everyone on this planet. To understand the GHE, students and citizens need an understanding of the chemical processes underlying this environmental phenomenon. Citizens need to be scientifically literate in relation to this phenomenon in order to participate in democratic decision-making and to take appropriate actions in their daily lives. As the GHE is a global issue it will require collective and individual actions to prepare for the likely climatic changes and to reduce the further impact of the GHE.

This study focused on high school students' beliefs about, understandings of the GHE and their intentions to act in ways that would reduce greenhouse gas emissions. Aspects of the GHE that are taught in high school science were also investigated. The study was conducted in five schools each in Western Australia (Australia) and Kerala (India) and data were collected from 438 Year 10 and 12 students representing compulsory and post-compulsory stages of education in both states. Two hundred and thirteen students from Western Australia and 225 students from Kerala completed a questionnaire and a sample of students and heads of science were interviewed.

A Propositional Knowledge Statement (PKS) was developed, which is a set of propositions that outline science concepts necessary for an understanding of the GHE in terms of its causes, effects, mechanism and actions that can be taken to reduce greenhouse gas emission. In this study the PKS is considered to be the essential knowledge necessary to interpret the GHE, to take appropriate environmental action, and to make informed decisions as a scientifically literate member of society. The questionnaire and interviews were based on the PKS.

The study revealed that high school students strongly believe that the GHE is real and affecting the climate at present and will also affect it in the future. They consider that the GHE is a relatively important social issue and they believe that governments should conduct programmes to raise community awareness and enact strict laws to reduce the release of greenhouse gases.

Students' understanding of the GHE is inadequate to make informed decisions and take appropriate environmental actions as a scientifically literate member of society. The majority of students and their families are already taking or are considering taking 10 accepted actions to reduce greenhouse gas emissions by household activities. The majority of students are not prepared to sacrifice their personal comforts or conveniences to reduce greenhouse gas emissions and they have strong reasons for that, however, they believe that governments should enact strict laws to reduce greenhouse gas emissions and should sign the Kyoto protocol.

The GHE is not adequately represented in Western Australian and Kerala science and chemistry curricula. The heads of school science departments in Western Australia and Kerala consider that school science should do more to teach the GHE, as it is an important aspect of scientific literacy.

An ideal scenario of students' beliefs about, understanding of the GHE and commitments to take action that would enable individuals and communities to reduce greenhouse gas emission was developed based on the PKS and reports such as IPCC (2001), UNEP (2001), AGO (1999; 2000) and UN (1992). The actual scenario was based on the data from this study. The differences between ideal and actual scenarios were discussed and implications for improving education about the GHE were developed. Information about the curriculum and students' sources of information about the GHE, students' beliefs, understandings and intentions to act were mapped against the theory of reasoned action (Ajzen & Fishbein, 1980).

Dedication

This thesis is dedicated to the hallowed memory of my father **Professor S. Madhava Kurup,** whose perceptions and value systems guide me in the journey of life.

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I am grateful to my "guru" Professor Mark Hackling for his encouragement, excellent guidance and productive criticism at all stages of the research and preparation of this thesis. I also extend my sincere gratitude to Professor Patrick Garnett, my associate supervisor for his support, suggestions and critical comments at various stages of this research, despite his busy schedule. I thank Professor Max Angus for introducing me to Professor Mark Hackling and for suggesting that he supervise my research.

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Table of Contents

List of Figures

List of Tables

CHAPTER ONE

INTRODUCTION

Background

The greenhouse effect (GHE) affects everyone on this planet. There is a mounting concern over the welfare of our environment and this should mark the start of a new era of public responsibility. In environmental education, the development of appropriate knowledge about environmental issues is an important component of individual and collective environmental responsiveness. Environmental education is becoming an integral part of education and of science education. In Agenda 21 (United Nations, 1992) an agreement was made between nations regarding the contribution of environmental education to the defence of the environment. Further, the social character of environmental issues links them to the everyday habits of individuals, as well as to the future of our planet (Fleming, 1988; Lucas, 1988; Solomon, 1988). The solutions to major environmental problems are not easy and require major changes in lifestyle and an international agreement is required for cooperation in educating people about environmental issues, to an unprecedented scale (Houghton, Jenkins & Ephraums, 1990).

Numerous studies have been carried out in order to determine whether variables such as race, gender, family, income, occupational prestige, socioeconomic status, political ideology and age could be good predictors of environmental concern. The results show that all correlations are weak, as these variables are not strong predictors of attitudes and behaviour towards the environment (Boschuizen & Brinkman, 1995; Lyons & Breakwell, 1994; Scott & Willits, 1994). Global warming and the greenhouse effect are receiving considerable attention by scientists and policy makers world wide (Houghton, Callander & Varney, 1992). Dire predictions, apocalyptic talk and doom-and-gloom scenarios are not enough to inspire people to change either their politics or their day-to-day behaviour (Annan, 2002).

According to Fensham (1988), there is confusion about how to incorporate environmental issues and concerns in an effective way into school science curricula for deeper understanding of the issues. There are concerns that the existing curricula and instructional strategies are inadequate to meet the challenges faced by society. The problem therefore, is how to link social, environmental and technological issues in science education through the science curriculum (Kurup, 1995). Fensham (1990) has also argued that basic environmental issues are not adequately represented in science curricula. Only a small minority of the students who study science at school will go on to pursue science as a career or even as a science related leisure interest. For the remainder, school science is simply a part of general education. Teaching about environmental issues at school level has the potential to influence students' awareness, knowledge, understanding, beliefs, attitudes and actions, which have direct impact in society and the world in general. These issues have to be addressed in the curriculum within multiple contexts according to local situations and conditions. Costa (1995) and Kelly (1997) emphasised the need for curricula that show how science makes a difference in peoples' lives and in society.

It is time for us to help students realise that science is a powerful force in modern society and with an adequate understanding of the beneficial and harmful effects of science and technology, citizens can make responsible decisions about the matters affecting the environment. Scientific literacy is seen, as a civic competency required for rational thinking about science in relation to personal, social, political, and environmental problems and issues that citizens meet throughout life. The debate about an appropriate meaning for scientific literacy is in progress (AAAS, 1993; Bauer, 1992; Bybee, 1997). Further the AAAS (1997) consider that a scientifically literate persons use science knowledge, where appropriate, in making decisions, forming judgements, resolving problems and taking action in their daily lives. Koballa (1992) strongly argued that science related social attitudes such as those pertaining to acid rain, the greenhouse effect, destruction of the ozone layer, use of illicit drugs, and the finiteness of fossil fuels play a crucial role in the development and maintenance of a scientifically literate citizenry.

The science education community should identify and incorporate opportunities for the development of appropriate science related attitudes in school science programmes for an improved quality of life and a sustainable environment. According to Gauld (1982) scientific attitudes are desirable personal attributes that influence the making of value-based judgements. Scientifically literate persons understand basic scientific concepts, science policy issues and also exercise their civic responsibility in relation to environmental issues. Simpson, Koballa, Oliver and Crawley (1994) argued that science education policy and practices should aim to produce scientifically literate persons who participate in environmental efforts of the community by taking appropriate actions. Research on educational outcomes should therefore focus on the behaviours and actions of students following instructions (Lagowski, 1988; Power, 1981).

Fetherston (1997) argues that personally constructed knowledge is more likely to be enacted in real world situations and more likely to remain as a part of the learner's knowledge system than rote-learned science. Yager (1991) pointed out that knowledge is created and legitimised by means of social interchange in many forms. Social interactions between individuals in a variety of communities, and social and cultural settings are central to the building of knowledge by individuals. These interactions bring coherency to an individual's world of experience and to the community's knowledge base. It is possible to build-up a coherent knowledge base by participating actively in collective efforts and coping with the world of individual experience. This coherent knowledge linked strongly to values, and influences behaviours and action within a social setting (Staver, 1998). So learning should take place in a social constructivist setting and construction should involve both individual and social processes (Driver, Asoko, Leach, Mortimer & Scott, 1994; Johnson & Gott, 1996; Solomon, 1993).

The Problem

The greenhouse effect is frequently discussed within communities and the impact of this phenomenon is affecting the quality of our lives. However, it appears that insufficient focus has been given to this issue within high school science and chemistry curricula for individuals to develop understandings and concerns about the greenhouse effect, to take decisions and to act responsibly regarding this issue in daily life.

Research by Gambro and Switzky (1996) showed that in the USA, high school students possess low levels of environmental knowledge and could only recognize basic facts concerning environmental issues. They could not apply their knowledge to generate potential solutions for environmental problems. Further, Granell (1993) observed in a sample of university students that their knowledge of environmental issues related to energy was only superficial and their awareness of environmental consequences of their everyday behaviour was low. Research by Lucas (1988) revealed that people are not able to understand and cope successfully with science and technology issues in their lives even though they were able to provide scientifically correct answers to apparently simple questions. These studies indicate the need to develop strategies that develop lifelong learning and informed decision-making ability for appropriate environmental actions and particularly in the case of reducing greenhouse gas emissions.

Rationale and Significance

Given that both knowledge and affect are necessary for active participation in environmental action, more research is needed to determine the status of students' knowledge, attitudes, and beliefs about the GHE, and the extent to which environmental science knowledge influences beliefs, attitudes, intentions to act and action in daily life. This is important in relation to the greenhouse effect, in which the decisions and actions of individuals, and collectively over populations have a significant impact on the problem. It is important to determine whether science and chemistry curricula adequately address the environmental science issues and the extent to which these learning experiences affect the concerns, beliefs, decisions and actions of students in daily life.

Human activities that are taking place in different countries and cultures all over the world have an impact on the environment. A comparison of students' awareness, understanding and beliefs about the GHE, between developed and developing countries would therefore provide a richer understanding of what is happening in environmental science education.

This research will make an original contribution to the literature on science and chemistry education, giving directions for improving high school science and chemistry curricula and approaches for teaching and learning about the greenhouse effect. Further this research links science and chemistry education at high school to public understanding of science, scientific literacy and favourable and sustainable environmental action. This study will: identify and define the concepts and proposition necessary for understanding the greenhouse effect and for interpreting media reports about this issue; determine the extent to which the issue is represented in syllabus and school science programmes; and, collect data about students' beliefs about and understanding of the issue, and decisions and action taken in relation to the issue. No previous research has taken such a comprehensive view of students' learning about the GHE.

Purpose and Research Questions

The purpose of this study is to investigate the status of environmental science and chemistry education particularly in the case of the greenhouse effect in high school curricula in Western Australia (Australia) and in Kerala (India) and its influence on students' concerns, beliefs, decisions and actions in daily life. More specifically, the research will address the following research questions:

1. What do people need to know to understand the greenhouse effect, understand reports in the media and to make decisions about the issue in their lives?

2. To what extent is the greenhouse effect addressed in state science syllabuses and school science programmes in Western Australia (Australia) and Kerala (India)?

3. What do Year 10 and 12 students in Western Australia (Australia) and Kerala (India) know and understand about the greenhouse effect?

4. What beliefs do students in Western Australia (Australia) and Kerala (India) hold about the reality, importance and likely impact of the greenhouse effect?

5. What actions have students taken in relation to the greenhouse effect and what actions do they believe the government should take in Western Australia (Australia) and in Kerala (India)?

6. What are the main sources of information regarding the greenhouse effect for students in Western Australia (Australia) and Kerala (India)?

Overview of the Thesis

This research was conducted to investigate the status of environmental science education about the GHE in high school science and chemistry programmes in Western Australia (Australia) and Kerala (India) and its influence on students' beliefs, understanding and intentions to act in ways that would reduce greenhouse gas emissions. This study was conducted in five schools each from Western Australia and Kerala. The student samples were from Year 10 (age 15) and 12 (age 17) representing compulsory and post-compulsory stages of education in both countries. The sample comprised 438 students, 213 from Western Australia and 225 from Kerala.

A Propositional Knowledge Statement (PKS) was developed, which is a set of propositions that outline science concepts necessary for an understanding of the GHE in terms of its causes, effects, mechanism and actions that can be taken to reduce greenhouse gas emission. In this study the PKS is considered to be the essential knowledge necessary to interpret the GHE, to take appropriate environmental action, and to make informed decisions as a scientifically literate member of society.

A questionnaire, based on the PKS, developed for this study was used to identify students' beliefs, understandings, intentions to act in ways that would reduce greenhouse gas emissions and their sources of information about the GHE. Interviews were used to elicit more detailed responses from students than could be generated by the questionnaire. Document analysis was conducted to identify the status of the GHE in curriculum documents, textbooks, syllabuses, and teaching and learning programmes. Heads of science, a dean of studies and an academic programme coordinator were also interviewed to determine their views about the teaching of the GHE at their schools.

Following the literature review in Chapter 2, the methodology is outlined in Chapter 3. Data about students' beliefs about the GHE are presented in Chapter 4. Students' understandings about the GHE are presented in Chapter 5. In Chapter 6, data about students' intentions to act in ways that would reduce greenhouse gas emission are presented. Information regarding what is taught about the GHE is presented in Chapter 7.

In Chapter 8 ideal and actual scenarios are presented. The ideal scenario is developed based on the PKS and some important reports, and the actual scenario using the results from Chapters 4 to 7. The data are then mapped against the conceptual framework of this study. In conclusion, Chapter 9 presents a brief summary of the research findings, implications of the research, and the limitations of the research. In addition it makes recommendations for further research, and discusses the contribution of the research to science and chemistry education.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Aims of Environmental Education, Public Understanding of Science and Scientific Literacy

Modern science differs in a number of ways from that of past centuries, and schools are changed with the responsibility of preparing citizens to live in a rapidly changing world. An important feature of modern science is that research and development in science and technology is more socially driven and decided, than theory driven. Further, achievements in science and technology have led to the development of a global economy that is rapidly giving rise to the world community. The primary assets of a nation are no longer its natural resources but rather its production and utilisation of knowledge. Hurd (1998) argued that the fundamental issue to be faced by citizens today is openness towards science and technology, and an awareness of the limits and possibilities of science and technology in bringing about an improved quality of life, and/or increased harm to life on this planet.

For the development of an adequate understanding and awareness of environmental issues to help citizens cope with them in daily life, science education should aim to (Bybee, 1993; Ross, 1991; Zoller &Weis, 1983):

1. Provide students with the appropriate problem solving and decision-making skills.

2. Induce positive environmental attitudes.

3. Make science lessons more popular and topical by connecting them to real and important situations and issues.

4. Help students to appreciate the complex interdependence of different environmental factors.

5. Demonstrate that science and technology, apart from structured information and knowledge also involve important values and ethics.

A scientifically literate public would improve the quality of public decision-making and actions. Decisions and actions made in the light of an adequate understanding of the issues are likely to be better than decisions and actions taken in the absence of such understanding. Greater familiarity with the nature and findings of science will also help the individual to question pseudo-scientific information (Royal Society, 1985). Cross (1999) argued that citizens will, in one way or other, need to be involved in lifelong learning if they are to participate in the ongoing debate about changes occurring in society. The most important question, therefore, is what kind of education in science would help people make the social and personal judgements and actions regarding social and environmental issues? Fensham (1999) traced how the idea of measuring the connection between school science and the public awareness of science has evolved. Measuring students' science learning is a standard aspect of school science, it is not surprising that measurement of public awareness of science is now an established activity internationally.

Surveys conducted in most industrialised countries (Horning, 1992; Trakina, 1993) suggest adults are more interested in and more attentive to medical and environmental issues than other scientific matters, and that the level of attentiveness correlates positively with the duration of formal education. Contemporary scientific literacy entails more than familiarity with the procedural and conceptual knowledge of science; it includes a capacity and willingness to apply scientific principles in daily life. Further, scientific literacy should be viewed in terms of promoting lifelong learning rather than simple acquisition of knowledge, and involves the ability to take informed actions towards personal and social issues concerned with science and technology (AAAS, 1993; Bybee, 1995; Cobern, Gibson & Underwood, 1995; NRC, 1996). Goodrum, Hackling and

Rennie (2001) in their review of the quality of science teaching and learning in Australian schools defined scientific literacy as...

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

Jenkins (1999) examined quantitative and qualitative studies of public understanding of science conducted in many countries. His findings revealed that school science education, citizenship and public understanding of science are linked in a number of ways. One of the functions of schooling is the development of an informed citizenry. Citizens need to be scientifically literate in order to be able to contribute to decision-making about issues that have a scientific dimension, whether those issues are personal or broadly social or political. Jenkins argues for "citizen science", that is the science which relates in reflexive ways to concerns, interest and activities of citizens as they go about their everyday business. For most citizens, interest in science is linked with decision-making or action for specific personal, social and political purposes. Law, Fensham, Li and Wei (2000) in their study of public understanding of science as basic literacy, argued that a socio-pragmatic approach should be used to define science content, which will contribute to the scientific literacy of future citizens. Hence, the curriculum would identify content for learning based on its relevance for everyday coping and participation in social discussions, decision-making and actions. Environmental chemistry issues such as ozone layer depletion, greenhouse effect, air pollution, and disposal of nuclear waste can be easily incorporated in this way.

Laugksch (2000) argued for a number of aspects of scientific literacy to be included in science education programmes and research. First of all, scientific literacy stands for what the general public ought to know about science and enables citizens to become scientifically aware of science and science related public issues, and for decision-making process related to personal and social issues where scientific knowledge and awareness play an important role. Further, scientific literacy is necessary for the democratic process to operate in a technological society. The knowledge citizens need to understand environmental issues would be a mix of facts, vocabulary, concepts, history and philosophy of science, an understanding of science process, problem solving and decision-making skills, and attitudes and values.

Hand, Prain, Lawrence and Yore (1999) argued that an adequate conception of science teaching and learning requires an awareness of the nature of scientific literacy, nature of science and scientific inquiry, the role of reasoning and the role of epistemological beliefs. Further, their research in the USA showed that scientific literacy cannot be viewed as facts, skills and attitude but rather as interacting related dimensions of abilities, eg, habits of mind, knowledge and communication.

Public understanding of science and scientific literacy are an outcome of both formal and informal education. The only realistic way, however, to promote the kind of changes required in the public perception of scientific knowledge and the process by which it is produced, is through formal science education. Millar and Wynne (1988) have strongly argued that it is not possible to promote a better understanding of science simply by tagging a science, technology, society dimension on to a mainstream syllabus that portrays scientific knowledge as truth. The necessary change is more radical than that. Science classrooms should provide examples that illustrate the far-reaching implications for the real world of scientific issues where science policy and democratic decision-making are important to cope with the environmental issues in daily life.

National and International Reports

Global warming is accelerated by human activities like industrialization, deforestation, farming and increased energy consumption through transportation and use of air conditioners (IPCC, 2001; Ponting, 1993). There are several national and international reports emphasising the importance of education and community based actions to reduce the impacts of environmental problems.

The Australian Greenhouse Office (AGO) in its annual report revealed that household energy consumption is one of the major (almost one fifth) contributors to greenhouse gas emissions (AGO, 1999). The AGO has been involved in many awareness and educational programmes to promote public understanding about the impact of the GHE and its enhancement due to energy consumption (AGO, 2000).

The United Nations emphasised the role of education for making it easier for governments to promote policies that will help in decision-making about environmental issues (United Nations, 1992).

The United Nations Environmental Programme (UNEP) documents and Intergovernmental Panel for Climatic Changes (IPCC) reports indicate the extent of impacts of human actions and enhanced GHE. Further these reports provide suggestions for education about the causes, mechanism, importance and impacts of the GHE and ways by which greenhouse gas emission can be reduced.

Constructivist Learning Theory

What is learned in traditional science courses, which is mostly vocabulary, is soon forgotten. Too much teaching tends to frustrate learning; students need opportunities to be actively engaged in their own learning. Although a definitive theory of human learning has yet to evolve, enough has been learned to help us realise that much of the prevailing subject matter in science curricula and styles of instruction are outmoded (Tobin & Tippins, 1993). A suitable learning theory for the present context of environmental education should take into account the following issues of learning (Bybee, 1993):

1. New learning is influenced by whatever the student already knows.

2. What is to be learned by the student is limited by the extent to which it makes sense or is perceived to have personal or social relevance.

3. Not all students learn in the same way.

4. What is learned is influenced by the classroom environment.

5. The extent to which much of what is remembered and used is limited by the degree to which it is applicable, particularly to personal and social issues.

Central to the new conception of science education is the constructivist view of learning. Constructivism is a dynamic and interactive model of how humans learn. According to this theory students redefine, recognise and elaborate their current concepts through interactions with objects, peers and events in the environment (Anderson, 1987; Carvey, 1986; Champagne & Horning, 1987). Further, constructivist-learning theory suggests that learning takes place by actively constructing new meaning by using the existing conceptual frameworks to interpret new information, in ways that make sense to the learner. Von Glaserfeld (1992) argued that, in science, hypotheses, natural laws and other scientific theories should not be taught as truth but rather as the most viable explanations for phenomena. Further Tobin and Tippins (1993) argue from a constructivist point of view, that learners should use science concepts and processes to make sense of scientific issues using existing conceptual structures for decision-making about scientific issues in society.

Osborne and Wittrock's (1983) generative model of learning describes the cognitive processes involved in learning science. These process include not only the learner's background knowledge and alternative conceptions, but also the sometimes neglected process of attention, motivation and attribution, generation and metacognition. Applications of constructvist theory of teaching and learning involves challenging students current conceptions through discrepant events and experiences that conflict with students' current ideas and result in students realising that their current explanations are inadequate. Subsequently students should be provided with experiences that suggest alternative and more scientific ways of thinking about the world and taking actions in daily life (Champagne, 1987). At present, successful students in school science accumulate a great deal of passive knowledge, but often surprisingly little of what Layton (1992) calls knowledge for practical action.

Scott, Asoko and Driver (1991) argued that for effective conceptual change to take place, the following aspects in teaching and learning should be emphasised in the programme.

1. Whatever the instructional approach adopted, the teaching should aim to support students in making links between their existing conceptions and the science view.

2. Science learning involves epistemological as well as conceptual development.

3. Science learning involves socialisation into a particular way of looking at the world.

4. Involvement of students with both practical activities and discussions including arguments.

The basis for conceptual change is assimilation and accommodation of the concept (Champagne, 1987). The availability of knowledge does not necessarily ensure that it is accepted and assimilated. The acceptance and assimilation of knowledge depends on interest and maturity. Accommodation of the concept involves changes in one's cognitive structures and that such changes can be strenuous and potentially threatening, particularly when the individual is firmly committed to prior assumptions. People resist making such changes unless they are dissatisfied with their current concepts and find an intelligible and plausible alternative that appears fruitful for further inquiry. Posner, Strike, Hewson and Gertzog (1992) emphasised that anomalies identified with the existing conceptions provides a form of cognitive conflict that prepares the conceptual ecology for an accommodation. Based on these aspects of conceptual change the classroom discourse should aim at creating dissatisfaction with alternative conceptions and providing an acceptable scientific conception in terms of their intelligibility, plausibility and fruitfulness (Hewson & Thorley, 1989). Conceptual change is a complex and slow process and rarely occurs in a single step.

Knowledge cannot be transmitted but must be constructed. Scientific knowledge is public knowledge, and as such, is constructed and communicated through culture and social institutions of science (Driver, Asoko, Leach, Mortimer & Scott, 1994). Solomon (1993) explained that we have two worlds of knowledge: life-world knowledge and scientific knowledge. Lucas (1991) studied informal learning situations and sources of knowledge such as TV, museums and informative conversations and found that these informed life-world sources of knowledge are different in form when compared to scientific school knowledge. Children learn social skills long before they come to science lessons. Johnson and Gott (1996) have argued that more efforts should be directed at identifying the possible underlying causes for apparent difference between scientific knowledge and life-world knowledge. Science teaching should take account of these differences so that in science teaching and learning, scientific knowledge can be applied to science related social issues and informed decision-making in daily life. In education for sustainable environmental action, concepts should be linked with social aspects of environmental science and chemistry issues. Learning should take a constructivist approach so that awareness, understanding, beliefs, attitudes and values are developed in such a way as to support appropriate action in social settings.

Theory of Reasoned Action

The theory of reasoned action (Ajzen & Fishbein, 1980) helps us understand and predict behaviour and can be applied to different behavioural domains including understandings, attitudes, and taking actions in relation to environmental issues.

The basic assumption underlying the theory of reasoned action is that humans are quite rational and make use of all available information both personal and social before they act. Behaviour is defined as an overt action under an individual's volitional control and within the individual's capability (Ajzen & Fishbein, 1980). Many behaviours of interest to science educators and researchers are both overt and volitional.

People usually do what they intend to do. Behavioural intention is therefore a variable that best predicts a person's behaviour, provided that there is a consistency between the level of specificity of the behaviour and behavioural intention. Two factors uniquely determine intention, one personal in nature and the other reflecting social influence. Attitude towards behaviour, the personal component represents a person's general feeling of favourableness and unfavourableness toward some behaviour. As information is gained about the personal consequences of performing a behaviour, an attitude is formed. Information about an issue influences an individuals' beliefs regarding a particular behaviour in relation to that issue, thus linking the behaviour with its specific attributes or personal consequences of performance.

Subjective norm, the social component, represents the perception one holds about social pressure to engage or not to engage in a behaviour. Support for performing a particular behaviour received from people with whom an individual is motivated to comply, increases the likelihood that the behaviour will be performed. Normative beliefs form the basis for subjective norm; behavioural beliefs form the basis for attitude towards the behaviour.

The significance of the theory of reasoned action for science education research, is that it enables an investigation to both predict as well as explain the underlying motivation for the occurrence of a behaviour, provided consistency is maintained in the level of specificity of the target behaviour, behavioural intention, attitude and subjective norm. The theoretical structure linking these concepts is as follows:

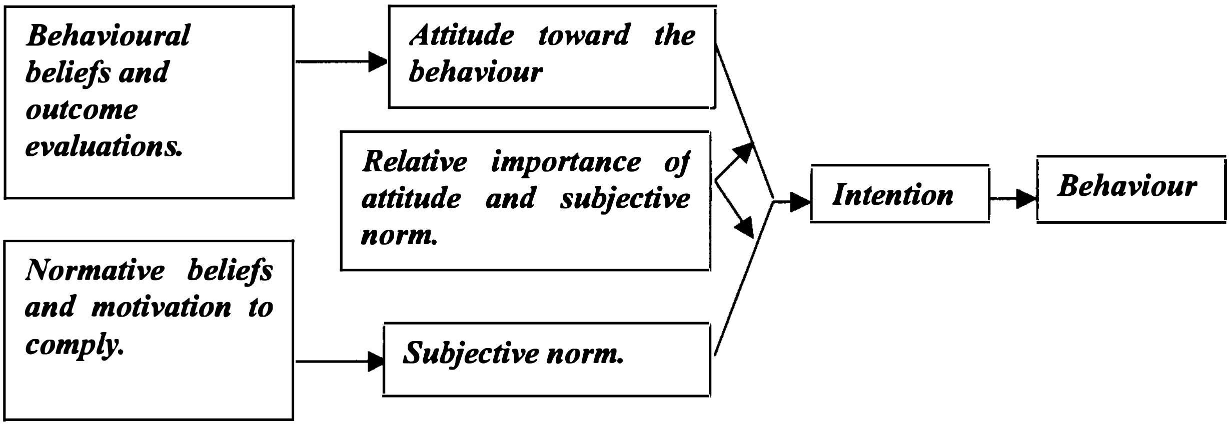


Figure 2.1. Relationship between beliefs, attitudes, subjective norm, intention, and behaviour (Ajzen & Fishbein, 1980).

Behavioural beliefs and outcome evaluations influence the formation of an attitude about performing a behaviour. Normative beliefs and motivation to comply shape the subjective norm ie, the social support for performing a behaviour. Subjective norm and attitude toward the behaviour both influence intention, though not necessarily to the same extent for each individual or behaviour. Behavioural intention is the best predictor of behaviour.

Based on the theory of reasoned action, Krynowsky (1988) developed the Attitude Toward the Subject Science Scale (ATSSS), which is used to predict attitude towards science. Shrigley and Koballa (1992) traced the attitude-knowledge link and found that it is supported by the theory of reasoned action. Further based on the theory of reasoned action Shrigley (1990) argued that science attitude scales can be expected to predict science related behaviour. Koballa (1984), in an exploratory study concerned with predicting an environmental behavioural intention towards recycling of soda cans, found that the correlation between attitude and behavioural intention rose considerably as attitude object, that is intention towards recycling of soda cans, become more specific.

In another study Koballa (1988) explored the theory of reasoned action by testing the behavioural intention of female students to enrol in elective science courses and confirmed that variables such as gender and science grades were found to have no significance for decision-making. Such a finding suggests that some variables long thought to mediate attitudes and behaviour such as socio-economic status, ethnicity and religious beliefs can be ignored. Further Crawley (1988) tested the effects of subjective norm on the teaching intentions of science teachers. The support of those within the teacher's professional sphere seemed to have little effect on behavioural intention; the precursor to behaviour. Crawley and Coe (1990) investigated the determinants of intentions to enrol in a high school science course using the theory of reasoned action. The evidence showed that the relative contributions of attitude and subjective norm to the prediction of behavioural intention varied among students depending upon sex, ethnicity, general ability and science ability. Though the relationship between attitude and behaviour continues to be a source of controversy, it is expected that a person's attitude will most often allow the person's behaviour to be predicted. Further, Schibechi (1983) has strongly argued that one of the important aspects of science curriculum should be selecting appropriate attitudinal objectives. In the case of environmental science and chemistry education, attitude, beliefs and experience must be addressed as these influence students' decisions and actions towards these issues in daily life.

Conceptual Framework

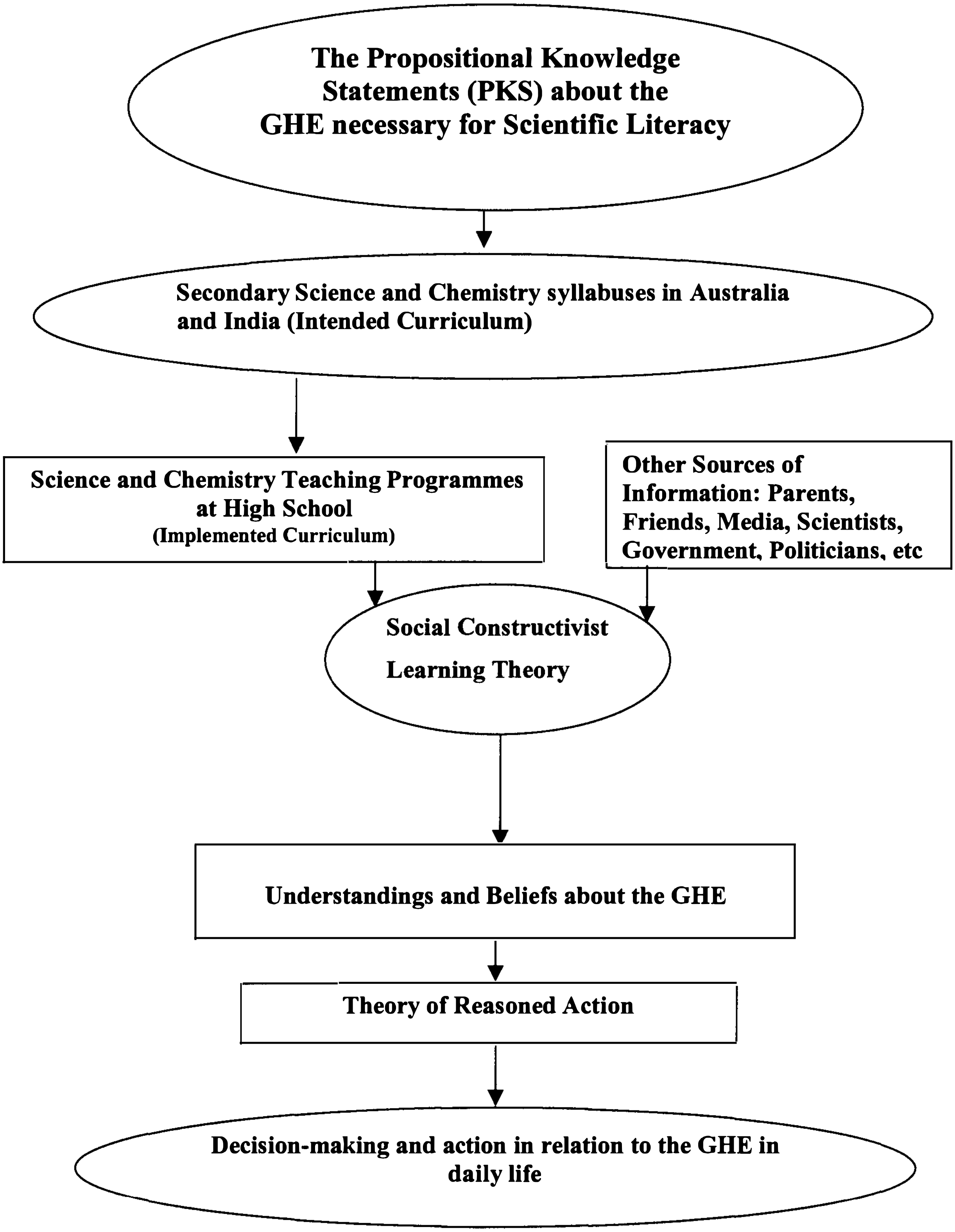


Figure 2. 2. Conceptual framework of the study.

Conceptual Framework

The arguments developed in the review of literature indicate that environmental science and chemistry issues should be included in science curricula and that the teaching and learning of these issues should be influenced by social constructivist learning theory. Teaching and learning about these issues should develop awareness, understanding, beliefs and attitudes that lead citizens to act in ways that maintain the quality of the environment. These learning outcomes are an important aspect of scientific literacy. The theory of reasoned action indicates how understandings, beliefs and attitudes influence intention to act and in turn influence behaviour. These are key elements of the conceptual framework for the proposed research, which is illustrated in Figure 2. 2.

Previous Research

Environmental Education and Public Understanding of Science

Numerous researchers have reported studies of community and local issues based learning including participation by the general public in education about environmental issues. Gallagher and Hogan (2000) advocate intergenerational community-based learning such as that described in their Thailand study. Primary school children under the guidance of their teachers identified ways of resolving forest related environmental problems in their local communities. Students framed questions, collected and interpreted data, refined data collection techniques and reported findings to the leadership and members of local communities. Using this information, students and adults identified a problem needing resolution and then formulated an action plan to address it. Finally they collaborated to implement and evaluate the effects of the action plan. Trumbell, Bonney, Bascom and Cabral (2000) at the Cornell Laboratory of Ornithology, USA, investigated the kinds of seeds that ground-feeding birds prefer to eat and involved the general public in a scientific investigation. They reported that the process of participating in the science project contributed to the general public's understanding about biology and about the scientific process. Further, this project helped in building a large database and has increased the participants' understanding of scientific processes through their engagement in authentic science. This opportunity provided a contrast to traditional, tightly scripted school laboratory investigations. These studies indicate the value of lifelong independent learning and participation in local environmental research activities for favourable environmental action.

Some other researchers found students are developing skills in dealing with controversial environmental issues from science lessons based on the contexts, discussions and personal experience of students. Gayford (1993) studied the effect of discussion-based group work in enhancing the understanding and awareness of environmental issues among 15-year-old students in England and found that this approach enabled students to make appropriate decisions about controversial issues related to their day to day life. Mason and Santi (1998) studied fifth grade students' changes of conception about the greenhouse effect and global warming due to socio-cognitive interactions in small and large group discussions using authentic contexts in an environmental unit. The results showed that classroom discussions led to the integration of new scientific knowledge into their conceptual ecology.

Robinson and Kaleta (1999) studied Polish high school students' responses to Roger Bybee's environmental threats (Bybee, 1987). The students ranked air quality, hazadours substances and water resources as the top three environmental threats based more on personal experience with the threats than whether or not they had taken environmental protection classes in school. Manazanal, Barreiro, and Jimenez (1999) studied the influence of ecology fieldwork on students' attitudes toward environmental protection. Fieldwork enables the learner to develop an understanding of the complex framework of ecological relationships that are related to the environmental issue. Consequently, the students developed a favourable environmental attitude based on the influence of direct experience. This study demonstrates that appropriate information and direct experience can influence attitudes and potentially behaviour.

Research was conducted to identify public understanding of radiation and radioactivity after the Chernobyl nuclear accident (Lucas, 1987). The research showed that there was a low level of general understanding of the term radioactivity and a widespread lack of clarity about the period of time for which radioactive waste might continue to be hazardous. Eijkelhof, Klaassen, Schottle and Lijnse (1987) studied public understanding of radioactive materials and radiation after the Chernobyl nuclear accident. The research revealed considerable difference between 'lay' and 'expert' mental models of the phenomenon. Eijkelhof and Millar (1988) identified some limitations of public understanding of science and science related issues.

Alternate Conceptions of Various Environmental Issues

Considerable information is available regarding students' alternative conceptions in various topics in chemistry and based on that, it is possible to draw relevant conclusions about how to improve teaching to provide more informed conceptions (Garnett, Garnett & Hackling, 1995). Further, Kornberg (1991) argued that whatever educational strategy is employed it is clearly advantageous if it begins early before complex alternative conceptual frameworks are established and before attitudes and prejudices based on those alternative ideas harden. Students' conceptions about ozone layer depletion and global warming show an array of limitations when compared with the actual scientific explanations, and confusions about the causes of ozone layer damage and global warming are leading to misconceptions, and those misconceptions are likely to persist (Boyes & Stanisstreet, 1992, 1994).

Students are aware of ozone as a gas but are not sure of its nature and get confused about ozone layer damage being a cause of the GHE. Misconceptions are embedded in a high framework of inertia as origins of one environmental problem are confused with the origins of another (Boyes, Chukran & Stanisstreet, 1993). Rye and Rubba (1998) showed that concept maps could be used as an interview tool to facilitate the externalisation of student understanding and awareness about global atmospheric change. Further Boyes and Stanistreet (1993) argued that students are unable to disentangle a whole series of environmental problems from overlapping causes, and sometimes assume that generally environmental friendly actions would help reduce all environmental problems.

Christidou and Koulaidis (1996) studied primary students' views about the ozone layer and its depletion using individual semi-structured interviews. They showed that children's conceptual models involve a variety of alternative conceptions, which can act as obstacles: that constrain understanding, and thus prevent the construction of adequate models. Christidou, Koulaidis and Christidis (1997) examined the relationship between children's use of metaphors and their mental models concerning the ozone layer and ozone depletion using semistructured interviews with Greek primary school children. They identified metaphors that can be used as an educational tool to enhance understanding of the ozone layer and its depletion. Koulaidis and Christidou (1999) inferred children's models of thinking about the greenhouse effect. The inferred models are differentiated according to the following criteria: a) position and distribution of greenhouse gases; b) existence of connection between the greenhouse effect and ozone layer and or its depletion; and c) types of radiation considered to be involved in the greenhouse effect.

Rye, Rubba and Weissenmayer (1997) investigated middle school students' alternative conceptions of global warming following a global warming unit. The findings of this study indicates that global warming instruction should help students clarify that ozone layer depletion and global warming are different environmental problems, and that the ozone hole does not enhance the greenhouse effect. Francis, Boyes, Qualter and Stanisstreet (1993), in their study of primary school students' ideas about reducing the greenhouse effect, revealed that children aged 8–11 years old appreciate that actions such as generating electricity from renewable sources and avoiding wasting electricity can help reduce the greenhouse effect. They also held positive ideas about recycling paper, planting more trees and believed that a reduction in automobile use would diminish the greenhouse effect. The study also identified two important difficulties for environmental education, first children have already constructed alternative models for the causes of the issues, second these issues being imperceptible to individuals are effectively abstract in nature and therefore are difficult to understand.

Fisher (1998) reported in his study that the greenhouse effect and ozone layer depletion are phenomena requiring detailed attention in school science. Children use a mix of scientific and life-world thinking for understanding these phenomena. The study revealed a progressive increase in employing scientifically based ideas over the years of secondary education. An understanding of the origin of children's ideas and of the conflation occurring in their explanations of the two phenomena can assist teachers in devising more effective programmes of study. Boyes, Stanisstreet and Papantoniou (1999) studied Greek high school students' perceptions about the ozone layer. The study revealed that the school students have a good understanding of the position and purpose of the ozone layer in terms of protection from harmful UV rays, but some also think that it helps keep the world warm or protects it from acid rain. Students were aware that the ozone layer is in danger and they believed that many varied forms of pollution are the cause.

Boyes, Chambers and Stanisstreet (1995) studied UK trainee primary teacher's ideas about the ozone layer. They were well aware of the nature, location and causes of ozone layer depletion. Many students confused ozone layer depletion with global warming. The proportion holding these ideas were similar to those of older secondary children, suggesting these misconceptions persist to the adult population. Since these ideas were found in final year trainee teachers, there is a danger that erroneous idea or attitudes based on them might be perpetuated in their teaching. In a similar study in the UK, Dove's (1996) investigation of student teachers' understanding of the greenhouse effect, ozone layer depletion and acid rain, revealed that there is familiarity with all these environmental issues but little understanding of the concepts involved. One common misconception is that the GHE is the result of ozone layer depletion, but there is a clear understanding that the ozone layer protects us from UV radiation and that it is currently being destroyed by CFCs. Burning coal is linked to the formation of acid rain, but there is little appreciation of why trees in Scandinavia are being destroyed by this process.

Hillman, Stanisstreet and Boyes (1996) studied trainee teachers' ideas about links between vehicle emissions and global environmental issues using a graphic questionnaire in the form of flow charts. Most respondents' understandings were that cars contribute to global warming and carbon dioxide is responsible. Two thirds realised that cars contribute to acid rain, but the unorthodox idea that carbon dioxide is responsible was predominant. A prominent misconception was that cars damage the ozone layer. The major concern raised by this study is that there is a possibility of these teachers' misconceptions being perpetuated in their teaching. Boyes and Stanisstreet (1997 a) identified a dominant conceptual model that 13 and 14 years old UK student hold about causes of the GHE and ozone layer depletion. Some students link the two phenomena and think that the holes in the ozone layer cause the GHE, and the GHE causes ozone layer damage. The most common suggested connection appears to be that holes in the ozone layer somehow allow more solar energy to arrive at Earth, and no distinction was being made between heat rays and UV rays.

Potts, Stanisstreet and Boyes (1996) studied the potential of global environmental issues as starting points for learning in science. The pre conceptions of children aged 12-13 about the nature, function and vulnerability of the ozone layer revealed that most children are familiar with the general location and nature of the ozone layer, but are less informed about the ozone layers' magnitude. Further, many children think that pollutants in general damage the ozone layer and some confused UV radiation with heat. Boyes and Stanisstreet (1997 b) studied children's idea about how car exhaust emissions affect three global environmental problems by using a graphic questionnaire in the form of flow charts. The study revealed that the majority of the children appreciated cars exacerbated global warming and that carbon dioxide is responsible. However, there are some misconceptions regarding acid rains and ozone layer depletion. Some students considered cars are emitting CFCs and damaging the ozone layer and also carbon dioxide emitted from cars is the cause of acid rains.

Misconceptions affect students' understanding of many environmental issues and Muson (1994) suggested that experiential learning or visiting places of interest could help develop more acceptable scientific conception. Wals (1992) argued that though different alternate conceptions of pollution and environmental issues can be found within one group of students, all of them are found to be concerned with the consequences of the issues regardless of the context in which they grew up or learned. In studies concerned with pollution and biodiversity, Brody (1990) identified that students at all levels have some understandings about the environmental issues but there are some important misconceptions also.

The research to date, has identified the following alternate conceptions held by school students about ozone layer depletion, greenhouse effect and acid rain:

- Causes of ozone layer depletion and the GHE are linked.
- Ozone layer depletion allows more radiation to reach the Earth and to be a cause of the GHE.
- The ozone layer protects us from harmful UV radiation, and also helps keep the world warm or protect it from acid rain.
- Pollution in general damages the ozone layer.
- No distinction is made between heat rays and UV rays.
- Cars emit CFCs and damage the ozone layer.
- Carbon dioxide emitted from cars causes acid rain.

Research has also revealed the following alternate conceptions among UK trainee primary school teachers regarding ozone layer depletion, the greenhouse effect and acid rain:

- The GHE is the result of the ozone layer depletion.
- Only little appreciation about why trees in Scandinavia are being destroyed by the acid rain.

- Limited understanding of the link between vehicle emission and global warming.
- Cars are contributing to acid rain as carbon dioxide is emitted.
- Cars are damaging the ozone layer as CFCs are emitted.

Science Technology Society (STS) Approach to Teaching and Learning Science

Science and technology have both great promise and danger. Citizens should understand and appreciate the applications of science and technology in matters such as diet, energy use and environmental issues in daily life. Many science concepts are linked with technology and issues in daily life, however, many existing science curricula fail to make links between science and technology and to present them in a social context. Further, technology is a part of each citizen's direct and daily experience and generally science is not. Technology is not yet adequately represented in the curriculum of many schools. Although science and technology are distinct, they are so intertwined that most interactions between them and society do in fact involve all three. Citizens have a genuine need to understand the impact of science and technology on our society and on many social issues. Education has a responsibility to meet this public need (Johnson, Johnson & Holubec 1986).

Decision-making is new to science classrooms, but it is a logical extension of inquiry and problem solving in personal and social contexts. Further, decision-making, choosing the best alternative to resolve an issue involves making value judgement on the desirability of each alternative (Bybee, 1993). Class discussions of science, technology and society issues help students develop insight into their current values and assumptions and recognise the importance of being receptive to ideas. It motivates them to develop sound values and to be responsive to change where necessary. Learning to apply their skills to solve problems and resolve issues give students encouragement to act and to participate as citizens (Yager, 1993).

The science technology society (STS) approach of teaching science emphasises teaching concepts in context and developing informed decision-making ability by linking science and technology with social issues. According to Fensham (1988), the STS approach emphases contextual learning and Yager (1991) suggests that STS strategies of teaching should provide students with the opportunities to perform citizenship roles as they attempt to resolve issues concerned with science, society and technology. Malcom (1987) argued that scientific knowledge, solutions to practical problems, culture, and human context are to be given emphasis and should be integrated in their presentation and that the STS model of instruction is best suited for this purpose.

It is not productive for a society to have its citizens react solely on an emotional basis, or just demanding answers. It is essential that they ask questions, obtain evidence for decision-making, understand the limitations of scientific evidence, and participate in formulating effective environment related policies. Their and Hill (1988) studied the influence of the Chemical Education for Public Understanding Programme (CEPUP, 1987) which aims to develop chemical concepts and processes associated with current social issues. The study endorses the need for activity-based learning, and highlights the importance of taking the message out into the community. Kortland (1996) argued that students increase their decision-making ability through an STS approach to learning about environmental issues. Further, the National Science Teachers Association (NSTA, 1982) stated the goal of science education should be to produce citizens who are able to use scientific knowledge in every day decision-making. Such individuals both appreciate the value of science and technology in society and understand the limitations of science.

Hofstein, Aikenhead and Riquarts (1988) emphasise the need for teacher student collaboration and flexibility for incorporating topical events and local examples into STS science lessons. Holman (1988) described the importance of STS in ensuring social justice by helping students to make considered judgments concerning issues facing society. Environmental education should help students to empathising with concerns regarding the use and abuse of technology in society (Solomon, 1988). Further, Layton (1988) argued that science and technology should be introduced to students with social norms and Hunt (1988) found the STS approach is providing a basis for learners to understand the beneficial and harmful aspects of technology. According to the studies of Bradford, Rubba and Harkness (1995), STS courses helped college students to hold more informed, realistic views about scientific and technological aspects in society and to become active and informed decision-makers on science and technology related social issues.

Public education has two responsibilities, one to society and the other to individuals within the society. The combinations of policy statements by national organisations in Australia, UK and USA and research studies strongly support an STS approach to instructions. Although the review of literature and research supporting an intended STS curriculum is a first step in reforming science education, policy statements and recommendations must not be confused with actual curricular changes. In short, recommendations for changes are not synonymous with actual changes in science curricula. There must be a real and accurate representation of STS in curriculum materials and instructional strategies that are used by science teachers. A survey of science and social science teachers (Barman, Harshman & Rusch, 1982) indicated that the majority of teachers supported the integration of science and social science and supported teaching about STS topics. However, only a few indicated they are committed to initiating an STS programme. This was corroborated by the studies of Bybee and Bonnstetter (1987) who reviewed major textbook programmes and actual practises of teachers, and found a significant disparity between the intended STS curriculum and the actual implemented STS curriculum.

Examples of Effective Approaches for Environmental Science and Chemistry Education

Environmental science and chemistry issues are rooted in science and chemical fundamentals. The connection between theory and applications are often not strongly linked in the teaching/learning process. Applications are often included as additional features rather than as an integral part of teaching. In some of the innovative approaches, selection of activities that were relevant to local conditions made a lot of difference in terms of students' understanding and attitudes. Kee and McGowan (1997) presented fundamental principles of chemistry through a series of environmentally linked activities and found that there is a capability of revealing the underlying fundamental principle of chemistry through environmentally friendly actions. Leharane and Chowdhry (1995) used variety of acid-base complex metric titration with samples of local aquatic systems to develop a deeper understanding of acid rain and its effect on the aquatic system. It linked the environmental concern with the scientific concepts and process of acid-base titration.

Open-ended investigations provide myriad opportunities for linking chemistry concepts to environmental concerns. Devonshire (1996) investigated heavy metal pollution in the Bristol Channel using an open-ended task for the sixth formers that involved the analysis of heavy metal content of a particular variety of seaweed. While doing a project on water pollution for the students, Randall (1997) found that teaching with direct experience develops deeper understanding of the extent of the problem, but linking environmental issues with chemistry concepts also enhances learning. The studies of Kelter, Grundman, Hage and Carr (1997) observed that the analysis of water pollutants is interesting chemically, and relates well to the interdisciplinary nature of the modern chemistry curriculum.

Juhl, Yearsley and Silva (1997) explained the difficulties students experience with identifying the correct apparatus and method while doing open-ended investigations, however, these activities provide a valuable taste of an authentic scientific experience. Davison and Hewitt (1993) argued that to manage our environment properly we must be more informed about the natural process to maintain the equilibrium of nature and impact of our activities on Earth. The interdisciplinary nature and co-operative learning with open-ended scientific investigations gives students independence and self motivation that is necessary for a deeper understanding of the environmental issues and an awareness of the actions they could take in daily lives that will maintain the quality of the environment.

Limitations of Previous Research and Significance of the Proposed Research

Research has focused on students' understanding and attitudes about specific environmental issues. Most of the research data about students' awareness and understandings of specific environmental issues has been collected using questionnaires and interviews. Zimmermann's (1996), analysis of 15 years of research on environmental education emphasised the importance of understanding how interaction of knowledge and beliefs influence informed environmental action. The proposed research focuses on these relationships.

Arcury and Johnson (1987) argued education has a strong positive relationship to environmental knowledge and attitude. However little work has been directed towards the development of instruments to probe environmental knowledge, attitudes and actions (Musser & Malukus, 1994). Eiser, Reicher and Podadec (1995) argued that environmental issues should not be treated in isolation but in terms of a broader interpretive framework and set of values that can guide investigation of students' conceptual frameworks and values. This would predict how they would intent to act in relation to particular environmental issues.

The proposed research aims to identify the concepts and propositions necessary to understand the GHE and interpret media reports on this issue. The extent to which the GHE is represented in the intended and implemented curriculum will also be determined. Data for Year 10 and 12 students will show what beliefs, understandings students have about the GHE and the actions they have taken in relation to the issue, and their main sources of information about the issue. Data from developed and developing countries will provide a richer perspective. This research is unique in that no previous research has taken such a comprehensive approach to investigating students' learning about the GHE. Hence this research will provide new insights into the teaching and learning of the greenhouse effect, give direction for further research, and implications for teaching and curriculum regarding environmental science and chemistry issues, thereby providing a new contribution to the science and chemistry education literature.

CHAPTER 3

METHODOLOGY

Design of the Study

This study was conducted using a mixture of qualitative and quantitative methods for investigating the research questions and the findings were mapped against the conceptual framework of the study (Roberts, 1996). Multiple data sources were used so that triangulation of the data could be used for identifying key linkages between different aspects of the issues (Fielding & Fielding, 1986; Flick, 1992). An interpretative research paradigm has been selected as being appropriate to guide the search for patterns in the data and for generating assertions (Erickson, 1986; Isaac & Michael, 1997). Assertions and generalisations have been generated about issues where common patterns of responses were obtained (Coffey & Atkinson, 1996). The research design includes samples of secondary students from state capital cities in a developed country (Australia), and a developing country (India) to see if the status of the GHE in the science curriculum varies between countries. A comparison has been made between capital cities in Australian and Indian states, where it is appropriate (Hakim, 2000).

Participants

This study was conducted in Perth, Western Australia and Trivandrum in Kerala, India. Perth and Trivandrum are of comparable size and are state capitals. The participants in the study were students in Year 10 and 12 representing the end of compulsory and post-compulsory stages of school education in both states. Year 12 students were those who took chemistry as a subject.

Sample

Five schools each from Perth and Trivandrum were selected for this study (Three schools from the government sector and two from the private sector). In each state capital, the schools were selected so that they represented a range of socio economic status. Thirty Year 10 and 15 Year 12 chemistry students from each school were given a questionnaire, and five Year 10 students and three Year 12 students from each school were interviewed. The heads of science of these schools, one dean of studies from Australia and one curriculum coordinator from India were interviewed to gain insights into the teaching and learning programmes in their schools.

Procedure

Phase 1:
A content analysis of the GHE was conducted to generate the Propositional Knowledge Statement (PKS) that describes the minimum essential knowledge needed to understand the issue, interpret media reports about the GHE, and make decisions about the issue in their lives (Research Question 1).

Phase 2:
State curriculum, syllabus documents, textbooks, and teaching and learning programmes were analysed to identify the concepts included in the curriculum in relation to the GHE. Heads of science, a dean of studies and an academic programme coordinator were interviewed to determine the extent to which the GHE was represented in curricula and teaching programmes (Research Question 2).

Phase 3:
A questionnaire and student interviews were used to probe students' understanding of the GHE (Research Question 3), their beliefs about the GHE (Research Question 4), what actions they have taken in relation to the GHE (Research Question 5), and their main sources of information about the GHE (Research Question 6).

Development and Validation of Propositional Knowledge Statement (PKS)

Concepts necessary for an understanding of the GHE were analysed and defined as a set of propositions by a chemistry teacher, a science educator and a chemistry professor and author of a chemistry textbook. The Propositional Knowledge Statement (PKS) was sent to one chemistry professor and one environmental chemistry scientist of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, who were asked to validate the accuracy and adequacy of the propositions in terms of understanding the GHE, making sense of media reports about the GHE and making informed decisions about the issue in daily life. The chemistry professor was of the opinion more detailed knowledge should be known at Year 10 and 12 levels, but the environmental scientist from the CSIRO argued that great detail was not necessary at this level. The experts also provided suggestions for improving each of the propositions. The propositions were revised based on the suggestions made by the two experts. The PKS provided a framework to guide the development of data gathering instruments for this study, thus ensuring their validity. The PKS is attached as Appendix 1.

Instruments

A questionnaire and interviews were used to gather data from students.

Questionnaire

The questionnaire was based on the theory of reasoned action (Ajzen & Fishbein, 1980). The questionnaire is similar in structure to ones used in predicting behaviours and intentions in family planning, marketing research, voting behaviour, and in a case of nuclear safety that were based on the theory of reasoned action (Ajzen & Fishbein, 1980).

The questionnaire has five parts. The first part identifies concerns and beliefs about the issue, including the relative importance of the issue compared to other issues in daily life. The second part probes students' understanding of the GHE. The third part asks about actions taken regarding 10 easy ways of reducing greenhouse gas emissions. The fourth part probes students' reactions to a proposal to reduce car use. The fifth part deals with the students' sources of information about the GHE, and expectations about government actions. The questionnaire is attached as Appendix 2.

Steps in the construction of the questionnaire

Part A.

This part of the questionnaire sought to probe students' beliefs about the relative importance of the GHE compared to some other common issues of concern in daily life. The other common issues were identified from a sample of students at Year 10 and 12 by asking them to write 10 issues that concern them in daily life, in order of importance. Seven issues were chosen based on the responses given by the students in the researcher's school. Questions regarding students' beliefs about the reality and magnitude of the expected environmental changes due to the GHE at present and in the future were also identified and included (Research Question 4).

Part B

Based on the PKS, questions were framed to probe students' understanding of the GHE in four sections. Section 1 required students to complete and illustrate a partial diagram to represent the mechanism of the GHE; section 2 asked students to explain the diagrammatic representation; section 3 asked students about the GHE gases; and section 4 included questions regarding various aspects of the GHE, that is, causes, effects and mechanism. Part B provided information about students' understanding of the GHE (Research Question 3).

Part C

Part C included questions about the actions students and their family have already taken, are considering taking or not interested in taking about the 10 easy ways to reduce household greenhouse gas emissions identified by the Australian Greenhouse Office (AGO, 2000) (Research Question 5)

Part D

Part D presented a proposal to reduce car usage in the city by increasing the licensing fee, parking fees and petrol prices to reduce greenhouse gas emissions. Students were asked to respond to this proposal to determine whether they would support proposals such as this, that might be imposed by governments (Research Question 5).

Part E

Questions in Part E asked students how much information they obtained about the GHE from various sources. The sources of information were identified from a sample of Year 10 and 12 students at the researchers' school by asking them to write about their major sources of information regarding the GHE. These sources were further discussed with the experts in the field of science education, and the five sources; parents, teachers, textbooks, friends and media were included in the questionnaire. In this part they were also asked to write down the actions that they expect governments should take (Research Questions 5 and 6).

Pilot

The questionnaire was first piloted with selected students section by section at the researchers' school, and after that, the full form was piloted to check that the instrument could be administered and completed within one hour.

Interviews

Student interviews were conducted to obtain further elaboration of students' responses to the questionnaire. The questions focused on the mechanism of the GHE, scientific predictions and their intentions to act towards some proposals to reduce greenhouse gas emission. The interview questions for the heads of science focused on the teaching of the GHE in their school. Interview questions for the students are attached as Appendix 3 and questions for the interview with the heads of science are attached as Appendix 4.

Data Collection

Ethical clearance was obtained from the Edith Cowan University ethics committee before data collection. Permission was obtained from teachers and parents before administering the questionnaire and interviews.

Questionnaire

The questionnaire was administered in all selected schools by the teacher, under test conditions. Students were allowed one hour to complete the questionnaire.

Student Interviews

Semi-structured interviews were conducted with a sample of students who completed the questionnaire and were selected after analysing their responses on the questionnaire. A fair distribution of students from the full range of ability was interviewed and printed questions were given to the students while interviewing to ensure clarity of the questions (Brenner, Brown, & Canter, 1987). The interviews were tape-recorded.

Head of Science Interviews

Semi-structured interviews were conducted with heads of science from the schools participated in this study, a dean of studies and a curriculum coordinator. The interview questions were to obtain details of teaching about the GHE at lower school science and upper school chemistry.

Data Analysis

Analysis of data from documents, questionnaires and interviews used a range of qualitative and quantitative methods, which are described below.

Document Data

The analysis of the state syllabus and curriculum documents, textbooks, and teaching and learning programmes provided information about the extent to which the GHE is addressed in the science and chemistry courses in Western Australia and Kerala. Extracts were taken from documents to include in the records of data.

Questionnaire Data

A large number of the questionnaires was read and re-read to identify common categories of responses to the open questions. A coding manual (see Appendix 5) was developed which listed the codes for the various response categories. Using the coding manual the students' responses were coded into an Excel spreadsheet. Data were then imported into SPSS so that descriptive statistics could be calculated. Data from the five parts of the questionnaire were analysed as follows:

Part A deals with the students' beliefs about the GHE. The average ranking of the GHE compared with other issues was calculated, and the percentage of students giving various responses regarding their beliefs about present and future the impacts and magnitude of changes of the GHE were also calculated.

Part B deals with students' understanding of the GHE. Students' responses were coded into five levels of understanding. Level 1 represents the maximum understanding and Level 5 represents minimal understanding about the GHE. The percentages of students in these categories were calculated.

Part C deals with actions taken regarding 10 easy ways to reduce greenhouse gas emission at household level. Students' responses were coded into three categories; already doing, consider doing and not interested in doing and percentage of responses in each category were calculated.

Part D of the questionnaire presents students with a proposal to reduce car use for reducing greenhouse gas emission. Students' responses were first categorised into supporting or not supporting the proposal, and then into categories of reasons. A large number of the responses were read and re-read to identify common categories of responses. The percentage of responses in various categories were calculated.

Part E questions asked about students' sources of information about the GHE. For each of the sources, students indicated whether they got most, some and none of their information from that source. Percentages of the responses were calculated for sources of information. Students' expectations about governmental actions were categorised into six categories from the students' responses. Percentage of each category was calculated.

Interview Data

Audio recording of the semi structured student interviews were transcribed and analysed to provide further elaboration of the reasons for the responses given on the questionnaire. The interview data provided corroboration of questionnaire responses and quotations to illustrate student responses and reasons for responding in particular ways. Interviews with heads of science, the Dean of Studies and the Academic Programme Coordinator were analysed to clarify the details of teaching about the GHE in lower school science and upper school chemistry. These data were added to the information gathered from document analysis.

Interpretation of Data

The research questions and conceptual framework of the study guided the analysis of the data from the questionnaire and interviews. Coding and interpretations of students' and teachers' response from the questionnaire and interviews involved reading and re-reading the answers and identifying emerging patterns related students' beliefs, understanding and intentions to act regarding greenhouse gas emissions (Krathwohl, 1998). Assertions were developed from the emerging patterns in the data regarding students' beliefs, understanding and intention to act in ways that would reduce greenhouse gas emissions. The assertions were analysed further to identify key linkages and generalisations that support ideal and actual scenarios (Erickson, 1986). Triangulation of data from different sources helped corroborate findings and identify key linkages and generalisations that support the scenarios (Erickson, 1986; Fielding & Fielding, 1986; Flick, 1992). Some comparisons between Australia and India were made based on data gathered using common instruments (Hakim, 2000). Summaries of coded data and assertions based on the data are presented in the following results chapters.

CHAPTER 4

STUDENTS' BELIEFS ABOUT THE GREENHOUSE EFFECT

Introduction

The climatic changes as a result of the enhanced GHE are expected to contribute to major ecological, sociological, and economic changes. Most human activities, in one way or other, have a significant influence on the GHE. The decision each person makes about transport and energy use impact on greenhouse gas emission.

Generally speaking, beliefs reflect a person' past experiences. Beliefs determine attitudes and intentions to act regarding a phenomenon. According to the theory of reasoned action (Ajzen & Fishbein, 1980) beliefs have a powerful influence on behaviour. Assessing students' beliefs about the GHE may help explain their intentions to act regarding the GHE.

Students' beliefs about the GHE were studied in terms of its relative importance compared with other social issues, its reality, seriousness, the effect of the GHE on global warming, and the importance of personal and governmental actions. The sources of information from which students learn about the GHE were also investigated. The sources from which students get their information about the GHE are likely to influence the development of their beliefs.

Students' beliefs and their sources of information about the GHE were investigated using: (i) questionnaire question A. 1, which required students to rank the GHE against to six other important social issues; (ii) questionnaire questions A 2.1 to A 2.5, regarding the effects of personal and governmental actions on the GHE; (iii) questionnaire question E 1.1 to E 1.5, regarding sources of information about the GHE; and (iv) interview questions 2 and 3 which asked students about the reality of the GHE and asked them to predict what changes will be noticed in their capital city in the next 50 years in terms of the enhanced GHE.

Beliefs Regarding the Relative Importance of the GHE

Four hundred and thirty-eight students (Year 10 and 12) from Australia and India ranked seven important social issues according to their impact on them in daily life. The issues were: economic issues and poverty; the GHE; increasing crime; terrorism; health and diseases like AIDS; family breakdown; and increasing drug use. These issues were initially identified from a pilot study with a sample of students at Year 10 and 12 by asking them to write, in order of importance, 10 issues that concerned them. The seven most important issues were chosen based on the responses given by students at the researcher's school.

Students' ranking of the importance of the GHE is summarised in Figure. 4.1 and Table 4.1.

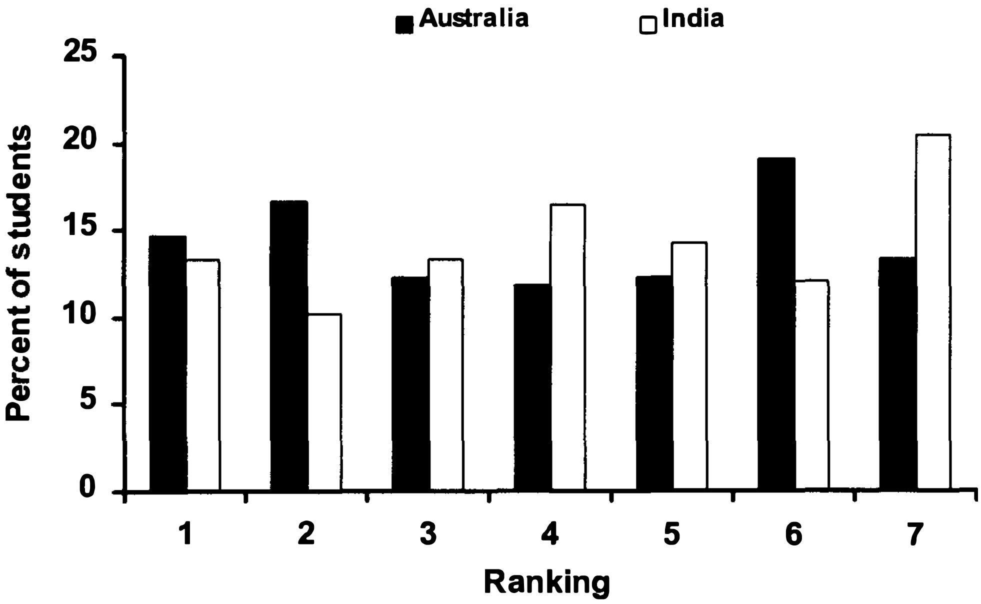


Figure 4. 1. The ranking of the importance of the GHE by Australian and Indian students, compared with six other issues. (1 = most important and 7 = least important).

Table 4.1. Mean ranking of the importance of the GHE by Australian and Indian students compared with six other issues (1=most important and 7=least important)

Issue	Mean rank		
	Australia	India	Overall
Economic issues and poverty	3.46	2.75	3.09
Health and diseases like AIDS	3.34	4.00	3.68
Increasing crime	3.52	4.05	3.79
The greenhouse effect	4.00	4.26	4.14
Terrorism	5.64	3.27	4.41
Family breakdown	3.99	4.82	4.42
Increasing drug use	4.13	4.85	4.50

Overall, students ranked the GHE fourth of seven important social issues. Economic issues and poverty, health and diseases like AIDS, and increasing crime were considered to be more important than the GHE. Terrorism, family breakdown and increasing drug use were considered less important than the GHE. It should be noted that the Australian data was collected before September 11, 2001 and the Indian data was collected after September 11, 2001. Overall, 14% of students ranked the GHE as most important and 17% ranked it least important of the seven issues. Australian students ranked the GHE fifth and Indian students' ranked it fourth out of the seven issues.

The following assertion can be made based on the students' ranking of the GHE.

Assertion 4.1

> According to the views of Year 10 and 12 students from Australia and India, the GHE is an important social issue of similar importance to increasing crime and terrorism

Beliefs Regarding the Seriousness and Effect of the GHE and Personal and Governmental Actions

Students' beliefs about the present and future impact of the GHE on the climate, the impact of personal actions and views about governmental actions were probed using questionnaire questions A 2.1 to A 2.5. Students indicated their views about a number of statements on an agreement scale, which ranged from strongly agree, agree, not sure, disagree, to strongly disagree. The results are summarised in Table 4.2.

Table 4.2. Students' beliefs about the seriousness and impact of the GHE, and personal and governmental actions. (n = 438)

Question	Statement	Percent student response				
		SA	A	NS	D	SD
A 2.1	There is no doubt that the GHE is affecting our climate	49.1	42	6.4	1.8	0.7
A 2.2	The GHE will change the climate of this planet in future	54	37.4	7.8	0.9	0
A 2.3	What I do has an effect on the GHE	12.6	51.1	25.2	8.7	2.3
A 2.4	Governments should conduct programmes to raise the community's awareness of this issue	49.1	39.9	6.7	3.9	0.4
A 2. 5	Governments should enact strict laws to reduce the release of greenhouse gases to the atmosphere	45.5	39.8	9.4	4.4	0.9

Note. (SA = Strongly Agree, A = Agree, NS = Not Sure, D = Disagree, SD = Strongly Disagree)

More than 85% of the students agreed or strongly agreed with the following statements about the GHE: There is no doubt that the GHE is affecting our climate; The GHE will change the climate of this planet in the future; Governments should conduct programmes to raise the community's awareness of this issue; and Governments should enact strict laws to reduce the release of greenhouse gases to the atmosphere. A much smaller percentage of students (64%) agreed or strongly agreed with the statement: What I do has an effect on the GHE. In this case, 25% of students indicated they were not sure about the effect they, as individuals, have on the GHE.

Most students believe the GHE is affecting the climate and will do so in the future. Most students believe governments should respond to this issue by raising community awareness and enacting legislation to reduce greenhouse gas emissions. However, a much smaller percentage of students recognise that the actions they take as individuals have an impact on the GHE. It is therefore likely that students will believe that the governments rather than themselves should respond to the issue.

The following assertions can be made based on the above data.

Assertion 4.2

> A large majority of Australian and Indian Year 10 and 12 students believe that the GHE is affecting our climate at present and will change the climate in future.

Assertion 4.3

> A large majority Australian and Indian Year 10 and 12 students believe that governments should conduct programmes to raise community awareness about the GHE and enact strict laws to reduce the release of greenhouse gases.

Assertion 4.4

> A small majority of Australian and Indian Year 10 and 12 students believe that what they do has an impact on the GHE, however a quarter of them are not sure about it.

Students' Beliefs Regarding the Reality of the GHE and Environmental Impacts

Students' beliefs about the reality of the GHE were probed by interview question 2; "Do you think the GHE is affecting our climate or is it just another scientific theory?". Ninety-five percent of students (76 students out of the 80 interviewed in Australia and India) indicated that the GHE is real and is affecting the climate. The following samples of student responses illustrate the range of student beliefs.

A 12/ 5 (Throughout this thesis subject codes are used to maintain anonymity. The subject codes are in three parts: first A or I to represent the country; 10 or 12 to represent the year level; and a subject number)
"Yes it is real and you know.......our climate is changing....... Summer is hot and beaches are lost. It is real"

A 10 / 29
"No it is not real..... it is against jobs and cars.... It is politics"

I 12 / 65
"Surely it is real....and it is affecting our climate also. No rains and dry summer and flooding during rainy season.......It is a real problem"

I 12 / 71
"It is a propaganda and just politics.......... Americans are doing it and you know they are not doing things there......It is not real and some scientists are paid to do ...there is no scientific evidence"

Most of the responses to the interview question 3(iii), "How will ecosystems be affected" were "I am not sure" (71 students out of 80 interviewed). Even though the students were encouraged to say whatever they know about it, they found it difficult to predict what will happen to ecosystems.

The students were also asked "What changes will we notice in Perth/ Trivandrum?". The following sample responses indicate the range of student beliefs.

A 12 / 46

"In the next 50 years ... well our beaches will be lost. Our climate will surely very may be 50 degrees ...... well bushes will be dried and there will be serious problems with agriculture and farming"

A 10 / 103

"Well I don't think there will be significant changes in the climate, this just a prediction and just politics.......this is to restrict people from using comforts.. This will not have any effect in Perth."

I 12 / 48

"In Trivandrum already sea erosion is common. Fishermen are already affected. So many diseases are coming to crops like coconut. Agriculture will be affected. Surely very hot to live. Drinking water will be a big issue..........City will be highly polluted. People will be having more breathing problem and so on."

I 10/ 121

"Since the climate changes are just a propaganda by the Americans no real effect will be there....they don't like third world.... No it is not going to make difference in climate. Trivandrum will develop well and it will be a good city in the next 50 years"

The interview responses from the Australian and Indian students were coded into categories. These results are summarised in Tables 4.3. and 4.4.

Table 4.3. Students' responses to the question "What changes will we notice in Perth?" (n = 40)

Categories of response	Percent of students
Beaches will be affected	65
The bush will be drier	47.5
More animals will be endangered	35
Summer will be terribly hot	27.5
More people will have skin cancer	28.5

Table 4.4. Students' responses to the question "What changes will we notice in Trivandrum?" (n = 40)

Categories	Percent of students
Sea erosion	70
Flooding	65
More crop diseases	47.5
More human diseases like cholera and malaria.	35
Climate will be very hot	27.5

Australian and Indian students believe that there will be beach erosion and that the climate will be hotter, however Indian students suggested there will be increased human and crop diseases. Students believe that the climate will be hotter and sea level rise will affect the beaches, however, they could not explain the scientific reasons for these changes.

The following assertion can be made based on the interview data regarding the reality and future implications of the GHE.

Assertion 4.5

Most of the Australian and Indian Year 10 and 12 students believe that the GHE is real and affecting our climate.

Sources of Students' Information Regarding the GHE

The sources of students' information regarding the GHE were probed by questionnaire questions E 1.1 to E 1.5. The data about whether they obtained most, some or none of their information from parents, teachers, textbook, friends and media are summarised in Table 4.5.

Table 4.5. Students sources of information regarding the GHE (n = 438)

Source	Percent of students		
	Most	Some	None
Parents	9.3	58.6	32.1
Teachers	51.8	38.7	9.5
Textbook	49.6	35.9	14.5
Friends	8.4	43.0	48.7
Media	55.2	38.1	6.7

Media, teachers, and textbooks were the students' major sources of information about the GHE. It is important to note that parents and friends were very minor sources of information about this issue. The main difference in the responses of Australian and Indian students related to the importance of textbooks as a source of information. Only 25% of Australian students compared to 71% of Indian students indicated that they obtained most of their information from textbooks.

The following assertions can be made based the above data.

Assertion 4.6

The majority of Australian and Indian Year 10 and 12 students obtain most of their information regarding the GHE from media, teachers, and textbooks. Parents and friends provide little information about the GHE.

Assertion 4.7

The textbook is a more important source of information about the GHE for Indian students than for the Australian students.

Chapter Summary

Students' beliefs regarding the GHE's relative importance in daily life, its reality, its effects like global warming and climatic changes, and the importance of personal and governmental actions were studied. Students' predictions regarding the future effects of the GHE in their city and ecosystem were also studied. From the results the following aspects of the students' belief can be identified.

- The GHE is an important social issue of similar importance to increasing crime and terrorism.
- Students strongly believe that the GHE is real and affecting our climate at present and will do so in the future.
- Though they believe that what they do has an effect on the GHE, they are not fully confident about it.
- They strongly believe that the government should conduct programmes to raise awareness of the GHE and enact strict laws to reduce greenhouse gas emission.
- The media, textbooks, and teachers are the main sources of information.
- Friends and parents provide minimal information regarding the GHE.
- Their confidence in predicting the expected changes over the next 50 years with the ecosystem and in their city was not very high and their predictions were not consistent with scientific predictions.
- Most of the predictions revealed beliefs that sea levels will rise and summers are going to be very hot.

Therefore in summary:

The Year 10 and 12 students in Australia and India strongly believe that the GHE is affecting the climate at present and will also affect it in the future, however, they are not sure of the impact of their personal actions and changes that are going to take place over the next 50 years in their capital city or in ecosystems. Further, the GHE is a relatively important issue to them and they got most of the information regarding the GHE from media, teachers and textbooks.

The Year 10 and 12 students in Australia and India also strongly believe that governments should conduct programmes to raise community awareness about the GHE and enact strict laws to reduce the release of greenhouse gases.

CHAPTER 5

STUDENTS' UNDERSTANDING ABOUT THE GREENHOUSE EFFECT

Introduction

The Greenhouse Effect (GHE) is a natural phenomenon, and without it, life as we know it would not exist. The enhanced GHE is causing global warming. It is important that students should be aware of environmental issues like the GHE and understand its causes, consequences and actions that should be taken to reduce its impact. The GHE is an abstract concept, hence teaching and learning about this issue cannot be through direct experience or by experiments. Causes of different global environmental problems overlap. Some gases responsible for the GHE also contribute to ozone layer depletion. In view of the complexity of these issues and their intangible nature, children will find the mechanism of the GHE difficult to understand. Much of the information available to students may come from informal sources outside school and this might increase the chances of alternative conceptions. Further, there is a chance that students' understanding of these issues might be centred only upon the views propagated by the media and governments rather than a scientific understanding of the nature, causes and mechanism of the phenomenon, if it is not effectively included in the science curriculum.

Propositional Knowledge Statement (PKS)

A propositional knowledge statement (PKS) was developed to describe the essential knowledge that a student at Year 10 requires to understand the phenomenon scientifically, in terms of causes, effects and mechanism. This knowledge is necessary to interpret media reports about the issue, and to make informed decisions, as a scientifically literate member of society.

The PKS was developed by a process comprising several stages. First it was discussed by a team including the researcher, a chemistry professor who is an author of a chemistry textbook, and a science education professor, who considered what aspects of the GHE, should be included in the PKS. The following aspects were agreed to be the basis for the PKS:

- The natural GHE and life on Earth.
- Types of radiation from the Sun, how they reach the Earth are reflected and absorbed.
- Greenhouse gases and their sources.
- Increased concentrations of greenhouse gases and the enhanced GHE.
- Global climatic changes.
- Strategies for reducing greenhouse gas emissions.

There were other aspects discussed regarding the GHE but they were not considered necessary for inclusion in the PKS. They were; the GHE on other planets like Mars, the conditions for a gas to absorb infra-red radiation, and too much details of the types of radiations and mechanism of the GHE. The draft of the PKS was developed by the researcher and was modified by the team after discussing each of the propositions in detail.

The draft PKS was sent to two experts (one chemistry professor and an atmospheric scientist from the CSIRO, Australia) for their suggestions. The PKS was revised based on their suggestions and is attached as Appendix 1. Student understanding about the GHE at Year 10 and 12 in Australia and India were investigated by collecting data by questionnaire and interview using the PKS as a framework to guide instrument development and data gathering.

To obtain a comprehensive picture of student understanding of the GHE, students' understanding of three core aspects of the issue were investigated. The three aspects were; the GHE and global warming, causes of the GHE, and the mechanism of the GHE. Table 5.1 summarises the interview and questionnaire questions used to probe students' understanding of the three aspects of GHE.

Table 5.1. Details of the of instruments used to probe students' understanding of the GHE

The GHE aspect	Instrument
Global Warming	Questionnaire questions Part B, 4.1, and 4.2. Interview questions 3(i), and 3(ii)
Causes	Questionnaire questions Part B, 4.3, 4.4, 4.5, 4.8, and 4.10.
Mechanism	Questionnaire questions Part B, 1, 2, 3, 4.6, 4.7, and 4.9. Interview question 1.

Data regarding global warming, causes and mechanism were analysed and assertions are developed on each aspect in this Chapter. The GHE data were also analysed and from this five different levels of understanding of the GHE were identified. The final discussion regarding the students' understanding of the GHE is based on the assertions from each section. This discussion generates a summary of students' understanding of the GHE.

The GHE and Global Warming

Students' understanding of the impacts of the GHE is considered in relation to the GHE keeping our planet habitable and the enhanced effect causing global warming. Students' knowledge of the rise in temperature and sea level in the next 50 years was also probed during the interview.

Four hundred and thirty-eight students (Year 10 and 12) from Australia and India answered questions B.4.1 and B.4.2 from the questionnaire regarding global warming. Percent of students correctly answering, that is: true / false / don't know; and who gave a correct answer with a valid scientific reason are given in Table 5.2.

Table 5.2. Australian and Indian Year 10 and 12 students' understanding of global warming (n = 438)

		Percent of students	
Question	Statement	Correct answer	With valid reason
B.4.1	The GHE is keeping our planet habitable	44.7 (True)	34.7
B.4.2	The enhancement of the GHE is causing global warming	84.9 (True)	48.9

The GHE keeps our planet habitable and without this effect the Earth's temperature would be much colder, and life as we know it, would not exist. The majority of students do not understand this at Year 10 and 12 in Australia and India. Only 44.7% students indicated that the statement is true (Question 4.1) and only 34.7% could give a valid scientific reason.

The following sample responses illustrate valid reasons given by students:

A 10/18

"The GHE gases help keep the earth warm"

A 12/62

"So that heat won't dissipate quickly, a relatively stable temperature is maintained, allowing lives to flourish"

The enhanced GHE causes global warming. Although 84.9% of students indicated the statement is true (Question 4.2), only 48.9% could give a valid scientific reason.

The following sample responses illustrate valid reasons given by students:

I 10/91

"CO_2 traps infra-red rays which heats up the earth causing global warming"

I 12/66

"The greenhouse gases absorb radiations (IR) and causes global warming (ie, increase in temp, of earth as a while).

Forty students (25 Year 10 and 15 Year 12) each from Australia and India were interviewed to gain richer data about their understanding of the GHE. Students' understanding of the anticipated rise in average global temperature and sea level were probed during the interview. Students' responses regarding the expected rise in average global temperature and sea level over the next 50 years are summarised in Table 5.3 and 5.4.

Table 5.3. Australian and Indian Year 10 and 12 students' responses about the expected temperature rise in the next 50 years (n = 80)

	Percent of students			
Country	1 to 2 °C	5 to 10 °C	More than 10 °C	Don't know
Australia	24	48	4	24
India	44	48	4	4
Total	34	48	4	14

Table 5.4. Australian and Indian Year 10 and 12 students' responses about the expected sea level rise in the next 50 years (n = 80)

	Percent of students				
Country	10 to 50 cm	1 m	1 to 2 m	10 m	Don't know
Australia	20	44	12	24	0
India	8	48	16	16	12
Total	14	46	14	20	6

The following sample interview responses illustrate students' understanding of expected rise in global temperature and sea levels.

Question: There are certain predictions by scientists about the GHE. By how much is the average global temperature expected to rise in the next 50 years?

A 10/92.

" Oh…… I am not sure! , Well the average temperature in Perth is 35 degree Celsius………. May be 5 to 10 degrees ….. and again you know ……how much you know ….. the gases like Carbon are exposed. Well …… 5 to 10 degrees in next 50 years."

I 12/31.

"I don't know"

Can you Guess?

"No I don't know."

I 10/75.

" .... I think may be ...... I think 30 degrees in next 50 years"

Question: By how much is the sea level expected to rise in the next 50 years?

A 12/53.

" I think sea level .... actually 1 metre every year .... Or ...no.. you know.... 1 metre....probably........ Yes 1 metre in the next 50 years."

A 10/95.

" 10 metre in the next 50 years...... well our beaches..... you know will lost...may be......."

I 10/75.

"Sir...... it ... is 1 to 2 metres.......in next 50 years"

I 10/142.

"1 metre"

I 12/18.

"Well ...... it is .... I think.... 10 metre.....in 50 years....it can cause problems .....in the beach ..... Sea erosion.... You know."

The United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climatic Changes (IPCC) to study climatic changes associated with the GHE. The IPCC's third assessment report on climatic changes (2001) made the following predictions regarding the rise in average global temperature and sea level:

- climate models predict that the global average temperature will rise by about 2^0C by the year 2100 if current emission trends continue; and
- the Earth's average sea level is predicted to rise by about 40 cm to a metre by 2100.

Students' understandings of the expected rise in average global temperature and sea level are not consistent with the predictions made by the IPCC. It is clear from the interviews that students are quite uncertain about the extent of the anticipated changes. Forty-eight percent of students predicted the average global temperature rise would be between 5 to 10^{0}C compared with IPCC data, which suggests the rise will be less than 2^{0}C over the next 50 years. Regarding sea level rise, 46% of students expected a 1m rise over the next 50 years and a further 34% of students expected a rise of greater than 1m. The IPCC suggests that the sea level rise will be less than 50cm over the next 50 years.

The following assertions can be made based on the above data:

Assertion 5.1

The majority of students did not understand that the GHE is keeping our planet habitable (Table 5.2).

Assertion 5.2

The majority of students understood that the GHE causes global warming, however, less than half of the students could explain how or why the enhancement of the GHE causes global warming (Table 5.2).

Assertion 5.3

Students' understandings of the anticipated average global temperature rise and sea level rise in the next 50 years are not consistent with scientific predictions (Tables 5.3 and 5.4).

Causes of the GHE

The enhancement of the natural GHE is due to increased human activities. Students' understanding of the causes of the GHE were probed by Questions B.4.3, B.4.4, B.4.5, B.4.8 and B.4.10 from the questionnaire. Australian and Indian Year 10 and 12 students' understanding about causes of the GHE are summarised in Table 5.5.

Table 5.5. Australian and Indian Year 10 and 12 students' understanding about the causes of the GHE (n= 438)

		Percent of students	
Question	Statement	Correct answer	With valid reason
B.4.3	We cannot conclude, based on the available scientific evidence, that human activities cause the change in global climate	63.2 (False)	42.9
B.4.4	Burning fossil fuels like coal, oil or gas can contribute to the enhancement of the GHE	85.8 (True)	70.0
B.4.5	Deforestation (cutting down trees) reduces the GHE	80.4 (False)	67.4
B.4.8	Cattle and sheep farming reduces the GHE	62.3 (False)	31.3
B.4.10	The concentrations of most greenhouse gases are increasing in the atmosphere because of human activities	84.5 (True)	65.3

Students' understanding of human activities that are causing the enhanced GHE was investigated by the questionnaire. Question B.4.3 focused on the climatic model predictions by the IPCC based on the present emission scenario. There is evidence that climatic changes have already begun. Although the climate varies naturally which makes it difficult to identify the effects of rising greenhouse gases, the temperature trend over the past few decades does resemble the pattern of greenhouse warming predicted by the models. These trends are unlikely to be due entirely to known sources of natural variability. While a degree of uncertainty remains, scientists believe that the balance of the evidence suggests a discernible human influence on global climate (IPCC, 2001).

The climate does not respond immediately to emissions. It will therefore continue to change for many years even if greenhouse gas emissions are reduced and gas concentrations stop rising (UNEP, 2001). Some important impacts of climate change, such as a predicted rise in sea level, will take even longer to be fully realised. Current climate models are only able to predict pattern change at a continental scale. Predicting how climate change will affect weather in a particular region is much more difficult. Thus the practical consequences of global warming for individual countries or regions remain very uncertain.

Sixty-two percent of students recognised that the statement in question B.4.3 was false, and 43% could give a valid reason. For example student **A 10/15** stated:

"because there is scientific evidence that human activities cause changes in global climate"

The complex wording and negative statement may have influenced the low percentage of correct response to this item compared to B.4.10.

Questions B.4.4, B.4.5, B.4.8 and B.4.10 focused on factors influencing greenhouse gas concentrations. Emissions started to rise dramatically in the 1800s due to the industrial revolution and changes in land use. Many greenhouse gas-emitting activities are now essential to the global economy and a fundamental part of modern life. Most emissions are associated with energy use and are produced when fossil fuels are burned. Oil, natural gas and coal (which emits the most carbon per unit of energy supplied) furnish most of the energy used to produce electricity, run automobiles, heat houses and power factories. Deforestation is the second largest source of carbon dioxide. When forests are cleared for agriculture or development, most of the carbon in the burned or decomposing trees escapes to the atmosphere. However when new forests are planted the growing trees absorb carbon dioxide, removing it from the atmosphere and fixing it in carbohydrates generated through photosynthesis.

Domesticated animals emit methane, the second most important greenhouse gas after carbon dioxide. Cattle, sheep and other ruminant animals produce methane by microbial activity within their digestive systems. Livestock account for about one quarter of the methane emissions, totalling some 100 million tonnes a year (UNEP, 2001).

Eighty-five percent of students recognised that the statement for Question 4.4 was true, and 70% could give a valid reason. Eighty percent of students recognised that the statement for Question 4.5 was false, and 67% could give a valid reason. Sixty-two percent of students recognised that the statement for Question 4.8 was false, and 31% could give a valid reason. Eighty-four percent of students recognised that the statement for Question 4.10 was true, and 65% could give a valid reason.

The following quotations illustrate valid reasons given by the students.
Question B.4.4: Burning fossil fuels like coal, oil or gas can contribute to the enhancement of the GHE.

A 12/4
"They produce more and more greenhouse gases which keep more heat in"

Question B.4.5: Deforestation (cutting down trees) reduces the GHE.

I 10/31

"If there are more trees the CO_2 content in the atmosphere will be less, ie, if there are less trees CO_2 must be more which leads to global warming"

Question B.4.8: Cattle and sheep farming reduces the GHE.

A 12/2

"Cows and sheep let off Methane"

Question B.4.10: The concentrations of most greenhouse gases are increasing in the atmosphere because of human activities.

I 10/64

"The gases coming from the vehicles, factories etc, contain greenhouse gases"

The majority of students gave a correct answer for all the questions, however a greater percentage of students understood the role of fossil fuels, deforestation and human activities than the influence of the domesticated animals on the GHE. The following assertions can be made based on the above data:

Assertion 5.4

> A large majority of students understood and explained the influence of human activities on greenhouse gas concentration, burning of fossil fuels, and deforestation on the GHE.

Assertion 5.5

> A small majority of students were aware that cattle and sheep farming enhanced the GHE but less than one third could explain why or how cattle and sheep increase the GHE.

Mechanism of the GHE

The Earth's atmosphere acts like a greenhouse, letting the Sun's energy in, but preventing some of the Earth's radiation from escaping to space. Students' understanding of the mechanism of the GHE was probed by questionnaire questions B.1, B.2, B.3, B.4.6, B.4.7 and B.4.9. These questions are related to how solar radiations are absorbed and reflected by the Earth and which gases in the atmosphere absorb and reflect the infra red radiation.

Students' responses to questions B.4.6, B.4.7 and B.4.9 about the mechanism of the GHE are summarised in Table 5.6

Table 5.6. Students' response to questions regarding the mechanism of the GHE (n = 438)

		Percent of students	
Question	Statement	Correct answer	With valid reason
B.4.6	The surface of the Earth absorbs solar radiation and emits infra red radiation	34.3 (True)	0.9
B.4.7	Greenhouse gases do not absorb infra red radiation	38.6 (False)	0.9
B.4.9	Oxygen, nitrogen and argon don't cause the GHE.	55.0 (True)	0.2

The Earths' climate is driven by a continuous flow of energy from the Sun. This energy arrives mainly in the form of visible light. About 30% is immediately scattered back into space, but most of the 70% is absorbed by the Earth's surface. The Earth emits energy in the form of infra-red radiation. Very little infra-red radiation passes straight through the air like visible light. Most infra red energy is carried away from the Earth's surface by air currents and clouds, eventually escaping to space from altitudes above the thickest layers of the greenhouse gas blanket (UNEP, 2001). The gases in the atmosphere that absorb infra-red radiations are called greenhouse gases. With the exception of water vapour, the other greenhouse gases constitute less than 1% in total of the atmosphere (Somerville, 1996).

Thirty-four percent of students gave a correct answer for question B.4.6, but less than one percent could explain the reason. Thirty-eight percent of students gave a correct answer to Question B.4.7 but less than one percent could explain the reason. Fifty-five percent of students correctly answered Question B.4.9 but only 0.2% could explain the reason. The majority of students were not aware of the scientific facts about the mechanism of the GHE.

The following quotations illustrate valid reasons given by the students.

Question B.4.6: The surface of the Earth absorbs solar radiation and emits infra red radiation.

I 10/2

"The surface of the earth absorbs solar radiation and heat up and then emits infra red radiations"

Question B.4.7: Greenhouse gases do not absorb infra red radiation.

I 10/5

"The greenhouse gases absorb infra red radiation thus increase the temperature"

Question B.4.9: Oxygen, nitrogen and argon don't cause the GHE.

I 12/1

"Because they allow the infra red radiation to pass through it to the stratosphere as they are diatomic"

Less than 1% of the students gave a valid scientific reason in support of their answers to these questions.

Students completed a diagram to represent the mechanism of the GHE and explained the diagram (Questionnaire questions B.1 and B. 2). The following sample responses to Question B. 2 illustrate the range of explanations of GHE mechanisms provided by the students:

I 10/91

"The earth receives light of different wavelenghts from sun. The ozone absorbs harmful ultra violet radiation and lets other pass through. Some of the light incident on earth is reflected back as infra-red light. CO_2 *molecule have the ability to absorb the infra-red radiation reflected from earth. This heats up the atmosphere due to trapped radiation and is called the Greenhouse effect"*

A 12/3

"The atmosphere stops majority of solar radiation from entering our atmosphere and the greenhouse effect makes holes for it to come through"

A 10/2

"The arrows indicate the sun's rays hitting earth. In usual circumstances they would bounce back and reflect back into space but due to the harmful emissions they do not go through the atmosphere, thus increasing the temperature of the earth"

A 10/3

"Solar radiation is released from the sun and travel to earth. They enter the atmosphere hitting the earth and bouncing of it. Instead of going away for the earth the are traped in the atmosphere cause the temperature to rise"

I 12/29

"In this diagram maximum percentage of the sunlight entering the earth's atmosphere get reflected from the surface. In that some fractions are absorbed by the carbon di oxide present in the atmosphere, which helps in the maintenance of the normal temperature during the night time. The harmful ultra violet radiations are absorbed by the ozone layer"

I 12/62

"Radiation from the sun are prevented from entering the earth by the greenhouse gases like CO, CO_2 etc., As a result only a part of the radiation (infra-red) are reaching the earth. The main reason for this is the production of harmful gases like CO. due to pollution from automobile smoke from the factories etc"

I 10/137

"due to the excess presence of greenhouse gases like CO_2, CH_4 etc, the terrestrial radiation emitted by the earth is trapped by them. Now when the terrestrial radiation is trapped, the temperature of the earth increases resulting in global warming and hence resulting in the melting of the polar ice caps leading to the submergement of the ports and islands.

Actually these gases allow solar radiations to enter the atmosphere but does not allow the terrestrial radiations to escape fully"

Students' knowledge of the greenhouse gases was probed by questionnaire Question B.3 on the questionnaire: "What are the greenhouse gases?". Students' responses to this question are summarised in Table 5.7.

Table 5.7. Australian and Indian Year 10 and 12 students' identification of Greenhouse gases (n = 438)

	Percent of students						
	Australia			India			
Gas	Yr12	Yr10	Total	Yr12	Yr10	Total	All students
CO_2	52.0	46.3	48.3	90.6	90.6	90.6	70.1
CH_4	36.0	15.5	28.1	61.3	62.6	62.2	45.7
H_2O	2.6	1.3	1.4	16.0	40.6	32.4	17.4
N_2O	14.6	2.1	6.5	17.3	4.6	8.9	7.8
O_3	17.3	2.1	7.5	10.6	38.0	28.9	18.5
CFC	42.6	18.1	26.7	4.6	10.0	9.7	18.0
CO	16.0	20.2	18.7	22.6	17.3	19.1	18.9
O_2	2.6	0.7	1.4	0.0	1.3	0.9	1.1
N_2	4.0	5.0	4.7	0.0	1.3	0.9	2.7
H_2	2.6	2.9	2.8	1.3	2.0	1.7	2.3

Greenhouse gases include CO_2, CH_4, H_2O, N_2O, O_3, and CFCs. The students' responses also included gases like CO, O_2, N_2 and H_2.

Seventy percent of the students understood that CO_2 is a greenhouse gas and for the other gases the percentages were; CH_4 45.7%, O_3 18%, CFC 18%, water vapour 17% and 7% N_2O.

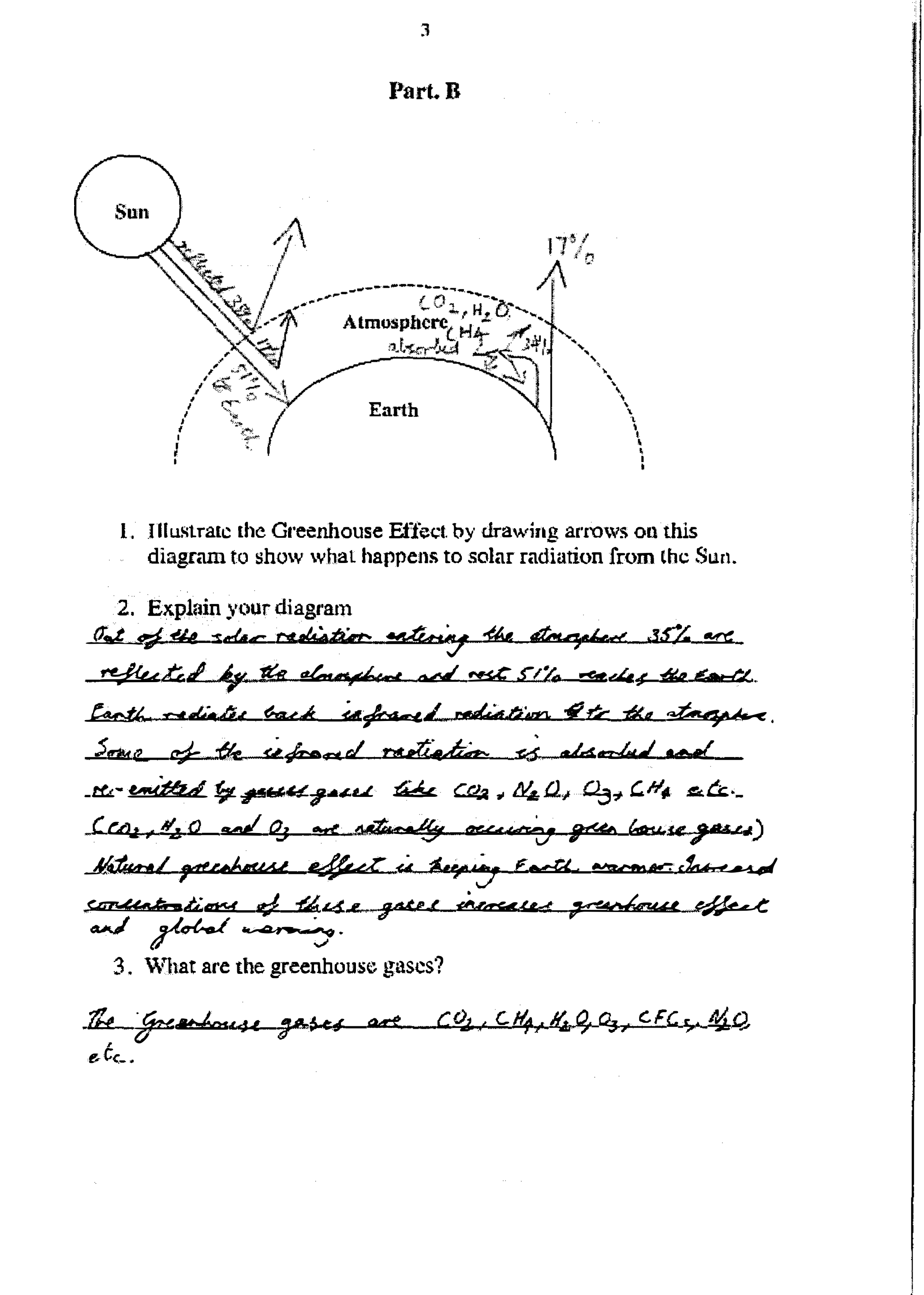
Analysis of students' responses to Questions B.1, B. 2 and B.3 in the whole sample revealed that five levels of understanding of the GHE could be identified. Level 1 represents the highest level of understanding and level 5 represents the lowest level of understanding exhibited by the students in the sample. Each of these levels is explained below.

Level 1.

The mechanism of the GHE was explained correctly and represented accurately in a diagram.

At level 1, students explained that:

- Sunlight passes through the atmosphere
- Most solar radiation is absorbed by the Earth's surface and warms it
- Some solar radiation is reflected back to space by the Earth and the atmosphere
- Infra red radiation is emitted from the Earth's surface
- Some infra red radiation is absorbed and re emitted by greenhouse gases
- The effect is to warm the surface of the Earth and the lower atmosphere
- The natural GHE is due to the presence of naturally occurring greenhouse gases which trap some of the infra-red radiation in the atmosphere
- This effect causes the Earth to be warmer than it would otherwise be
- Increasing concentrations of several gases like CO_2, CH_4, N_2O, CFCs, O_3, water vapour, (identified at least 3 gases) enhanced the natural GHE
- The enhanced GHE has the potential to produce global warming.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Part. B

1. Illustrate the Greenhouse Effect by drawing arrows on this diagram to show what happens to solar radiation from the Sun.

2. Explain your diagram

Out of the solar radiation entering the atmosphere 35% are reflected by the atmosphere and rest 51% reaches the Earth. Earth radiates back infrared radiation to the atmosphere. Some of the infrared radiation is absorbed and re-emitted by gases like CO_2, N_2O, O_3, CH_4 etc. (CO_2, H_2O and O_3 are naturally occurring green house gases) Natural greenhouse effect is keeping Earth warmer. Increased concentrations of these gases increases greenhouse effect and global warming.

3. What are the greenhouse gases?

The Greenhouse gases are CO_2, CH_4, H_2O, O_3, CFCs, N_2O etc.

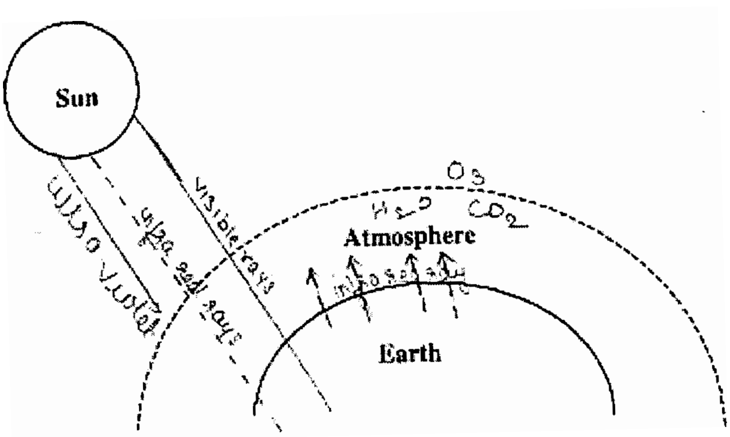
Figure 5.1. Sample of Level 1 student response

Level 2.

The mechanism of the GHE was represented accurately in the diagram; however, the explanation of the mechanism was not complete. Students did not differentiate between natural and enhanced GHE.

At level 2, students explained that:

- Sunlight passes through the atmosphere
- Most solar radiation is absorbed by the Earth's surface and warms it
- Some solar radiation is reflected back to space by the Earth and the atmosphere
- Infra red radiation is emitted from the Earth's surface
- Some infra red radiation is absorbed and re emitted by greenhouse gases
- The GHE is enhanced by the increasing concentrations of gases like CO_2, CH_4, N_2O, CFCs, O_3, water vapour (identified at least 2 gases) and causes global warming.



1. Illustrate the Greenhouse Effect by drawing arrows on this diagram to show what happens to solar radiation from the Sun.

2. Explain your diagram

Sun emits visible rays, infra red rays and ultra violet ray. The visible and infra red rays pass through the atmosphere and reaches earth surface. The sun light heats the surface of the earth and emit infra red rays. The infra red rays are absorbed by the CO_2 H_2O and O_3. The atmosphere get heated up and the atmosphere in turn warms the earth's surface.

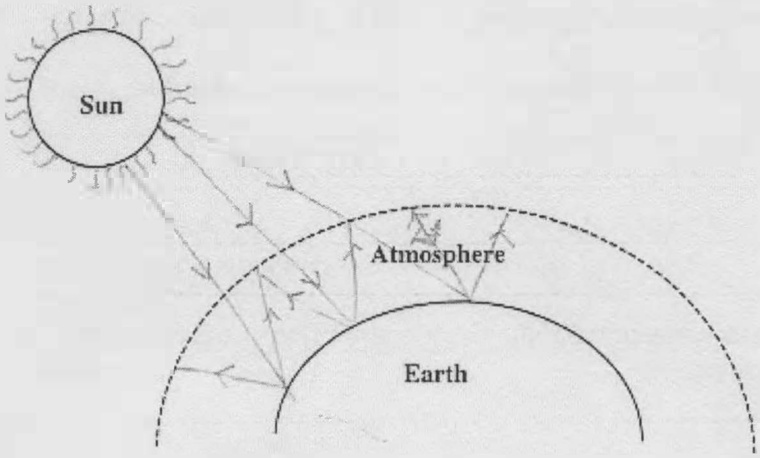
Figure 5.2. Sample of Level 2 student response

Level 3.

The diagrammatic representations and explanation of the mechanism of the GHE were not complete, however, students did understand that CO_2 was involved in trapping reflected rays and causing global warming

At level 3, students explained that:

- Sunlight passes through the atmosphere
- Most solar radiation is absorbed by the Earth's surface and warms it
- The Earth re-emits radiations that are completely absorbed in the atmosphere
- CO_2 absorbs and re-emits the radiations in the atmosphere and causes global warming
- Increased production of CO_2 is causing increased global warming
- Students were not aware that some solar radiation is reflected back to space from the Earth or from the atmosphere.



1. Illustrate the Greenhouse Effect by drawing arrows on this diagram to show what happens to solar radiation from the Sun.

2. Explain your diagram

The solar radiations of sun are reflected back to atmosphere and these radiations are absorbed by CO_2 present in the atmosphere. This is because carbondioxide has to tendency to absorb the warm from ~~the~~ reflected by earth. Thus CO_2 makes the atmosphere warm.

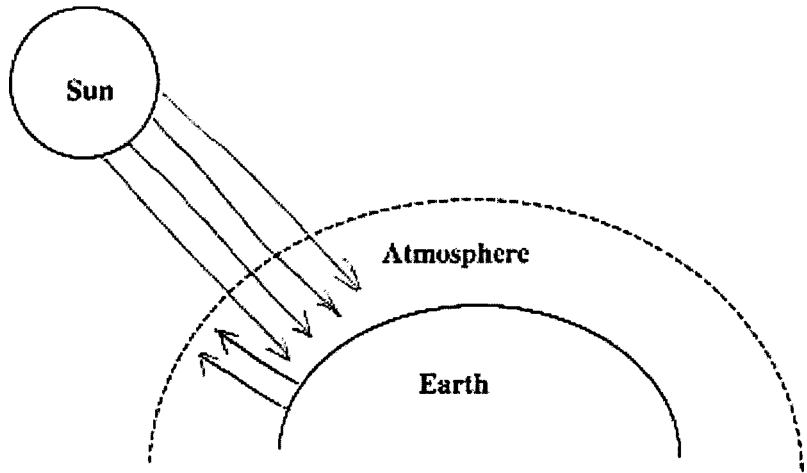
Figure 5.3. Sample of Level 3 student response

Level 4.

Confused ozone layer depletion with the GHE

At level 4, students explained that:

- Production of gases like CFCs, and CO_2 cause holes to form in the ozone layer
- The holes in the ozone layer allow UV radiation to pass through the atmosphere
- The increased concentration of UV radiation is causing global warming.



1. Illustrate the Greenhouse Effect by drawing arrows on this diagram to show what happens to solar radiation from the Sun.

2. Explain your diagram

The ozone layer breaks down from the use of greenhouse gases which leads to higher UV rates and increased global warming. The ozone layer absorbs heat and keeps the warm air in.

Figure 5.4. Sample of Level 4 student response

Level 5.

Minimal understanding of the GHE

At level 5, students provided little accurate information and the following are the main general observations:

- Diagrams were inaccurate
- Explanations were incomplete and not scientifically correct regarding global warming and many of these students stated that pollution is causing global warming.

At this level students represented pollution in the diagrams and believed that pollution is causing global warming. Students were not sure about how solar radiations are absorbed or reflected.

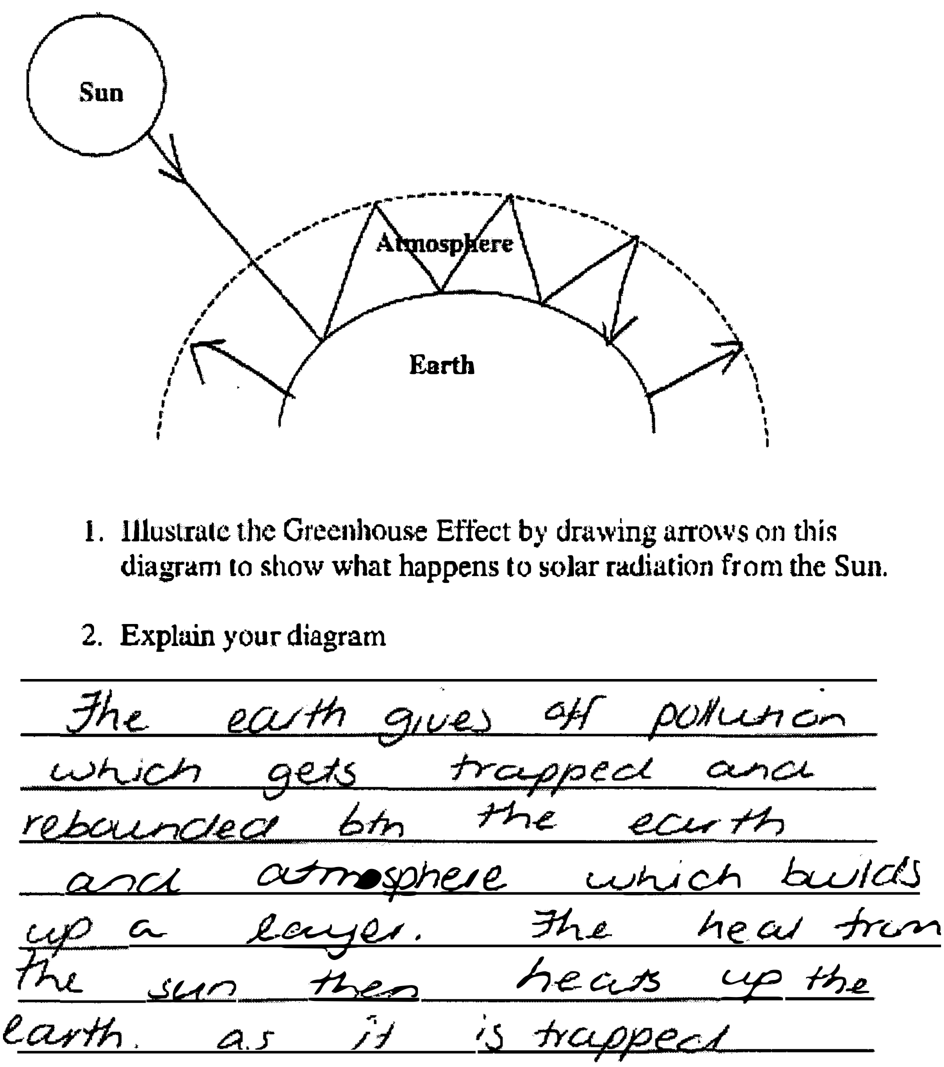


Figure 5.5. Sample of Level 5 student response

Student responses on the questionnaire were coded into five levels of understanding of the issue based on the criteria described above. Eighty students were interviewed with a fair distribution of students between levels 1 to 4 and with least numbers at level 5. The interview responses in some cases were more elaborate than those provided on the questionnaire, however, they did confirm their written explanations.

The following are some of the interview responses to the interview question: "Would you explain your diagram, which shows what happens to solar radiation from the Sun?"

A- 10- 39. (Level 4)

"Ah ... ok.. Since increase there in Carbon dioxide ...... in the atmosphere is dangerous....because...global warming. Atmosphere thins .... Sun UV rays to enter Earth cause global warming..... in the diagram shows thin the atmosphere......well that is causing global warming you know"

A - 10 - 8. (Level 4)

"Sun ... UV go ...into atmosphere some UV reflect from atmosphere some trapped .....atmosphere go on get ... What the problem gets and you know ....the CFCs causing it.... The hole in the atmosphere ..... the polar ice is melting you know...In my diagram it is ....shown the hole you know .... The ozone hole .... The gases CFCs causing it you know... producing lot of these gases .... These gases trap the heat and reflected back ..... and heating the Earth"

A - 12 - 36. (Level 3)

" Radiation come in .... Heat Earth.... Heat is not escaping .... Causing the warming up..."

Question: What is the reason why the heat is not escaping?

" You know .... Gases Carbon oxide....Methane....gases released more and more....gases trap completely the heat..... as more of these gases more heat is trapped...and reflected causing global warming... you know it is making Earth very hot...."

I - 12 - 24. (Level 3)

"Sun ray coming in Earth... Heat is reflected from Earth....In my diagram.. yes.. I have shown like the reflected rays are trapped....and reflected back and you know it is heating up....the atmosphere....It is mainly due to pollution... I mean factories

....producing lot of these gases I mean ... carbon di oxide.....these gases trap completely the heat..... and reflected back ... completely... to Earth and heating Earth.... You know causing global warming...."

The percentage of students' who understood the mechanism of the GHE at levels 1 to 5 is illustrated in Figure 5.1.

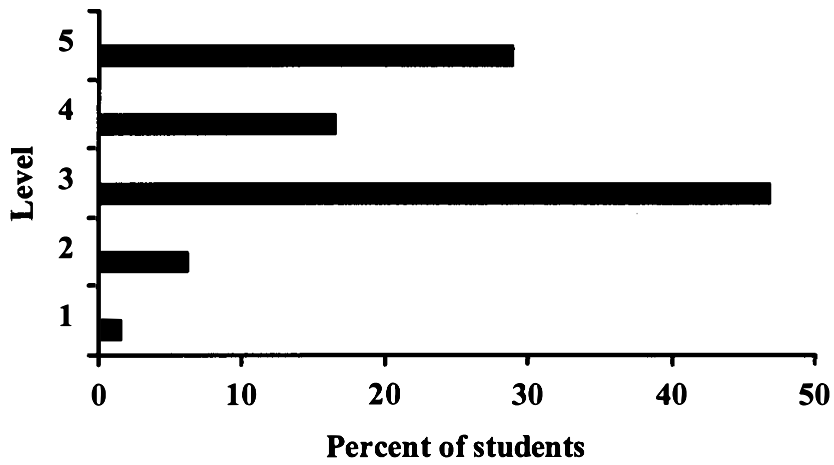


Figure 5.6. Percentage of students who understood the GHE at Levels 1 to 5 (n = 438)

These data regarding the students' understanding of the GHE mechanism in five levels by Australian and Indian Year 10 and 12 students, are shown in greater detail in Table 5.8

Table 5.8. Australian and Indian Year 10 and 12 Students' Understanding of the GHE in Five Levels (n = 438)

		Percent of students		
Country	Levels	Year 12	Year 10	Total
	1	4.1	1.4	2.4
Australia	2	12.3	3.6	6.6
	3	6.8	43.5	30.8
	4	27.4	16.7	20.4
	5	49.3	34.8	39.8
	1	2.7	0	0.9
	2	6.7	5.3	5.8
India	3	65.3	60.0	61.8
	4	4.0	17.3	12.9
	5	21.3	17.3	18.7

Overall in the sample: 45.4% of students either had a minimal understanding or significant misconceptions about the GHE (Level 4 and 5); 47.8% of students had a modest understanding of the mechanism of the GHE (Level 3); and only 7.8% of students had a sound understanding of the GHE (Levels 1 and 2). In the Australian sample the majority (60.2%) of students have either minimum understanding or misconceptions about the GHE (Level 4 and 5), whereas in the Indian sample the majority of students (61.8%) have modest level of understanding (Level 3). Based on these data about the mechanism of the GHE, the following assertions can be made.

Assertion 5.6

Less than 10% of all students could provide a complete or nearly complete and scientifically accurate explanation of the mechanism of the GHE.

Assertion 5.7

The majority of students in Australia have either minimal understanding or misconceptions about the mechanism of the GHE (Levels 4 and 5).

Assertion 5.8

The majority of students in India have a modest understanding about the mechanism of the GHE (Level 3).

Chapter Summary

In this study, students' understanding of the GHE was probed using the questionnaire questions and subsequent student interviews to clarify their responses. Students' responses in three core areas of the GHE, and at the five levels of understanding of the GHE mechanism, gave a full picture of student understanding of the GHE. The following are the major aspects of the students' understanding of the GHE.

- The majority of students did not understand that the GHE is keeping our planet habitable.
- The majority of students understood that the GHE causes global warming, however, less than half of the students could explain how or why the enhancement of the GHE causes global warming.
- Students' understandings of the anticipated average global temperature rise and sea level rise in the next 50 years are not consistent with scientific predictions.
- A large majority of students understood and explained the influence of human activities, burning of fossil fuel, and deforestation on the GHE.
- A small majority of students were aware that cattle and sheep farming enhanced the GHE but less than one third could explain why or how cattle and sheep increase the GHE.
- Less than 10% of all students could provide a complete or nearly complete and scientifically accurate explanation of the mechanism of the GHE.

- The majority of students in Australia have either minimal understanding or misconceptions about the mechanism of the GHE (Levels 4 and 5).
- The majority of students in India have a modest understanding about the mechanism of the GHE (Level 3).

Therefore in summary:

The majority of Year 10 and 12 Australian and Indian students' understanding of the GHE is inadequate to make informed decisions and take appropriate environmental actions as a scientifically literate member of society.

CHAPTER 6

STUDENTS' INTENTIONS TO ACT REGARDING PROPOSALS TO REDUCE GREENHOUSE GAS EMISSIONS

Introduction

Science may not be able to predict the exact timing and ascertain the precise intensity of changes in climate, however, there is sufficient evidence to indicate that further global warming will occur, even if all emissions of greenhouse gases were to cease today (IPCC, 2001). Continued unabated emissions will increase the probability of extreme, irreversible changes in the climate and in ecosystems (UNEP, 2001). Action is required on two fronts; one to address the cause of the problem, that is control emissions of greenhouse gases; and two, effectively adapt to impacts of climate change. Further actions must be taken to control the emissions of greenhouse gases from all possible sources. Personal and governmental actions are very important in this context.

The most important source of greenhouse gas emissions is the use of fossil fuels in power stations, transportation and doing just about everything that uses energy to keep the economy going. The IPCC (2001) in its third report, has clearly indicated that climate change is real and getting worse. It is politics and not science that is delaying action. In a democratic nation, citizens' awareness and understanding of an issue play a vital role in decision-making by the government as well as by individuals. These decisions have far reaching consequences regarding the impact of the GHE.

According to the theory of reasoned action (Ajzen & Fishbein, 1980) on the basis of different experiences, people may form different beliefs about the consequences of performing behaviours. These beliefs determine intention to act to a particular situation. In this study, students' were presented with hypothetical proposals to reduce greenhouse gas emissions so as to elicit from them their intentions to act regarding the GHE.

Students' intention to act regarding the GHE were investigated using: questions from Part C of the questionnaire, regarding actions that can be taken to reduce greenhouse gas emissions; a proposal to reduce car use to reduce greenhouse gas emissions in Part D of the questionnaire; and Part E.2, which is about the steps governments should take to reduce release of greenhouse gases; and interview questions 4 and 5 about proposals to reduce greenhouse gas emissions.

Students' and their Family's Intentions to Act Regarding Accepted Strategies for Reducing Greenhouse gas emissions

According to the Australian Greenhouse Office (AGO, 2000) Australian households generate almost one fifth of Australia's greenhouse gases. This would be true for most nations. Each year, Australian households produce 15 tonnes of greenhouse gases more than the previous year through everyday activities such as transport, household energy use, and decay of household waste in landfills.

Four hundred and thirty-eight Year 10 and 12 students from Australia and India indicated the actions they are, or might take, in relation to 10 widely accepted ways of reducing greenhouse gas emissions (AGO, 2000). Students indicated whether they and their family was 'already doing' were 'considering doing' or were 'not interested in taking action' in relation to the 10 actions. The results are summarised in Table 6.1.

Table. 6.1. Australian and Indian Year 10 and 12 students and their families' intentions to act regarding 10 widely accepted ways of reducing greenhouse gas emissions. (n= 438)

Question	Action	Percent of students		
		AD	CD	NI
C.1	Walk, cycle or use public transport rather than using a car	56.4	20.2	23.4
C.2	Use compact fluorescent lights in place of normal globes	36.9	29.4	33.7
C.3	Reduce hot water consumption, by washing clothes in cold water or by fitting water efficient showerhead.	51.6	20.3	27.8
C.4	Insulate your home to reduce electricity used for heating and cooling	45.2	28.7	26.1
C.5	Replace an electric hot water system with a solar or high efficiency gas system	27.1	33.7	39.2
C.6	When buying a new car, choose one that is fuel-efficient rather than high powered	43.6	33.3	23.2
C.7	Conserve existing trees and plant new trees	65.7	20.2	14.0
C.8	Switch off the lights and electrical appliances when they are not needed	87.6	8.5	3.9
C.9	When purchasing electrical appliances, choose one that is high energy star rated rather than a cheaper one	58.3	24.5	17.2
C.10	Use manual mechanical devices wherever possible instead of using electricity, eg, Avoid using electric can openers, electric knife, etc.	67.4	15.1	17.4

Note. AD = Already doing; CD = Consider doing; NI = Not interested in taking action.

For all of the 10 potential actions, the majority of the students and their families are either already taking action or considering taking action. The most positive responses were in relation to turning off lights and electrical appliances, using manual rather than electric devices, and conserving and planting trees. The least positive responses were in relation to actions that require a capital investment for replacing hot water systems or light globes or for installing insulation.

Except for the issues of hot water consumption, and conserving and planting trees, Australian and Indian students indicated their intentions to act without much variation. Climatic variations and the serious issue of deforestation in India may the reason for these variations.

The following assertion can be made based on the above data.

Assertion 6.1

The majority of Year 10 and 12 Australian and Indian students reported that they and their families are already taking action or consider taking action regarding the 10 easiest ways of reducing greenhouse gas emissions from household energy use and transportation.

Students' Intentions to Act Regarding Proposals to Reduce Use of Cars, Electricity and Air-conditioners

Students' intentions to take actions that would reduce greenhouse gas emissions were investigated by presenting them with a number of proposals for reducing use of cars, electricity and air-conditioners.

Passenger vehicles produce considerable greenhouse gas emissions and contribute to air pollution in the cities. Four hundred and thirty-eight Year 10 and 12 students from Australia and India were asked to react to the following proposal (Part D of the questionnaire):

"Cars produce large quantities of greenhouse gases and contribute to air pollution in cities.

A political party has developed a proposal to restrict the number of cars that can enter your capital city by imposing very high parking fees and reducing the number of parking bays in the city centre. The party also proposes to double the price of petrol and car licensing fees to discourage car use."

Students responded to this proposal by indicating whether they strongly support, support, were undecided, oppose, or strongly oppose the proposal. Students were also asked to give a reason why they supported or opposed the proposal. The results were analysed to determine whether students supported the proposal and then to identify their reasons for supporting or opposing the proposal.

Data regarding Year 10 and 12 Australian and Indian students' support for the proposal are given in Table 6.2.

Table 6.2. Students' response to the proposal to reduce car usage.

Students' response	Percent of students		
	Australia (n = 213)	India (n = 225)	Total (n = 438)
Strongly Support	2.4	13.8	8.3
Support	19.2	30.7	25.2
Undecided	26.9	19.1	22.9
Oppose	24.0	22.7	23.3
Strongly Oppose	27.4	13.8	20.3

The reasons given for supporting or opposing the proposal were coded into five categories based on the responses given by the 438 Australian and Indian Year 10 and 12 students. Each category was defined in terms of a number of pointers, which are listed overleaf. A response reason was placed in one of these categories if it included at least two of the pointers for that category.

1. **Strong reason for the supporting the proposal to discourage car use to reduce the GHE**

- The increasing number of cars produce more pollution and greenhouse gas emissions
- The increasing number of cars create traffic jams, make more pollution and it takes longer to reach your destination
- More people would use public transport and it can be very effective and systematic
- Increasing the price of petrol and licensing and parking fees is the only way to reduce this problem

2. **Concerned with the GHE but not supporting the proposal**

- Greenhouse gas emissions and pollution are very important
- The public transport system is not reliable and does not cover all suburbs
- Private vehicles are the only way for people to reach their offices in time or appointments
- Increasing the price of petrol and licensing makes it difficult for people to manage their budget

3. **Undecided because of the lack of flexibility of the proposal regarding public transport and not having faith in political parties and governments**

- Pollution by cars as well as public transport is a real problem
- People are already affected by tax and a further increase is really difficult
- Governments always do things by increasing tax and there should be some other way
- Imposing a price rise is not fair, some people can afford and some cannot afford these price rises

4. **Not supporting the proposal due to reasons other than the GHE**

- Private cars are important to reach your destination in time
- Public transport is not reliable
- Price increases are difficult to cope with
- An increase in the price of petrol increases the price of many other things
- Reducing greenhouse gas emissions should start with industries

- Scientists should produce more eco-friendly cars and it should be less expensive

5. Not supporting the proposal and not concerned about the GHE.

- Time is very important
- A city is only a small place compared to the country so that the emissions in the city are not a serious problem to the country
- Increasing the price of petrol will mean only the rich can afford the luxury of a private car
- A car is a personal convenience to reach places and it is a right
- Make more fuel efficient cars less expensive

The results were analysed based on the codes generated and are given in Table 6.3.

Table 6.3. Percentage of students giving various reasons for supporting or opposing the proposal to reduce car use

Reasons	Percent of students		
	Australia (n = 213)	India (n = 225)	Total (n = 438)
Strong reason for supporting the proposal	18.9	44.2	32.1
Not supporting but concerned with the GHE	1.0	-	1.0
Undecided because of lack of flexibility of the proposal	27.2	19.2	23.0
Not supporting due to reasons other than GHE	17.0	7.9	8.8
Not supporting and not concerned with the GHE	35.9	35.3	35.6

The following responses illustrate the range of reasons given by students to support or oppose the proposal.

A 12 / 1 (Oppose)

"Because car petrol is an everyday need and could throw Australia's economy out of equilibrium"

A 12 / 16 (Strongly Oppose)

"I earned it and I don't want to loose it"

A 12 / 36 (Undecided)

"Some people live a long way from the work and there is no public transport on offer, or non that will run on time to get to their work or stop close to their workplace, therefore driving their own vehicle would be easier.

I agree that people should use public transport more, but it doesn't mean petrol/ parking/ licensing fees have to increase. This is especially unfair to those in rural areas who have no choice but to drive"

A 10 / 61 (Support)

It is a good idea to reduce pollution in this way, although it may not be good for families who may not have enough money to keep up with rising petrol prices and car licensing fees"

I 10/ 2 (Support)

Many people drive to the city in cars etc. even if it is only a short walk from their homes. Also they prefer move from shop to shop in their cars even if it is the adjoining shop. Reducing the parking bays and increasing prices of petrol certainly discourage the car uses. Thus will if only a small amount reduces the greenhouse gas which are emitted"

I 12 / 3 (Strongly Support)

The day by day increase in vehicles especially private cars produce maximum pollution. If we impose all those above suggestions it will be a great success because it will be difficult for them to handle any private vehicles. Therefore they will use the public transport thereby reducing pollution and thus cant contribute greatly to reduce the greenhouse effect"

I 12 / 4 (Strongly Oppose)

"Today our world which we live in highly mechanised and developed. So we cannot even think of travelling to various places in public transport which is a waste of time. We have to reduce the pollution by driving eco- friendly vehicles. But trying to stop use of cars is highly illogical ... And today we cannot even dream of living without a vehicle"

I 10 / 33 (Undecided)

"Greenhouse effect is a global problem. So its solution also should be in a global level. When such a system is introduced in a smaller city it won't be much use as its effect will be very insignificant. However it will just help in creating a new problem for the people living there. As the aim is the number of car users will reduce as they won't be able to afford it and this will help in widening the gap between poor and rich. So in my opinion a better method is to use any other eco friendly fuel such as CNG"

The majority of Year 10 and 12 Australian and Indian students (56%) were undecided or oppose or strongly oppose the proposal of reducing car use to reduce greenhouse gas emissions and 44% of students have strong reasons for opposing or strongly opposing the proposal.

Eighty Year 10 and 12 Australian and Indian students were asked to react to the following proposal (Interview question 4)

"If you were the Premier/Chief Minister of your state government, and the Minister for the Environment proposed that your government put a 25% tax on electricity to fund research and development to reduce greenhouse gas emission from electricity generation, would you approve this proposal."

The results are given in Table 6.4.

Table. 6.4. Australian and Indian students' responses to the proposal to increase tax on electricity to fund research and development.

Country	Percent of students		
	Approve	Approve with changes	Disapprove
Australia (n = 40)	10	15	75
India (n = 40)	20	50	30

The following sample student responses illustrate the range of students' reaction to the proposal.

A 12 / 46

Student: *"No No 25% tax, already people are fed up with tax and 25% is too much"*

Researcher: This is to fund research and development to reduced greenhouse gas emission.

Student: *"Well that is good but it ... it should be and not by increasing tax. Lot of money is wasted by the government, ... and they should find money for this. Government should not ask people to pay more money"*

A 10 / 103

Student: *"Surely I will approve this proposal it is a very important issue and more research is needed to find an environmental solution. It is highly polluted these days"*

Researcher: People will not be happy with 25% increase

Student: *"That is ok, this is for a good cause. I will surely approve this"*

I 12 / 65

Student: *No way... This will make more corruption. It will never go for research. This will go to politicians and they live like kings in this poor country. I will not approve such increase to make people suffer. Already we are not getting enough electricity and lot of power cut. Increase the cost is unwanted for any reason"*

I 10 / 121

Student: *"Yes I will approve it. It is very essential. Already there is power cut and we need solution for that. People will use electricity less and find an alternate source is very important"*

Researcher: It is 25% tax and people will be unhappy

Student: *"No that is not an issue the issue is finding more power good for the environment and people use less electricity"*

Eighty Year 10 and 12 Australian and Indian students were asked to react to the following proposal (Interview question 5)

"The Minister also proposes banning the sale and use of air conditioners to reduce electricity consumption and greenhouse gas emission. Will you approve this proposal?"

The results are given in Table 6.5

Table. 6.5. Australian and Indian students' responses to the proposal to ban air conditioners.

Country	Percent of students	
	Approve	Disapprove
Australia (n = 40)	5	95
India (n = 40)	20	80

The following sample student responses illustrate the range of reactions to the proposal.

A 12 / 5

Student: *"I will not approve this. Air conditioner is necessary during winter. People will find it difficult if this is done"*

Researcher: Do you have an air conditioner at home?

Student: *"Yes"*

A 10 / 29

Student: *"Yes I will approve it is necessary for the environment. This is causing UV problem also"*

Researcher: Do you have an air conditioner at home?

Student: *"No"*

I 12 / 71

Student: *"No I will not approve it. You know hospital etc, need it. It is getting hot these days. It is better to have very energy efficient air conditioner"*

Researcher: Do you have an air conditioner at home?

Student: *"Yes"*

I 10 / 121

Student: *"Yes I will approve this. This is a poor country and this is luxury. This should be banned. There is no need of air conditioners in Kerala"*

Researcher: Do you have an air conditioner at home?

Student: *"No"*

The majority of the students have strong reasons to oppose the proposal, particularly those that have an air conditioner at home. They enjoy their personal comforts and are not prepared to sacrifice them.

The following assertion can be made based on students' responses to the three proposals to reduce greenhouse gas emissions.

Assertion 6.2

> The majority of Year 10 and 12 Australian and Indian students are not prepared to sacrifice personal comforts and convenience to reduce greenhouse gas emissions.

Students' Suggestions for Actions that the State and National Governments should take to Reduce Greenhouse Gas Emissions

Four hundred and thirty-eight Year 10 and 12 students from Australia and India were asked to suggest actions that they believe the state and national governments should take to reduce the release of greenhouse gases (Part E. 2 of the Questionnaire). Six categories of response were identified from among the responses given by the students. The percentage of responses in each category are summarised in Table 6.6.

Table. 6.6. Australian and Indian Year 10 and 12 students' suggestions for state and national governmental actions that could be taken to reduce greenhouse gas emissions (n = 483).

Suggested governmental action	Percent of students
Restrict greenhouse gas emissions by law including signing the Kyoto Protocol	61.2
Research for alternate energy sources and alternate fuels	39.3
Cut down fewer trees and plant more new trees	33.8
More information and education about the issue	25.6
Restricting the use of private vehicles and fines for more emission from the vehicles	10.0
Not at all concerned with the governmental actions and no faith in governmental actions.	0.9

The majority of students (61%) considered that the government should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto Protocol. A significant number of students considered that the government should take action regarding research for alternate energy sources and fuels (39%); cut down fewer trees and plant more (34%); and provide more information and education (26%) to reduce greenhouse gas emission.

The following assertion can be made based on the data.

Assertion 6.3

The majority of Year 10 and 12 Australian and Indian students suggested that the governments should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto Protocol. A considerable number of students suggested the governments should take steps to do research on alternate energy sources and fuels, stop cutting down tress and plant more new trees, and provide more information and education regarding reduction of greenhouse gas emission.

Chapter Summary

Students' intentions to act regarding the reduction of greenhouse gases were studied by identifying their actions regarding 10 widely accepted ways of reducing greenhouse gas emissions, their reactions to proposals regarding the use of cars and, air conditioners and increasing cost of electricity, and their suggested actions that state and national governments to take.

The following observations were made based on the data.

- The majority of students and their families are already taking action or considering taking action regarding 10 accepted ways to reduce greenhouse gas emissions by household activities.
- More than 65% of the students and their families are already switching off lights and electrical appliances when they are not needed, using manual mechanical

devices wherever possible instead of using electricity, and conserving existing trees and planting new trees.

- The majority of students were undecided or oppose or strongly oppose with strong reasons the proposal to reduce the use of cars to limit greenhouse gas emissions.
- The majority of students disapproved of the proposal to increase the cost of electricity to fund research and development.
- The majority of students disapproved of the proposal to ban air conditioners to reduce greenhouse gas emissions.
- The majority of students suggested that the government should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto protocol.
- A considerable number of students suggested that governments should conduct more research on alternative sources of energy and fuel, cut down fewer trees and plant more new trees, and provide more information and education about the GHE.

Therefore in summary:

The majority of Australian and Indian Year 10 and 12 students and their families are already taking or considering taking action regarding 10 accepted ways to reduce greenhouse gas emissions by household activities. The majority of students are not prepared to sacrifice their personal comforts or convenience and they have strong reasons for that. However, they suggested that the governments should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto Protocol.

CHAPTER 7

WHAT IS TAUGHT AND LEARNED ABOUT THE GREENHOUSE EFFECT AT SCHOOL

Introduction

Environmental education does not usually occupy enough curriculum time to allow such issues to be contextualised and discussed fully (Dillon, 2002). The importance of preparing students for decision-making on socio-scientific issues has been recognised by the American Association for the Advancement of Science and the National Research Council (AAAS, 1989: NRC, 1996). To develop scientific literacy for citizenship, there is a need to include science related social issues in the science curriculum (Kolsto, 2001). Further, Goodrum, Hackling and Rennie (2001) argued that the main purpose of science education in the compulsory years of schooling is the development of scientific literacy. Scientifically literate citizens are able to identify questions, draw evidence-based conclusions and to make informed decisions about the environment and their own health and well being.

Jenkins (1999) suggested that one of the functions of schooling is the development of an informed citizenry. Citizens need to be scientifically literate in order to be able to contribute to decision-making about issues that have a scientific dimension, like the GHE. The GHE requires individual and collective actions to reduce the impact of the phenomenon on climate change. Ultimately it is beliefs about an issue that affect a person's behaviour, however, the person's understanding of the issue can influence these beliefs. Students' understanding of an issue can be informed by the curriculum, textbook, teaching and learning at school. The GHE is a very important science related social issue and it should be properly addressed at schools as future citizens need to have a better understanding of the phenomenon, and will need to make lifestyle decisions that affect greenhouse gas emissions.

The present status of the GHE in science and chemistry curricula in Australia and India was studied at 10 schools, by analysing curriculum documents, interviewing selected students at these schools, and by interviewing heads of science. The syllabus, textbooks, learning programmes of schools and the curriculum documents in the states of Western Australia and Kerala were analysed to determine the extent to which the GHE is included in science and chemistry curricula.

Present Status of GHE in Science and Chemistry Curricula

The present status of the GHE in science and chemistry curricula in Western Australia and Kerala was studied at compulsory and post-compulsory stages of education. At the compulsory stage, Year 8 to 10 science curricula were analysed and at the post-compulsory stage, Year 11 and 12 chemistry curricula were analysed.

Western Australia

In the compulsory years of secondary education in Western Australia, that is up to Year 10 level, it is the school that decides what topics are to be included in science teaching and learning programmes based on the student outcome statements. There are nine major learning outcomes, which are organised into two groups, that is *Working Scientifically* and *Conceptual Outcomes* (Education Department of WA, 1998)

The GHE could be included in the curriculum and be used to develop any one of the learning outcomes. For example it could be included in programmes of study for Year 9 or 10 students to develop all the nine outcomes in science using the following suggested link between the GHE and science learning outcomes.

1. Investigating

Students investigate to answer questions about the natural and technological world using reflection and analysis to prepare a plan; to collect, process and interpret data; to communicate conclusions and to evaluate their plan, procedures and findings.

Climatic models

- Students can make models of climatic variations based on the data available and predict the climatic variations and compare with the scientists' data and predictions.

2. Communicating Scientifically

Students communicate scientific understanding to different audiences for a range of purposes.

Student Project Presentations

- Students can develop and produce a project about the GHE in terms of its effects, and personal actions to reduce the greenhouse gas emissions. The project report could be used to communicate findings as an oral report, a poster or a formal written report.

3. Science in Daily life

Students select and apply scientific knowledge, skills and understandings across a range of contexts in daily life.

Awareness about the GHE

- Awareness about the human actions, enhanced greenhouse gas emissions and global warming
- Awareness about the enhanced GHE and possible personal, community and governmental actions to reduce the greenhouse gas emissions

4. Acting Responsibly

Students make decisions that include ethical consideration of the impact of the process and likely products of science on people and the environment.

Personal, community and governmental actions to reduce the greenhouse emissions

- Importance of taking actions about all possible ways to reduce greenhouse gas emissions
- Understanding the importance of Governments making commitments to the Kyoto protocol

5. Science in Society

Students understand the nature of science as human activity

Enhanced GHE due to human activities, and GHE modelling

- Increased greenhouse gas concentrations after the industrial revolution
- Computer modelling of the GHE as an example of how scientists use computer models to predict future impacts of natural phenomena.

6. Earth and Beyond

Students understand how the physical environment on Earth and its position in the universe impact on the way we live.

Natural and enhanced GHE

- Natural GHE makes the life possible in the Earth
- Enhanced GHE due to human activities causes global warming

7. Energy and Change

Students understand the scientific concept of energy and explain that energy is vital to our existence and to our quality of life.

Solar radiations to Earth

- Absorption and emissions of solar radiations by the Earth
- Mechanism of the GHE

8. Natural and Processed Materials

Students understand that the structure of materials determines their properties and that the processing of raw materials results in new materials with different properties and uses.

Greenhouse gas emissions from combustion of fossil fuels

- Greenhouse gas emissions from transport
- Greenhouse gas emissions by domestic energy use

9. Life and living

Students understand their own biology and that of other living things, and recognise the interdependence of life.

Natural and enhanced GHE in terms of sustainability of life in the Earth

- Natural GHE making the life possible in the Earth
- Enhanced GHE impacts on ecosystems causing problems for sustainability of life on certain ecosystems

Out of the five Western Australian schools selected for this study, the GHE was included in the curriculum of only one school, and was taught in Year 9.

The Curriculum Council controls the syllabus for the Year 11 and 12 chemistry courses in Western Australia. The current chemistry syllabuses (Curriculum Council, 2001) do not mention the GHE. The syllabuses focus on chemical facts, laboratory preparations, properties, reactions and toxicity of substances rather than environmental aspects of chemistry phenomena. Five schools where this study was conducted used the same textbook (Garnett, 1996), which included an explanation of the GHE, however that was not included in the teaching and learning programmes of these schools as the teaching learning programmes were strictly based on the chemistry syllabus. The Curriculum Council moderates the teaching and learning programmes and the assessments across schools so that the schools tend to follow similar teaching, learning and assessment structures.

Kerala

The course followed in Kerala at the Year 10 level is based on the syllabus prepared by the Central Board of Secondary Education (CBSE, 2001) and the textbook developed by the National Council of Educational Research and Training (NCERT), India. To be affiliated to the Central Board of Secondary Education (CBSE), which is the examination conducting authority at Year 10 and 12, it is compulsory that the schools should follow the syllabus. The science syllabus at Year 10 level has five units of study and they are *Energy, Food and Health, Environment and Living Resources, Natural Resources* and *Universe*. The GHE can be included in *Energy, Environment and Living Resources, Natural Resources* and *Universe* units. The carbon cycle is included in the *Environment and Living Resources* unit. In the *Energy* unit, absorption of solar energy by the Earth is mentioned. In the textbook for standard 10 the GHE is mentioned in the chapter on Ecological Balance as a part of the importance of carbon dioxide (NCERT, 1999a, p. 118-119).

> *"The carbon dioxide in the atmosphere also performs another major role. The earth receives light of different wavelengths from the sun. The ozone in the upper atmosphere absorbs most of the harmful ultraviolet radiation and lets the other wavelengths passthrough. However, some of the light incident on earth*

is reflected back in the form of infra red light, that is light whose wavelength is greater than that of red light. Carbon dioxide molecules have the ability to absorb the infra red radiation reflected from the earth. A blanket of carbon dioxide can, therefore, trap infra red light in the atmosphere to heat up. This heating due to trapped radiation is called the GREENHOUSE EFFECT.

A similar phenomena is observed inside an automobile. The sun's ray enter the car through the glass windows. Some of this light is reflected from the metal and the upholstery inside the car in the form of infra red light. The glass windows like the CO_2 can trap this reflected infra red light and cause the interior of the car to heat up considerably. In fact the name greenhouse is derived from a glass structure used to cultivate potted plants in some countries.

Water vapour and ozone also have the ability to trap infra red radiation and also sometimes referred to as greenhouse gases. However, water vapour is only found near the surface of the earth, and ozone only in the upper reaches of the atmosphere. Carbon dioxide which is much more evenly distributed in the atmosphere and contributes to the greenhouse effect to a larger extent.

The proportion of carbon dioxide can, therefore, affect the temperature of the atmosphere. If this proportion increases, the temperature is liable to rise."

There is also a lesson in the Year 10 English textbook (NCERT, 2000, p. 83 - 85) about the GHE. The lesson includes an explanation of the GHE using a garden greenhouse analogy and compares that with the GHE of the Earth. Students study the GHE from a diagrammatic representation in the English textbook, which states that carbon dioxide traps the reflected heat and causes the GHE. In the textbook students' exercises include completing an incomplete passage, writing a newspaper extract about global warming based on an extract given, and a GHE crossword. Students in the compulsory years of education learn science and English as core subjects, and therefore should learn about the GHE.

At the Year 11 and 12 levels, there is no mention of the GHE in the chemistry syllabus or in the textbook developed by NCERT (CBSE, 2001: NCERT, 1999b). The chemistry syllabus for Year 11 and 12 prepare students' for three-hour theory and practical national board examinations. The theory examination is for 70 marks and practical examination for 30 marks. The chemistry theory at Year 11 and 12 are divided into units and chemical concepts in each unit are clearly described in the syllabus. The textbook is exclusively based on the chemical concepts in the units described in the syllabus. There is no scope for the inclusion of the GHE within the framework of the chemistry course followed in Kerala in Year 11 and 12 chemistry. This study was conducted in five schools and none of those schools included the GHE in their teaching and learning programmes at the post-compulsory stage in chemistry.

The following assertions can be made based on the analysis of curricula, teaching and learning programmes and textbooks used regarding the GHE at schools in Australia and India.

Assertion 7.1

> The GHE is not adequately represented in teaching and learning programmes for science in the compulsory years of schooling in five Western Australian schools included in the study. There is no mention of the GHE in the Western Australian Year 11 and 12, Chemistry syllabuses.

Assertion 7.2

> The GHE is briefly mentioned in the Indian Year 10 science textbook, as a part of a section on the importance of carbon dioxide; however, it is not fully described with all its mechanisms, effects and impacts. There is no mention of the GHE in the Year 11 and 12 Chemistry syllabus or textbook.

Students' Reports about what is Taught or Learned about the GHE at School

Forty students each from Australia and India were interviewed about what is taught at their school regarding the GHE. In the interview, students were asked the following questions: "Have you been taught about the GHE in science/chemistry at school? Has it been taught in any other school subject? What aspects of the GHE were discussed in class?" The students' responses to the first question are summarised in Table 7.1

Table 7.1. Percentage of Australian and Indian Year 10 and 12 students who have been taught the GHE at school.

Students response	Australia (n = 40)	India (n = 40)
Taught in science	51.5	88.5
Taught in other learning areas	47.0	21.25
Taught in Year 11 or 12 Chemistry[a]	0.0	0.0

Note [a] Only the 15 Year 12 students in each country responded to the question about Year 11 and 12 studies.

Many students were not sure what aspects of the GHE they had been taught in lower secondary science in Western Australia. Thirty-five out of 40 students interviewed said they could not remember what they were taught. Typical of the student comments were: *"I am not sure and remembering as it is long time ago"* (A 10 –45). *"I think heating effect, not sure"* (A 10- 105).

In India, Year 10 students learned about the GHE as a heating effect due to trapped radiation by the carbon dioxide gas as mentioned in the textbook. This finding is consistent with the student understandings of the GHE revealed in the questionnaire as the majority of students had only a moderate level of understanding about the GHE (Level 3) as described in Chapter 5.

Based on the students' responses, the following assertion can be made.

Assertion 7.3

A large majority of Indian students indicated that they had been taught some aspects of the GHE by Year 10 in science. About half of the Australian students had been taught something about the GHE by Year 10. The number of Year 10 students who were taught about the GHE in other subjects was greater in Australia. All of the Year 12, students (n = 30) who were interviewed indicated that they had not been taught about the GHE in Year 11 or 12 chemistry.

Heads of Science Department's Views about the Teaching of the GHE in Schools

The heads of science from the five Australian and five Indian schools involved in this study were interviewed regarding the status of GHE in their science and chemistry programmes. A Dean of Studies in one Australian school and an Academic Programme Coordinator in one Indian school were also interviewed. The responses given by the Heads of Science, Dean of Studies and Academic Programme Coordinator are summarised below, question-by-question.

Interview Question 1.

"What are lower secondary students taught about the GHE in science at your school?"

The Australian heads of science were not sure whether the GHE is included in their science programmes. They indicated that it could be taught at Year 9 in the *Energy and Change* unit, however it is not prescribed in the school programme and individual teachers are free to include or omit the topic.

The following are some of the response given by the Australian heads of science.

Head of Science (Australia) 4

"Yes, in Year 9 we teach greenhouse effect. It is in gases and atmosphere. Well, carbon cycle is taught and carbon dioxide and its importance is dealt well. Consequences and global warming are also dealing there. So it is taught at Year 9 science. Yes not in full details as you expect in your questionnaire"

Head of Science (Australia) 1

"It is up to the teachers who teaches at that level. However life and living we should be addressing all environmental issues."

Since the GHE is mentioned in the Indian science textbook (NCERT, 1999a) at Year 10 level, the heads of science in India mentioned that it is taught at Year 10. The heads of science remarked that it is not an important area as it is not tested in the final board examination, so it may be just mentioned, and not taught in detail. The following are some of the responses:

Head of Science (India) 3

"Yah, it is in the standard 10 textbook. So it is taught. You know that is not an important area from where questions are coming for the CBSE examination. Well it is so just mentioned like that, that is all"

Head of Science (India) 5

"Well, yes, it is taught and there is Greenhouse effect in the textbook. As you expect in your questionnaire I doubt whether we teach. There may not be many questions in the exam from that area so just mention it is an importance of carbon dioxide. Of course it is an important issue and it should be properly taught"

Interview Question 2

"There is no mention of the GHE in the WA / Kerala Year 11 and 12 Syllabuses. Are you aware of any aspects of GHE taught to chemistry students in your school?"

All the heads of science interviewed, the dean of studies, and the academic programme coordinator all agreed that there is no mention of the GHE in the chemistry syllabus at the Year 11 and 12, level. The response to whether any aspects of the GHE taught to chemistry students was "*it is up to the teachers*" (HOD. Australia 1). There is an opportunity for the teacher to mention it when teaching about carbon dioxide in Year 11.

The following are some of the responses from the heads of science:

Head of Science (Australia) 4

"Yes it is not there in the syllabus, I am more of a Biologist than a Chemist. I don't know ....really I have not heard anyone talking that they are teaching Greenhouse Effect in upper school TEE Chemistry. No I don't think it will be as it is not in syllabus"

Head of Science (India) 1.

"*Teachers would be more focused to the syllabus and finishing the syllabus in time for the examinations. Students may not also be very keen to learn something that is not in syllabus at this stage. Students would be keen to listen just a talk rather than learning things in detail to issues that are not in syllabus"*

Interview Question 3

"Are you aware of any other learning areas that teach about the GHE? *Society and Environment* for example?"

In Australia, two out of the five heads of science said that they were not aware of any other learning area teaching about the GHE. Three heads of science and the dean of studies said that they were aware of GHE being taught in *Society and Environment*, but they were not sure how much or in what context it was taught.

The researcher remarked that there were a considerable number of students who have misconceptions about the GHE and it may be due to the teaching in the *Society and Environment* learning area by the teachers who do not understand the science behind the GHE. All the heads of science said "*probably*" and the dean of studies said "*there is a likely high chance for that*".

All the heads of science in India said they are not aware of any other learning area teaching about the GHE. The academic coordinator mentioned that it might be discussed in geography.

Interview question 4

"Should your school do more to ensure your students have a better understanding of the GHE?"

All the heads of science in Australia and India who were interviewed fully agreed that their schools should do more to ensure that the students have a better understanding about the GHE. The following are some of the responses.

Head of Science (Australia) 1

"Yes, very very important issue. We should do more"

Head of Science (Australia) 3

"Yes we should, and more open-ended and project like tasks should be given. We should ensure that it is not left out."

Head of Science (India) 5

"Now you know what is happening is just concentrating for the examinations and teaching for getting good marks. Students and parents want only that. We teachers should do more"

Head of Science (India) 2

"See the greenhouse effect is mentioned in just one line in the textbook, and well I don't think that is enough. It seems according to the syllabus it is not very important. Well it should be very clearly describe in the syllabus, textbook.......only then it can be taught effectively."

Interview question 5

"How do you think the GHE should be taught, to be effective?"

The responses from the Australian heads of science revealed the following views:

- It should be taught in detail and hands-on experiments should be included to show the GHE.
- The mechanism of the GHE should be taught fully so that students understand the importance of their role in reducing the GHE.
- It should be taught in a cross-curricular manner so that would be considered from social, economic, political and, scientific angles.
- Students should be presented with the realities about the climatic model predictions.
- Students should do independent learning about the impacts in terms of climatic changes.

The response from the Indian heads of sciences revealed the following views:

- Students should make models and reports about the GHE.
- Students should make computer-generated models of the GHE in the computer classes.
- There should be debates and discussions.
- This should be an important area from which questions are asked in the public examination.

Interview question 6

"Do you think an understanding of the GHE is an important aspect of scientific literacy? What responsibility do schools have for improving the public understanding of science issues like the GHE?"

All the heads of sciences in Australia as well as in India agreed that the GHE is an important aspect of scientific literacy. The following are some of the responses:

Dean of Studies, Australia

"Very important aspect of scientific literacy. Issue like GMF, stem cells research also should be dealt well at school science...... Perhaps we have to teach it well"

Curriculum Coordinator, India

"Definitely it is a very very important aspect of scientific literacy. Actually people should understand its impacts and climatic variations these days. Lot of discussion is going on now a days in the media. I strongly feel it should be dealt well in syllabus and textbook"

Based on the interview data of the heads of sciences in Australia and India the following assertions can be made:

Assertion 7.4

Australian heads of sciences remarked that the GHE might be taught at lower secondary students at Year 9 in science. It is up to the science teachers who are teaching at this level to decide. The GHE is not mentioned in the Year 11 and 12 chemistry syllabus therefore it may not be taught at this level.

Assertion 7.5

Indian heads of science remarked that the GHE is taught at Year 10 in science; however, it is not tested in the board examinations. The GHE is not mentioned in the Year 11 and 12, chemistry syllabus therefore it may not be taught at this level.

Assertion 7.6

Australian heads of science remarked that the GHE may also be taught in the Society and Environment learning area and that would probably be one of the reasons for the misconceptions about the GHE. Indian heads of science are not aware of any other learning area teaching about the GHE.

Assertion 7.7

Australian and Indian heads of sciences consider that the GHE is an important aspect of the scientific literacy and agree that the schools should do more to ensure students have a better understanding of the GHE.

Chapter Summary

The following are the major aspects of the teaching and learning about the GHE in Australian and Indian schools at compulsory and post-compulsory levels of science and chemistry respectively, based on the curricula, syllabus, textbooks, and students' and heads of science' responses.

- The GHE is not included in the teaching and learning programmes at the compulsory stage of science education in Australia.
- The GHE is mentioned in the Year 10 science textbook in India, however, it is not fully explained.
- At the post-compulsory stage, there is no mention of the GHE in the chemistry syllabuses in Australia and India.
- The majority of Australian and Indian students learn something about the GHE by Year 10 in science, though not in any detail.
- Australian students learn about the GHE in other learning areas like Society and Environment, more than the Indian students.
- According to Australian heads of sciences it is up to the teachers teaching science to decide whether the GHE should be taught or not at the lower secondary level.
- According to the Indian heads of sciences the GHE is mentioned in the textbook of Year 10 science, however, it is not treated adequately so that students can learn about its mechanism, effects and impacts.
- Australian heads of sciences remarked that the teaching of the GHE in other learning areas are one of the reasons for the student misconceptions about the GHE.

- Australian and Indian heads of sciences remarked that schools should do more to ensure that students have a better understanding of the GHE.
- Australian and Indian heads of sciences consider that the GHE is an important aspect of scientific literacy.

Therefore in summary:

The GHE is not adequately represented in Australian and Indian science and chemistry curricula. In Australia, teachers have the choice to teach the GHE in science and in India, the science syllabus and textbook mention the topic, however, it is not represented sufficiently for the students to develop an understanding of the GHE. The heads of science in Australia and India consider that Australian and Indian schools should do more to teach the GHE, as it is an important aspect of the scientific literacy.

CHAPTER 8

DISCUSSION AND GENERALISATIONS

Introduction

The conceptual framework of this study is informed by the theory of reasoned action (Ajzen & Fishbein, 1980) and links students' understandings, and beliefs to their intentions to act regarding environmental issues such as the GHE. An understanding of the GHE is an important aspect of scientific literacy. Scientific literacy and public understanding of environmental issues developed in science classrooms can provide a foundation for informed decision-making about socio-scientific issues like the GHE and empower communities to take appropriate actions for a sustainable, green and clean environment (Bamford, 1999; Hart, 2002; Olson et al, 1999; Solomon, 1999).

This Chapter draws together the arguments developed from the data presented previously in Chapters 4 (Students Beliefs about the GHE), 5 (Students' Understanding about the GHE), 6 (Students' Intentions to Act Regarding Proposals to Reduce Greenhouse Gas Emissions) and 7 (What is Taught and Learned about the GHE at School), and makes connections with the conceptual framework of this study, the literature and previous research. This process has been used to generate ideal and actual scenarios of students' beliefs, understanding and intentions to act to reduce greenhouse gas emissions. Further key themes are formulated and links are made to the theory of reasoned action.

Research questions and the conceptual framework of the study guided the analysis of the data from the questionnaires and interviews. Coding and interpretation of students' and heads of science' responses involved reading and re-reading the answers to identify emerging patterns in the data (Krathwohl, 1998). Assertions were made based on the analysis and interpretation of the data. In this Chapter, links between the data from Chapters 4 to 7 are identified and connections made with the conceptual framework, the literature and previous research. Triangulation of data from different sources helped identify key linkages and generalisations that support possible scenarios (Erickson, 1986; Fielding & Fielding, 1986; Flick, 1992).

An ideal scenario of students' beliefs, understandings and intentions to act in ways that would reduce the GHE can be formulated based on the Propositional Knowledge Statement (PKS) and a number of key reports (AGO, 2000; IPCC, 2001; UN, 1992; UNEP, 2001). Further, based on the data gathered in this study regarding students' actual beliefs, understandings and intentions to act towards the GHE, an actual scenario can be generated and compared to the ideal scenario.

Ideal Scenario

The aspects of students' beliefs, understandings and intentions to act in ways that would reduce the impacts of the GHE, which were investigated in this study, are illustrated in Figure 8.1. These key aspects are considered in the ideal scenario. The extent to which students realise these key aspects are identified in the actual scenarios.

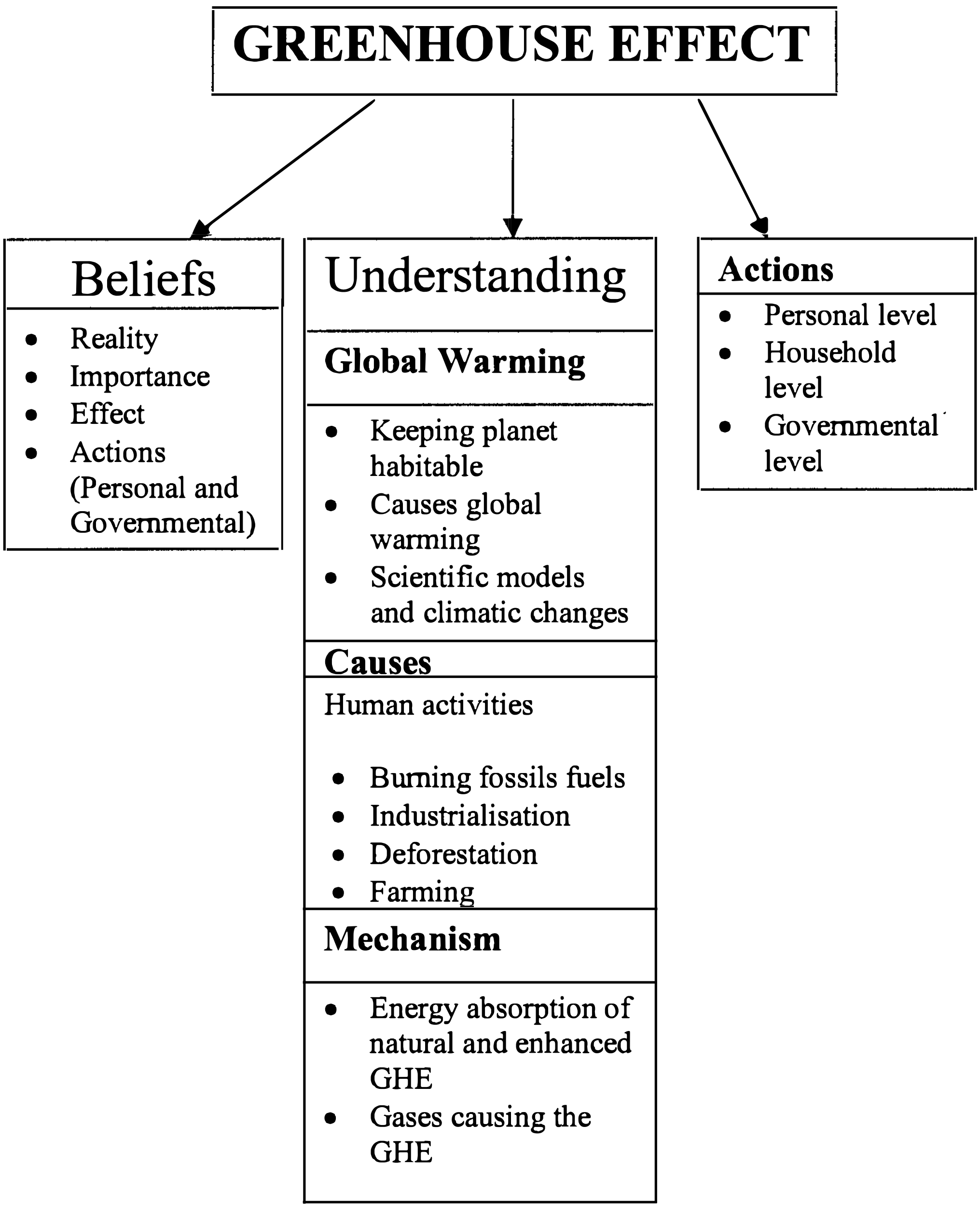


Figure 8.1. Aspects of students' beliefs, understanding and intentions to act regarding the GHE investigated in this study.

The Propositional Knowledge Statement (PKS), which was developed and validated by experts, include propositions about: the importance of the natural GHE; the causes, mechanisms and impacts of the enhanced GHE; and the importance of reducing greenhouse gas emissions. The PKS represent the essential knowledge that high school students need to understand the GHE, interpret media reports and to inform appropriate actions to reduce greenhouse gas emission. Further, the IPPC report (IPCC, 2001), UNEP document (UNEP, 2001), Australian Greenhouse Office reports (AGO, 1999, 2000) and United Nations report (UN, 1992) all provide suggestions for education about the causes, mechanism, importance and impacts of the GHE, and ways by which greenhouse gas emissions can be reduced. The ideal scenario is based on the PKS and the reports listed above. The ideal scenario describes students' beliefs, understandings and commitments to take actions that would enable individuals and communities to reduce greenhouse gas emissions.

Students believe that the GHE is:

- Real and affecting our climate, and will continue to affect our climate in the future.
- An important social issue that requires personal, community and governmental actions to reduce its effect.

Students understand that:

- The GHE is a natural phenomenon in terms of absorption and emission of solar radiation by the Earth and its atmosphere, thereby keeping the planet habitable.
- Human activities like burning fossil fuels for electricity and transportation, industrialisation, deforestation and farming have increased greenhouse gas emissions.
- Enhanced concentrations of greenhouse gases have increased the heat energy trapped by the atmosphere resulting in increased global temperatures, a rise in sea levels and changes in the climate.

Students are committed to take appropriate decisions and actions to reduce greenhouse gas emission by:

- Reducing energy consumption in their homes and from transportation, and by supporting and engaging in community and governmental level actions to reduce greenhouse gas emissions.

Figure 8.2. The ideal scenario

The enhanced GHE has caused climate changes and an increased incidence of natural disasters such as droughts, bushfires and floods, and hotter summers and cooler winters (IPCC, 2001). It is time for us to find a path that is better for people and less harmful to the environment with the policies, knowledge and technologies at our disposal today. The human family should take tentative steps in this enlightened direction (Earth Summit, 2002). In this context, it is very important that high school students should be scientifically literate and be committed to acting in ways that reduce greenhouse gas emissions.

Actual Scenario

The actual scenario provides a picture of students' beliefs, understandings and intentions to act in ways that would reduce greenhouse gas emissions, and is based on the data gathered from Year 10 and 12 Australian and Indian students in this study. The major findings from the student survey and interviews are discussed in terms of the research literature and previous studies, before generating the actual scenario.

Students' Beliefs about the Greenhouse Effect

In this research, the following aspects of students' beliefs about the GHE were studied; its reality, relative importance compared to other social issues, effect on global warming, and what actions the governments and they, personally, should take. The major findings of this study regarding students' beliefs about the GHE (Chapter 4) were the following:

Reality

- The majority of Australian and Indian Year 10 and 12 students believe that the GHE is real and affecting our climate at present and will affect it in the future (Assertion 4.2).

Relative importance

- Australian and Indian Year 10 and 12 students ranked the GHE fourth of seven important social issues which include: economic issues and poverty, the GHE, increasing crime, terrorism, health and diseases like AIDS, family breakdown, and increasing drug use. It can therefore be concluded that the GHE is considered by students to be an important social issue (Assertion 4.1).

Effect on global warming

- The majority of Australian and Indian Year 10 and 12 students believe that there will be substantial changes to average global temperature and sea level rise over the next 50 years, however, their estimates of these changes are not consistent with scientific predictions (Assertion 4.7).

Personal and governmental actions

- A small majority of Australian and Indian Year 10 and 12 students believe that what they do has an impact on the GHE, however, a quarter of all the students are not sure how they have an impact on the GHE (Assertion 4.4).
- The majority of Australian and Indian Year 10 and 12 students believe that governments should conduct more programmes to raise community awareness about the GHE and enact strict laws to reduce greenhouse gas emissions (Assertion 4.3).

The Australian Greenhouse Office (AGO, 1999) investigated community awareness of, and attitude to climate change. The research revealed that 19% of the Australian public rated the environment as the issue of most concern to them, ahead of economic issues. The enhanced GHE was rated seventh in importance in a list of 17 environmental issues. Further, respondents indicated that all governments need to be, and seen to be leading the way in terms of reducing greenhouse gas emissions. Another survey of over 1000 British 15 and 16 years olds revealed that of four issues; loss of ozone layer, destruction of tropical rain forests, global warming and greenhouse effect, and loss of animal and plant species; global warming and the greenhouse effect was ranked third (Morris & Schagen, 1996). In this study of Australian and Indian Year 10 and 12 students the GHE was ranked fourth among seven important social issues which included economic issues and poverty, health and diseases like AIDS, increasing drug use, terrorism, family breakdown and increasing crime. These three studies confirm that many secondary students and members of the general public consider the GHE to be an important social issue that they are concerned about.

In this study, a large majority of the students (more than 85%) believe that governments should conduct more programmes to raise community awareness about the GHE and enact strict laws to reduce the release of greenhouse gases. This finding is consistent with the findings of the Australian Greenhouse Office's investigation regarding the public's attitudes about environmental issues (AGO, 1999). In this study, a small majority of Australian and Indian Year 10 and 12 students believe that what they do has an impact on the GHE, however a quarter of all the students are not sure about it. These data suggest that students' may believe governments have a greater role to play than individuals in solving this environmental problem.

Students Understanding of the GHE

The following are the important findings from this study regarding the students' understanding of the GHE:

Global warming

Keeping our planet habitable

- The majority of Australian and Indian Year 10 and 12 students did not understand that the natural GHE is keeping our planet habitable (Assertion 5.1).

Causes of global warming

- The majority of Australian and Indian Year 10 and 12 students understand that the GHE causes global warming, however, less than half could explain how or why (Assertion 5.2).

Scientific models of climatic changes

- The majority of Australian and Indian Year 10 and 12 students' understanding of anticipated global temperature rise and sea level rise are not consistent with scientific predictions (Assertion 5.3).

Causes of the GHE

Burning fossil fuels and deforestation

- A large majority of Australian and Indian Year 10 and 12 students understand and explained that the burning of fossil fuels and deforestation increase the GHE (Assertion 5.4).

Farming

- A small majority of Australian and Indian Year 10 and 12 students were aware that cattle and sheep farming enhanced the GHE but less than one third of all students could explain why or how cattle and sheep increase the GHE (Assertion 5.5).

Mechanism of the GHE

Students' understanding of the absorption and reflection of solar radiation by the Earth and atmosphere, and gases causing the GHE were investigated. The students' understanding of the mechanism of the GHE were categorised into five levels. Level 1 represents the highest level of understanding and level 5 represents the lowest level of understanding exhibited by the students in the sample.

- Less than 10% of students provide a complete and scientifically accurate explanation of the mechanism of the GHE (Assertion 5.6)
- The majority of the Australian students have a minimal understanding or misconception about the mechanism of the GHE (Level 4 and 5) (Assertion 5.7)
- The majority of Indian students have a modest understanding about the mechanism of the GHE (Level 3) (Assertion 5.8).

The majority of students in this study have a general or big picture understanding of the GHE, however, less than 10% could explain the details of the energy flow mechanism. The majority of students could not identify greenhouse gases other than carbon dioxide.

To be able to understand the importance of actions like switching off lights when they are not needed to reduce the GHE, students should be able to link scientific aspects of the GHE and its energy flow mechanism. It is observed from this study that most students are unable to link power generation, carbon dioxide emission and energy trapping to subsequent enhancement of the GHE. Figure 8.3 illustrates the conceptual links between electricity consumption in the home and global climatic changes.

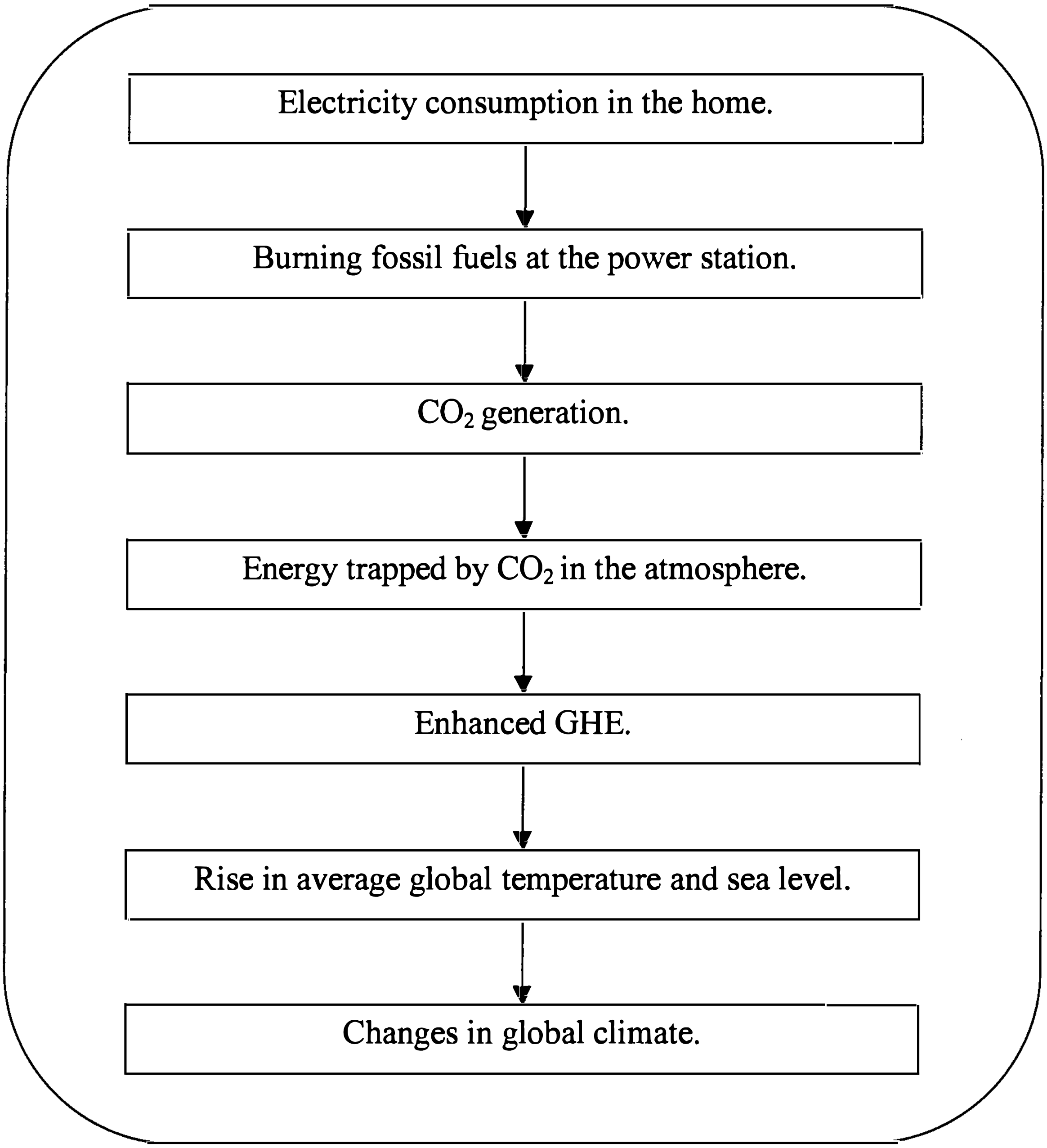


Figure 8.3. Links between electricity consumption and global climatic changes

It is also observed from this study that a significant number (about 18%) of students confused ozone layer depletion with the GHE. Many students think that the holes in the ozone layer are allowing UV radiation to pass through the atmosphere and cause global warming. There are also a significant numbers of students (about 30%) who think that pollution is the cause of global warming (Level 5 category of understanding). Students' understanding of the causes and mechanism of the GHE is inadequate and that is why they could not explain the importance of reducing personal energy use to reduce greenhouse gas emissions. To realise the importance of energy use and greenhouse gas emission, it is necessary to understand the causes and mechanisms of the GHE.

The previous research regarding students' understanding of the GHE focused on different models of student understanding and misconceptions about the GHE and ozone layer depletion. Studies by Rye and Rubba (1998); Koulaidis and Christidou (1999); and Mason and Santi (1998) focused on students' understanding of the GHE and examined their knowledge about the processes and gases involved, global warming, impacts and misconceptions. The study by Rye and Rubba (1998) also revealed that the student understanding of the GHE is not adequate in terms of energy flow mechanism, causes and global warming. They also found that students were finding it difficult to understand the GHE and its causes, effects and mechanism. Studies by Francis, et al. (1993), Boyes and Stanisstreet (1997a), and Fisher (1998) revealed students' misconceptions about ozone layer depletion and the GHE. The misconception of GHE being caused by ozone layer depletion was a common aspect in the studies of students' understanding of the GHE among primary and secondary students in the UK and other European countries. Dove (1996), Hillman, et al. (1996), and Boyes, et al. (1995) revealed that student teachers also hold misconceptions about the ozone layer depletion and the GHE. In this study also, it was demonstrated that many students have misconceptions about the GHE being caused by ozone layer depletion (Level 4 category of understanding).

Compared to the previous research, this study could identify strengths and weaknesses of students' understanding of the GHE. This study has revealed two significant weaknesses in students' understanding of the GHE; energy flow mechanisms, and the sources and roles of greenhouse gases other than carbon dioxide. In addition to this, many students do not understand that the GHE is keeping the planet habitable and many students do not have an accurate understanding of the anticipated rise in average global temperature and rise in sea level.

The fact that students at high school have only a vague, big picture understanding of the GHE and could not explain the causes, effects and mechanisms of the phenomenon is a serious problem as it limits their capacity to make informed decision about their day to day energy use.

Students' Intentions to Act in Ways that would Reduce Greenhouse Gas Emissions

Students' intentions to act in ways that would reduce greenhouse gas emissions were investigated in relation to reduction in household energy use, and reducing the use of air conditioners and cars. Students were also asked about actions that should be taken by governments. The situations and scenarios were set in contexts that are relevant to both Australian and Indian families.

The following statements summarise findings about students' intentions to act in ways that would reduce greenhouse gas emissions:

Household reduction of greenhouse gas emission

- The majority of Australian and Indian Year 10 and 12 students and their families are already taking, or considering taking actions regarding 10 easy ways of reducing household energy consumption and thereby greenhouse gas emissions (eg, use compact fluorescent lights, switch off lights and electrical appliances when they are not in use, etc.) (Assertion 6.1).

Sacrificing comfort and convenience to reduce greenhouse gas emissions

- The majority of Australian and Indian Year 10 and 12 students are not prepared to sacrifice personal comforts or convenience to reduce greenhouse gas emission by using public transport instead of cars, or by reducing the use of air conditioners (Assertion 6.2).

Government actions

- The majority of Australian and Indian Year 10 and 12 students suggested that governments should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto protocol. A considerable number of students (about 40%) suggested that governments should take steps to do research on alternative energy sources and fuels, reduce deforestation and plant more trees, and provide more information and education regarding reduction of greenhouse gas emissions (Assertion 6.3).

The majority of students and their families are already taking actions where they don't have to make a capital investment in their home eg. turning off lights. The motivation for these actions may be to reduce electricity bills rather than to reduce greenhouse gas emissions. Their responses to proposed changes, which require capital investment, were not that positive eg. installing insulation. Household energy consumption is a major contributor to greenhouse gas emissions (AGO, 2000) and personal actions are very important in reducing emissions. Energy use for transportation, air conditioners and other comforts also play a vital role in greenhouse gas emissions. The majority of students are not prepared to sacrifice their personal conveniences or comforts for reducing gas emissions. They are not prepared to use public transport rather than cars or reduce the use of air conditioners. Regarding actions that governments should take, the majority of students suggested that the governments should enact strict laws to reduce greenhouse gas emission and sign the Kyoto protocol. The irony here is that students are expecting governments to reduce greenhouse gas emission, yet are not prepared to make hard decisions themselves. Governments can only reduce greenhouse gas emission by imposing cost penalties on activities that generate greenhouse gases, eg. taxes on cars and fuels.

No previous study has specifically set out to identify students' intentions to act in ways that would reduce the GHE, however, the importance of such studies is mentioned extensively in the science education literature (AAAS, 1989; Fensham, 1997; Gayford, 2002; Kolsto, 2001; NRC, 1996). Studies have been conducted to identify decision-making about biological conservation (Grace & Ratcliffe, 2002), however, there were no findings from this study of relevance to this research on the GHE.

Global warming is accelerated by human activities like industrialisation, deforestation, farming and increased energy consumption through transportation and use of air conditioners (IPCC, 2001; Ponting, 1993). In democratic societies the importance of education lies in making it easier for governments to promote policies that will help alleviate the problem (United Nations, 1992). Informed decision-making is considered to be an important outcome of science education (Bybee, 1993; Fensham, 1988; Malcom 1987; Yager 1993). It is important to provide opportunities for students to act as responsible citizens particularly towards environmental issues. The inclusion of opportunities to develop problem solving and decision-making in science curricula has been argued by many authors (Aleixandre & Munoz, 2002; Dillon, 2002; Gayford, 2002; Gough, 2002; Hart, 2002; Weelie & Wals, 2002; NRC, 1999; Roth, 1992).

According to the theory of reasoned action (Ajzen & Fishbein, 1980) a persons' intention to act regarding an issue is influenced by their understandings and beliefs about the issue. This study has identified high school students' understandings and beliefs about the GHE, and their intentions to act to reduce greenhouse gas emission.

The main findings of this study regarding the students' beliefs, understanding and intentions to act to reduce greenhouse gas emission are:

Beliefs

Students believe:

- The GHE is important and real (Assertions 4.1 and 4.2);
- governments need to solve the problem (Assertion 4.3); and
- they are not sure of their personal impact on the GHE (Assertion 4.4).

Understandings:

Students:

- do not realise the GHE keeps the planet habitable (Assertion 5.1);
- understood the GHE is causing global warming but don't have an accurate knowledge of its effects on climate and sea levels (Assertion 5.2 and 5.3);
- have a reasonable understanding of sources of the greenhouse gas carbon dioxide, however, they have a limited understanding of the sources and impact of other greenhouse gases (Assertion 5.4 and 5.5); and
- have a poor understanding of energy flow mechanisms of the GHE (Assertions 5.6, 5.7 and 5.8).

Intentions to act to reduce greenhouse gas emissions:

Students:

- are or will take easy personal energy saving actions but are not prepared to make sacrifices (Assertions 6.1 and 6.2); and
- believe governments should solve the problem by enacting strict laws and by signing the Kyoto protocol (Assertion 6.3).

Linking students' beliefs, understanding and intentions to take actions that would reduce greenhouse gas emission, the following actual scenario has been developed.

Beliefs

The majority of students believe that the GHE is real and is affecting our climate at the present and will do so in the future, however, they are not sure about their personal impact on greenhouse gas emissions. They also believe that governments should enact strict laws to reduce greenhouse gas emissions.

Understandings

The majority of students understand that the GHE is causing global warming, although they could not explain how or why. They did not understand that the natural GHE is keeping the planet habitable and they have either minimal understanding or misconceptions about the mechanism of the GHE. They understand and are able to explain the role human activities play in enhancing the GHE; however, their understandings of the expected rise in average global temperature and sea level were not consistent with scientific predictions.

Actions

Most students and their families are already taking or considering taking action regarding 10 easy ways to reduce household energy consumption and greenhouse gas emissions. They are not prepared to sacrifice their personal comforts or convenience to reduce greenhouse gas emissions, and they held strong views about this. They suggested that governments should enact strict laws to reduce greenhouse gas emission and sign the Kyoto protocol.

Figure 8.4. The actual scenario.

The ideal scenario describes what high school students should believe, understand and be prepared to do to reduce greenhouse gas emissions, considering the importance of the issue at present and its impact on global climatic changes. The actual scenario describes high school students' actual beliefs, understanding and willingness to act to reduce greenhouse gas emission and is based on the data gathered in this study. The common aspects in ideal and actual scenarios include: an understandings that the GHE causes global warming; the importance of community and governmental actions; students believe that the GHE is real and causing global warming; and, they expect the government to enact strict laws to reduce greenhouse gas emission and sign the Kyoto protocol. The major differences are in understanding the energy flow mechanism and the importance of personal actions to reduce greenhouse gas emission where their knowledge about the links between energy consumption, greenhouse gas emission and energy trapping by the atmosphere is inadequate to explain the importance of personal actions to reduce greenhouse gas emission in the actual scenario.

Opportunities for Learning about the GHE

The opportunities for the students to learn about the GHE in high school science is limited in Western Australia and Kerala. This study has revealed that it is not adequately represented in the science curriculum in Western Australia, and in Kerala, it is only briefly mentioned in the Kerala Year 10 science textbook as part of a section that describes the importance of carbon dioxide (Assertions 7.1, 7.2, and 7.3). In Western Australia, heads of science remarked that the GHE might be taught in the lower school, however, it is up to the teachers to decide whether it is taught. In Kerala, although it is mentioned in the science textbook, it is not tested in board examinations and therefore will only be given superficial attention by the teachers (Assertions 7.4, 7.5 and 7.6). The students' main sources of information about the GHE that emerged from the analysis of the data in this study, are the media, teachers and textbooks. It was noted that the textbook is a more important source of information about the GHE for students in Kerala than for students in Western Australia. However, the GHE is mentioned only along with the importance of carbon dioxide in the Kerala Year 10 science textbook (Assertions 4.5, 4.6 and 7.2).

The heads of science in Western Australia and Kerala consider that the GHE is an important aspect of scientific literacy and schools should do more to ensure students have a better understanding of the GHE. Further they admit that at present the GHE is not adequately included in science teaching and learning programmes (Assertions 7.4, 7.5, and 7.7). They remarked that there should be clear directives in syllabuses and curriculum frameworks for the teachers, there should be adequate teaching and learning materials for the GHE, and the GHE should be included in assessments.

The GHE is a very important environmental issue and it should be properly addressed at high school so that citizens have a better understanding of the phenomenon to make lifestyle decisions that affect greenhouse gas emission. The reality is, that at present, it is not adequately represented in science curricula in Western Australia and Kerala at compulsory and post-compulsory stages of science education. In Western Australia it is up to the teachers to decide whether the GHE should be included in the teaching and learning programmes at compulsory stages of science education. In Kerala the GHE is briefly mentioned in the science textbook in relation to the importance of carbon dioxide gas, however, the GHE is not fully described with its causes, mechanism and impacts. At the post-compulsory stage, there is no mention of the GHE in chemistry syllabuses or textbooks in Australia or India. The heads of science in Australia and India consider that the GHE is an important aspect of scientific literacy and the schools should do more to ensure students have a better understanding of the phenomenon.

The beliefs, understandings and intentions to act described in the actual scenario are a reflection of what is taught and learned at high school and the information students obtain from the media. Since it is not mentioned in the syllabuses and only briefly mentioned in some textbooks, it is unlikely to be taught in science at high school. Students say they obtain most of their information about the GHE from the media (Assertion 4.5) and this probably explains students have a general awareness of the issue but do not understand the science of the mechanism of global warming. In India the importance of carbon dioxide gas is mentioned in the Year 10 science textbook, and as a consequence many Indian students have a modest level of understanding (Level 3) about the mechanism of the GHE.

Based on the actual scenario and what is taught and learned at high school and sources of students' information regarding the GHE, general assertions can be formulated.

General Assertions

The following general assertions can be formulated regarding high school students' beliefs, understandings and intentions to act towards the GHE based on actual scenarios, what is taught and learned at high school and sources of information.

General Assertion 1
(Students Beliefs about the GHE)

The majority of students believe that the GHE is real, and affecting the climate at present and will continue to do so in the future, and is an important social issue which needs strong governmental actions to solve the problem. They are not sure about the impact of their personal actions in reducing greenhouse gas emissions.
(Assertions, 4.1, 4.2, 4.3, and 4.4)

General Assertion 2
(Students understanding of the GHE)

Although the majority of students understand and are able to explain the role of human activities that contribute to the enhancement of the GHE, the majority of students did not understand the energy flow mechanisms of the GHE and their understanding of the expected rise in average global temperature and sea level are not consistent with scientific predictions.
(Assertions, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, and 5.8)

General Assertion 3

(Willingness to act to reduce greenhouse gas emission at personal and community level)

The majority of students and their families are already taking or consider taking actions regarding 10 easy ways to reduce household energy consumption. They are not prepared to sacrifice their personal comforts or conveniences to reduce greenhouse gas emission and they held strong views about this. They suggested that governments should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto protocol.

(Assertions, 6.1, 6.2, and 6.3)

General Assertion 4

(Curriculum and sources of information)

The GHE is inadequately represented in Year 10 Science and Year 12 Chemistry curricula in Western Australia and Kerala (India), and students obtain most of their information about the phenomenon from the media.

(Assertions, 4.5, 7.1, 7.4, 7.5 and 7.7)

Closing the Gap between the Actual Scenario and the Ideal Scenario

The differences between ideal and actual scenarios reflect the status of the GHE in the syllabus, textbook and implemented curriculum at high school. Improvements to the curriculum are needed to close the gap between the actual and ideal scenarios.

This study has revealed that at present the GHE is not adequately represented in high school science. Thus students' understanding of the causes and mechanism of the GHE is inadequate and that is why they could not explain the importance of reducing personal energy use to reduce greenhouse gas emissions. More opportunity is needed for developing decision-making skills about environmental issues like the GHE (Aleixandre & Munoz, 2002).

The science curriculum should provide enough opportunity for critical processing of authorative sources of information about the GHE. The PKS could be considered as a guide to developing a GHE topic in science. Students should be aware of IPCC reports and climatic models used to make predictions about global temperature and sea level rises and this should be included in textbooks. Teaching programmes should provide situations for developing criteria for evaluating possible solutions to problems. Students should debate issues related to the use of public transport, air conditioners and other comforts and conveniences where energy consumption is vital in terms of greenhouse gas emission and thereby global warming.

The challenge for science educators is to make science relevant to the lives of students and explain scientific findings in ways that they can be applied in daily life (Goodrum, Hackling & Rennie, 2001). It is also important to link scientific and environmental issues with social and cultural contexts to amplify their significance and to emphasise the personal, social and governmental actions needed to address the issues, particularly issues such as the GHE (Dillon, 2002; Hart, 2002; NRC, 1999).

Mapping Research about the GHE onto the Theory of Reasoned Action

The scenarios and general assertions about high school students' views of the GHE can be mapped with the theory of reasoned action, and the connections between opportunities to learn about the GHE in the curriculum, students' beliefs, understandings and intentions to act to reduce greenhouse gas emissions are illustrated in Figure 8.5.

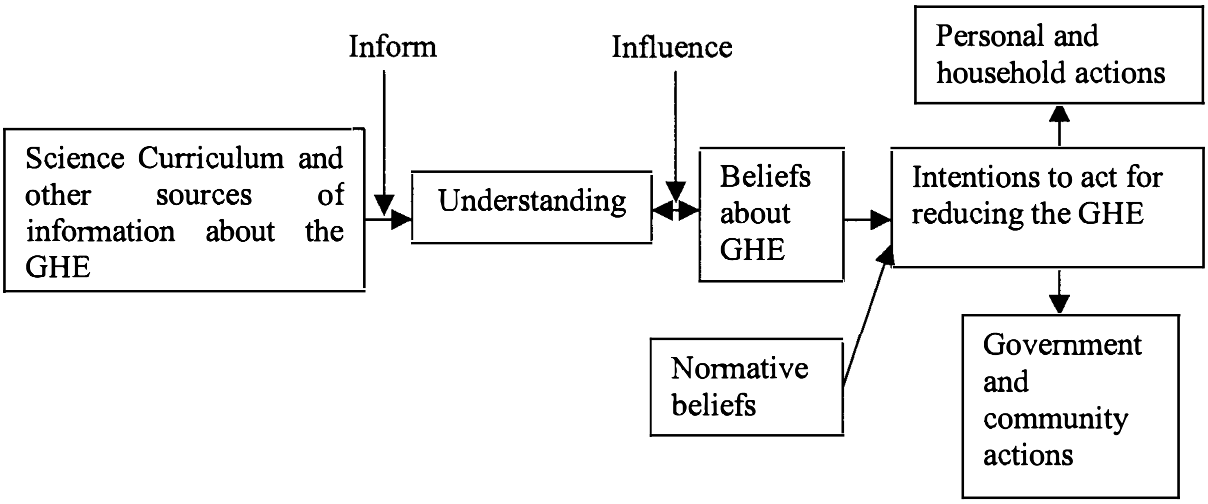


Figure 8.5. High school students' beliefs, understanding and intentions to act towards the GHE based on curriculum and other sources of information.

The theory of reasoned action (Ajzen & Fishbein, 1980) helps in understanding and predicting intentions to act regarding social issues. Information derived from school science and from the media informs and influences students' understandings and beliefs about the GHE. In addition to beliefs about the GHE, students' beliefs about how others will view their actions to reduce greenhouse gas emissions (i.e., their normative beliefs) will also influence their intentions to act (Ajzen & Fishbein, 1980). It should be noted that normative beliefs were not investigated in this study as the focus was on curriculum, students' understandings, beliefs and intentions to act in relation to the GHE.

In an ideal situation, the science curriculum would be based on the PKS and students would be able to understand the causes, mechanisms and impact of the GHE and they would hold strong beliefs about the reality and importance of the GHE and be committed to reducing greenhouse gas emissions. If students were scientifically literate about the issue, students would be more critical consumers of media reports. These understandings and beliefs about the impact and importance of the phenomenon would likely influence their intentions to act towards the issue at a personal household level and at governmental and community level.

In the actual scenario, students get most of the information about the GHE from the media. As students have limited exposure to concepts about GHE mechanisms, school science is not providing enough opportunity for students to develop scientifically correct understandings of the phenomenon. This leads to a big vague picture level of understanding and beliefs where they are not sure how their own personal actions would reduce greenhouse gas emissions. Consequently they believe that governments should solve the problem and they are not ready to sacrifice their personal convenience and comforts.

According to the theory of reasoned action, students' beliefs and their normative beliefs influence their intentions to act on greenhouse gas emissions. In the ideal scenario, it is expected that students hold appropriate beliefs and understandings about the phenomenon, so that they would have intentions to act in ways that would reduce greenhouse gas emissions. The difference between the ideal and actual scenarios should be carefully analysed so that appropriate changes can be made to science curricula by the departments of education in Australia and in India.

The main aim of environmental education should be to prepare students for participation in personal, social and governmental actions for a sustainable and green environment. To make informed decisions, citizens need to be informed (Aleixandre & Munoz, 2002; Gough, 2002; NRC, 1999). Scientific literacy is a high priority for all citizens, helping them to be interested in scientific matters, to be sceptical, to be able to identify questions and to make informed decisions about the environment and their own health and well being (Goodrum et al., 2001; Hackling, 2002; Hackling et al., 2001). Informed citizens would create an atmosphere for increased partnership between communities and governments for change or at least make it easier for politicians to promote the policies that will help to alleviate the issues (Gayford, 2002; UN, 1992). There is a need for change in direction regarding environmental education in terms of what might learning look like, what might teaching look like and what might curriculum look like (Dillon, 2002). In this context, the scenarios developed in this study are important and require further examination and action.

CHAPTER 9

CONCLUSIONS

Introduction

The main focus of this research was to identify high school students' beliefs about, understanding of the GHE, and intentions to act in ways that would reduce greenhouse gas emission. These aspects were related to what is taught in high school science. This Chapter presents a summary of the research in which major findings are presented as answers to the research questions. The implications for science curricula, teaching and learning are addressed. The limitations of this study are discussed, contributions of this study are outlined and the recommendations for future research are made.

Findings of the Research

The purpose of this research was to investigate the status of environmental education about the GHE in high school science and chemistry in Western Australia (Australia) and Kerala (India) and its influence on students' beliefs, understandings and intentions to act in ways that would reduce greenhouse gas emissions. This study was conducted in five schools in each of Western Australia and Kerala. The student samples were from Year 10 and 12 (age 15 and 17 years) representing the end of compulsory and post-compulsory stages of education in both countries. The sample comprised 438 students, 213 from Western Australia and 225 from Kerala.

Several sources of data were used in this study. The questionnaire developed for this study was used to identify students' beliefs, understandings, intentions to act regarding reduction of greenhouse gas emissions, and their sources of information about the GHE. Student interviews were used to get a richer picture of students' beliefs, understandings and their intentions to act to reduce greenhouse gas emissions. Documents were analysed to identify the status of the GHE in curricula, textbooks, syllabuses, and teaching and learning programmes. Interviews were conducted with students, heads of science, a dean of studies and an academic programme coordinator.

The following research questions were addressed and findings are presented:

Research Question 1

What do people need to know to understand the GHE, understand reports in the media and to make decisions about the issue in their lives?

The GHE is a natural phenomenon, and without it, life as we know it would not exist. The GHE is an abstract concept, hence teaching and learning about this issue cannot be through direct experience or by experiments. Causes of different environmental issues overlap. Some gases responsible for the GHE also contribute to ozone layer depletion. In view of the complexity of these issues and their intangible nature it would be difficult to understand this phenomenon well unless it is taught and learned effectively. Considering all these aspects, a Propositional Knowledge Statement (PKS) was developed to describe the essential knowledge that a student at high school (Year 10 level, age 15 years) requires to have a scientific understanding of the GHE in terms of its causes, mechanism and effects, to interpret media reports about the issue, to take appropriate environmental action, and to make informed decisions as a scientifically literate member of society.

Science and chemistry concepts necessary to understand the GHE in terms of its importance, mechanism, impacts, and actions that can be taken to reduce greenhouse gas emission were analysed and defined as a set of propositions. The PKS consists of a set of propositions that outline the nature of the GHE its mechanism, causes, effects, impacts based on scientific predictions, and importance in daily life including the Kyoto protocol.

One chemistry professor and one atmospheric scientist from the CSIRO, Australia were asked to validate the accuracy of the propositions required to understand the GHE and make informed decisions about the issue in daily life. Feedback from these experts was used to revise and improve the PKS. The PKS is attached as Appendix 1.

In this study, the PKS is considered to be the knowledge necessary for a person to understand the GHE, interpret reports in the media and to make informed decisions about the GHE in daily life as a scientifically literate citizen.

Research Question 2

To what extent is the GHE addressed in state science syllabuses and science programmes in Australia and India?

This study was conducted in Western Australia and Kerala as representing Australia and India.

In order to find out the extent to which the GHE is addressed in state science and chemistry syllabuses and science programmes in Australia and India, curriculum documents, textbooks, syllabuses, and teaching and learning programmes from Western Australia and Kerala were analysed. Interviews were conducted with heads of science (n=10), a dean of studies, an academic programme coordinator and students (n=80) regarding what is taught and learned about the GHE at high school.

In Western Australia

Year 10. The analysis of curriculum documents in Western Australia revealed that the GHE could be included in the science curriculum and could be used to develop any one of the nine science learning area outcomes. The GHE is not specifically mentioned in the curriculum framework document (Curriculum Council, 1998). Out of five schools in Western Australia selected for this study, the GHE was included in the curriculum of only one school and was taught in Year 9.

About half of the Western Australian students interviewed mentioned that they were taught some aspects of the GHE by Year 10 in Science or in the Society and Environment learning areas.

According to the heads of science in Western Australia the GHE might be taught to lower secondary students in Year 9 science. It is up to the teachers who are teaching at this level to decide whether to include the issue in their teaching programmes.

Year 12. The current Year 11 and 12 chemistry syllabus (Curriculum Council, 2001) do not mention the GHE. Five schools where this study was conducted used the same textbook (Garnett, 1996), which included an explanation of the GHE, however, it was not included in the teaching and learning programmes of these schools. Students indicated that they had not been taught about the GHE in Year 11 or 12 in chemistry. The heads of science remarked that the GHE is not mentioned in the Year 11 and 12 chemistry syllabuses therefore it may not be taught at this level.

In Kerala

Year 10. The analysis of curriculum documents in Kerala revealed that the course followed at Year 10 is based on the syllabus (CBSE, 2001) and textbook developed by the NCERT (NCERT, 1999 a). The science syllabus has five units and contents in each unit are described. There is no direct mention of the GHE in the syllabus; however, the carbon cycle is included in the *Energy and Living Resources* unit. In the *Energy* unit absorption of solar radiation is mentioned. In the textbook for standard 10, the GHE is mentioned in the chapter *Ecological Balance* as a part of the importance of carbon dioxide (NCERT, 1999 a, p. 118-119).

A large majority of Indian students indicated that they had been taught some aspects of the GHE by Year 10 in science. The heads of science remarked that the GHE is taught at Year 10 in science, however, it is not tested in the board examinations.

Year 12. At Year 11 and 12 levels, there is no mention of the GHE in chemistry syllabuses or textbooks developed by the NCERT (CBSE, 2001; NCERT, 1999b). All the students interviewed, mentioned that they had not been taught about the GHE in Year 11 or 12 Chemistry. The heads of science remarked that the GHE is not mentioned in the Year 11 or 12 syllabuses or textbook therefore it may not be taught at this level.

Research Question 3

What do Year 10 and 12 students in Australia and India know and understand about the GHE?

The Propositional Knowledge Statement (PKS) was developed and validated to describe the knowledge needed by a scientifically literate citizen to understand and make decisions about the GHE. The questions in Part B of the questionnaire were designed to probe students' understanding of the PKS.

In order to obtain a clear picture of students' understandings of the GHE, three aspects of the GHE were investigated. The three aspects were; the GHE and global warming, causes of the GHE, and mechanism of the GHE. Two hundred and thirteen students from Western Australia and 225 students from Kerala completed the questionnaire and 40 students from each state were interviewed to probe their understandings of the GHE.

General aspects of the students' understandings of the GHE are discussed first and important characteristics of student understandings found in Western Australia and Kerala are discussed separately.

GHE and Global Warming

- The majority of students did not understand that the GHE is keeping our planet habitable.
- The majority of students understood that the GHE causes global warming, however, less than half of the students could explain how or why the enhancement of the GHE causes global warming.
- Students' understandings of the anticipated average global temperature rise and sea level rise in the next 50 years are not consistent with scientific predictions.

Causes of the GHE

- A large majority of students understood and explained the influence of human activities, burning of fossil fuels, and deforestation on the GHE.

- A small majority of students were aware that cattle and sheep farming enhanced the GHE but less than one third could explain why or how cattle and sheep increase the GHE.

Mechanism of the GHE

Students' understanding of the mechanism of the GHE were analysed and grouped into five levels based on their responses in terms of explanation, accuracy of the diagram and identification of greenhouse gases. Level 1 represents the highest level of understanding and Level 5 represents the lowest level of understanding exhibited by the student in the sample. Pointers were developed for categorising student responses into different levels. The following are the major findings:

- Only 8% of all the students could provide a complete or nearly complete and scientifically accurate explanation of the mechanism of the GHE (Level 1 and 2).
- About 47% students have a modest understanding of the mechanism of the GHE (Level 3).
- About 45% of the students either have a minimal understanding or significant misconception about the GHE (Level 4 and 5).

Important variations found between Western Australia and Kerala were: Sixty percent of the students in Western Australia have either minimal understanding or misconceptions about the mechanism of the GHE (Levels 4 and 5), and only 48% of students overall (46% in Year 10 and 52% in Year 12) could identify carbon dioxide as a greenhouse gas.

About 62% of students in Kerala have a modest level of understanding about the mechanism of the GHE (Level 3) and 90% of the students could identify carbon dioxide as a greenhouse gas.

Research Question 4

What beliefs do students in Australia and India hold about the reality, importance and likely impact of the GHE?

Students' beliefs about the GHE were studied in terms of the relative importance of the GHE compared to six other social issues, its reality, seriousness and effect on global warming, and their beliefs about actions that should be taken by governments. Information about students' beliefs was elicited through questionnaire and student interviews.

General aspects about the students' beliefs regarding the GHE are discussed first and differences between student beliefs found in Western Australia and Kerala are discussed separately.

The following are the important observations of students' beliefs regarding the GHE:

- Students ranked the GHE fourth in importance among seven social issues that were of concern to them. Economic issues and poverty, health and diseases like AIDS, and increasing crime were considered to be more important than the GHE.
- A large majority of students believe that the GHE is affecting our climate at present and will change the climate in future.
- A large majority of students believe that governments should conduct more programmes to raise community awareness about the GHE and enact strict laws to reduce greenhouse gas emission.
- A small majority of students believe that what they do has an impact on the GHE, however, a quarter of them are not sure about it.

There are no significant variations observed between the students from Western Australian and Kerala. The data from Western Australia were collected before September 11, 2001 and data from Kerala was collected after that. This would have affected the students' ranking of terrorism. Western Australian students ranked health and diseases like AIDS first and Kerala students ranked economic issues and poverty first.

Research Question 5

What actions have students taken in relation to the GHE, what do they believe they should do, and what actions do they believe the government should take in Australia and India?

Student intentions to act regarding proposals to reduce greenhouse emission were investigated using; questionnaire questions regarding actions that can be taken to reduce the greenhouse gas emission, a proposal to reduce car use, steps governments should take to reduce release of greenhouse gases, and interview questions which are about proposals to reduce greenhouse gas emissions by banning air conditioners and increasing taxes on electricity to fund research and development.

General aspects about the students' actions regarding the GHE are discussed first and differences between Western Australia and Kerala are discussed separately.

The following are the important observations regarding the students' intentions to act:

- The majority of students and their families are already taking action or are considering taking action regarding the 10 easiest ways of reducing household electricity consumption and thereby greenhouse gas emissions. The least positive responses were in relation to actions that require a capital investment, eg. installing insulation.
- The majority of students are not prepared to sacrifice their personal comforts or convenience (eg. use of car, air conditioners), and they have strong reasons for that.
- The majority of students suggested that governments should enact strict laws to reduce greenhouse gas emissions and sign the Kyoto protocol.
- A considerable number of students suggested that governments should take steps to do research on alternate energy sources and fuels, stop cutting down tress and

plant more trees, and provide more information and education regarding the reduction of greenhouse gas emissions.

Important variations found between Western Australia and Kerala were:

- Only 22% of students in Western Australia either supported or strongly supported the proposal to reduce the car use whereas, 45% of students in Kerala either supported or strongly supported the proposal.
- Regarding proposals to increase tax on electricity for research and development, in Kerala (n=40) 70% of students either approved or approved with changes the proposal whereas in Western Australia (n=40) 75% of students rejected the proposal.

Research Question 6

What are the main sources of information regarding the GHE for students in Australia and India?

The sources of student information regarding the GHE were probed by questionnaire questions. The five main sources of information considered in this study were parents, teachers, friends, textbooks and the media.

The following are the major observations regarding students' sources of information regarding the GHE:

- The majority of students obtain information regarding the GHE from media, teachers and textbooks.
- Parents and friends provide little information about the GHE.

The Western Australian sample ranked sources of information about the GHE in the order: media, teachers and textbook; and, the rank order in Kerala was teachers, textbook and media. The textbook was a far more important source of information for the Kerala students. In Kerala 99.5% of students indicated that they obtain most or some of their information regarding the GHE from their textbook and in Western Australia only 69.4% students obtained most or some of their information regarding the GHE from their textbook.

Implications for Science Curricula, Teaching and Learning Programmes

The implications for science curricula, teaching and learning programmes arising from this research are associated with developing scientific literacy, public understanding of science and informed decision-making ability based on the ideal and actual scenarios, and general assertions generated in this study.

This study has shown the status of the GHE at high school science in terms of ideal and actual scenarios. The ideal scenario regarding students' beliefs, understandings and willingness to act in ways that would reduce greenhouse gas emissions should be the target of high school science curricula. From the actual scenario, it is evident that at present adequate emphasis is not given to the GHE in high school science curricula.

It is evident from this study that when scientific concepts regarding the GHE are included in the curriculum, teaching and learning programmes and textbook, students have a better understanding about it, eg. in Kerala, the GHE is included in the Year 10 textbook and it was found that about 62% students have a modest level of understanding of the mechanism of the GHE. Curriculum developers, science educators and teachers should include environmental issues in science curricula, textbooks, teaching and learning programmes, and examinations.

Adequate emphasis should be given to the GHE in science curricula, teaching and learning programmes to enhance the scientific literacy and public understanding of science (Kolsto, 2001; Summers, et al., 2001). Developing scientific literacy is one of the main purposes of science education in the compulsory years of schooling (Hackling, et al., 2001).

Based on the importance of the GHE and the findings of this research it is recommended that:

1. The causes, mechanisms and impacts of the GHE be included in Year 9 – 10 science and Year 11 – 12 chemistry syllabuses, textbooks and examinations. This study has shown that unless the GHE is included in syllabuses and examinations it is unlikely to be included in teaching programmes.
2. Teachers be provided with professional development and curriculum resources to support them in implementing programmes of work that address the GHE and provide opportunities for students to consider actions that could be taken at personal, household and community levels to reduce greenhouse gas emissions.

The enacted science curriculum should emphasise local environmental issues, participating in social action and making important personal, social and community based decisions regarding the issue (Gough, 2002.b).

Limitations of the Research

Several limitations of this research have been identified and are associated with the selection of samples, data gathering, data analysis and interpretations and generalisability of the findings.

Limitations of the sample

Five schools each from Perth and Trivnadrum were selected for this study. Out of five schools from both cities, three were from the government sector and two were from the private sector. Thiry students from a Year 10 mainstream science class and 15 students from Year 12 chemistry classes were selected from each school to complete the questionnaire. Five students from each Year 10 class and three students from each Year 12 class were interviewed to elicit more elaborate responses than those obtained from the questionnaire. The selection of schools was from different suburbs representing a range of socio-economic status. All efforts were made to make the samples as representative as possible of both cities. A larger sample would have been more representative. This sample was only drawn from capital cities in Western Australia and Kerala and therefore there are limits to the generalisability of the findings.

Limitations of data gathering

One of the major limitation of the data gathering was the Australian data was collected before the September 11, 2001 and the Indian data was collected after that. This might have affected students' rating of the relative importance of terrorism in Part A of the questionnaire by Australian and Indian students.

Students were selected for the interviews after the analysis of the questionnaire data, which took about three to four months. This delay resulted in missed opportunities for the researcher to clarify students' questionnaire answers. Although the researcher interviewed the students with their own answers, students took time to identify what they had written. It would have been better had it been done within one month after answering the questionnaire. Although the questionnaire was not too long, fatigue would have influenced the richness of responses to questions at the end of the instrument.

To determine what aspects of the GHE were included in the curriculum, curriculum documents, textbooks and teaching and learning programmes were analysed, and students, heads of science, a dean of studies and an academic programme coordinator were interviewed. Additional valuable data could have been collected if the teachers teaching these classes had also been interviewed.

Limitations of the data analysis and interpretations

The data analysis and interpretations involved generating assertions, scenarios and general assertions. The generation of assertions required the identification of patterns in the data. In this process frequently occurring events were dealt with effectively, however, infrequent events may have been lost as they did not emerge in the assertions and scenarios (Erickson, 1986).

Contributions of the Research

This research makes a major contribution in identifying students' beliefs, understandings and intentions to act in ways that would reduce greenhouse gas emissions in the context of what they have learned in high school science. No previous study has taken such a comprehensive approach to researching this issue. No previous study has researched students' intentions to act in ways that would reduce greenhouse gas emissions.

The PKS developed about the GHE is a set of propositions that outline science concepts necessary for an understanding of the GHE in terms of its causes, effects, mechanism and actions that can be taken to reduce greenhouse gas emission. This is a major contribution of this study and can guide curriculum developers and textbook writers in the preparation of curriculum documents. Differences between the ideal and actual scenarios can be used to identify the weaknesses of the present curricula, teaching and textbooks.

Recommendations for Future Research

This study has developed a new approach to conducting research into the status of environmental education, which involves defining the knowledge required to be scientifically literate about the environmental issue, and then investigating students' beliefs, understandings, and intentions to act, in relation to what has been included in the curriculum. This study has focused on only one issue, that is, the GHE and reduction of greenhouse gas emissions. Similar studies of other environmental and socio scientific issues need to be conducted to validate and establish the new research paradigm.

Although the study did not have as an aim, the evaluation and further development of the theory of reasoned action, research into students' understandings, beliefs and intentions to act in relation to environmental issues has the potential to elaborate the model and clarify relationships between understandings, beliefs and actions.

The research could also be extended to address students' normative beliefs by probing students' perceptions of how others would view actions they might take in relation to the environmental issue.

References

AAAS (American Association for the Advancement of Science). (1989). *Science for all Americans: Project 2061.* New York: Oxford University Press.

AAAS (American Association for the Advancement of Science). (1993). *Bench marks for science literacy: Project 2061.* New York: Oxford University Press.

AAAS (American Association for the Advancement of Science). (1997). *Resources for scientific literacy: Professional development.* New York: Oxford University Press.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood Cliffs, NJ: Prentice-Hall.

Aleixandre, M.P.J., & Munoz, C.P. (2002). Knowledge producers or consumers? Argumentation and decision making about environmental management. *International Journal of Science Education. 24* (11), 1171 – 1190.

Annan, K. (2002). Beyond the horizon. *Time*. August 26, No.34. 40 - 41.

Anderson, C.W. (1987). *Incorporating recent research on learning into process of science curriculum development*. Colorado Springs, CO: Biological Science Curriculum Study.

Arcury, T.A., & Johnson, T.P. (1987). Public environmental knowledge: A state wide survey. *Journal of Environmental Education, 18* (4), 31- 37.

AGO (Australian Greenhouse Office). (1999). *Annual report, 1998-99.* Canberra: Commonwealth of Australia.

AGO (Australian Greenhouse Office). (2000). *Global warming cool it: A home guide to reducing energy costs and greenhouse gases.* Canberra: Commonwealth of Australia.

Bamford, B. (1999). From environmental education to ecopolitics, Affirming changing agendas for teachers. *Educational Philosophy and Theory*, *31*, 157 –173.

Barman, D., Harshman, R., & Rusch, J. (1982). Attitude of science and social studies teachers toward interdisciplinary instruction. *The American Biology Teacher*, *44* (7), 421 – 426.

Bauer, H. H. (1992). *Scientific literacy and the myth of the scientific method.* Chicago: University of Illinios.

Boschhuizen, R. & Brinkman, F.G. (1995). The concept of cycle for environmental education. *Environmental Education Research*, *1*, 147- 158.

Boyes, E., Chambers, W., & Stanisstreet, M. (1995). Trainee primary teachers ideas about the ozone layer. *Environmental Education Research*, *1*(2), 133 – 145.

Boyes, E., Chuckran, D., & Stansstreet, M. (1993). How do high school students perceive global climatic change: What are its manifestations?, What are its origins?, What corrective action can be taken?. *Journal of Science Education and Technology*, *2* (4), 541-557.

Boyes, E., & Stanisstreet, M. (1992). Students perception of global warming. *International Journal of Environmental Studies*, *42*, 287-300.

Boyes, E., & Stanisstreet, M. (1993). The " Greenhouse effect": Children's perception of causes, consequences and cures. *International Journal of Science Education*, *15* (5), 531- 552.

Boyes, E., & Stanisstreet, M. (1994). The ideas of secondary school children concerning ozone layer damage. *Global Environmental Change*, *4* (4), 317- 330.

Boyes, E., & Stanisstreet, M. (1997 a). Childrens' models of understanding of two major global environmental issues (ozone layer and greenhouse effect). *Environmental Education Research*, *1*, 19 – 28.

Boyes, E., & Stanisstreet, M. (1997 b). The environmental impact of cars: Childrens' ideas and reasoning. *Environmental Education and Research*, *3*(3), 269 – 282.

Boyes, E., Stanisstreet, M., & Papantoniou, V.S. (1999). The ideas of Greek high school students about the " Ozone Layer". *Science Education*, *83*, 724 – 737.

Bradford, C.S., Rubba, P.A., & Harkness, W.L. (1995). Views about science-technology-society interaction held by college students in general education physics and STS courses. *Science Education*, *79* (4), 355- 373.

Brenner, M., Brown, J., & Canter, D. (1987). (Eds). *The research interview: Uses and approaches.* London: Academic Press.

Brody, M.J. (1990). Understanding of pollution among 4th, 8th and 11th grade students. *Journal of Environmental Education*, *22* (2), 24-33.

Bybee, R.W. (1987). Teaching about science technology and society. *School Science and Mathematics*, *87*(4), 274 – 286.

Bybee, R.W. (1993). *Reforming science education, social perspectives and personal reflections*. New York: Teachers College Press.

Bybee, R.W. (1995). Achieving scientific literacy. *Science Teacher*, *62*(7), 28 – 33.

Bybee, R.W. (1997). *Achieving scientific literacy: From purpose to practices.* Portsmouth, NH: Heinemann.

Bybee, R.W., & Bonnstetter, R.J. (1987). What research says: Implementing the science technology society theme in science education: perceptions of science teachers. *School Science and Mathematics*, *87* (2), 144- 182.

Carey, S. (1986). Cognitive science and science education. *American Psychologist*, *41* (10), 1123 – 1130.

CBSE (Central Board of Secondary Education). (2001). *Science Syllabus Effective from 2001*. NewDelhi: CBSE.

CEPUP (Chemical Education for Public Understanding). (1987). *CEPUP Annual Report*. (Lawrence Hall of Science, University of California at Berkely, USA.)

Champagne, A.B. (1987). *The psychological basis model of science instruction*. Colorado Springs, CO: Biological sciences curriculum study.

Champagne, A.B., & Horning, L.E. (1987). (Eds). *Students and science learning*. Washington, DC: American Association for Advancement of Science.

Christidou, V., & Koulaidis, V. (1996). Childrens model of ozone layer and ozone layer depletion. *Research in Science Education*, *26*(4), 421 – 436.

Christidou, V., Koulaidis, V., & Christidis, T. (1997). Childrens use of metaphors in relation to their mental models: The case of ozone layer and its depletion. *Research in Science Education*, *27*(4), 541 – 552.

Cobern, W.W., Gibson, A.T., & Underwood, S.A. (1995). Valuing scientific literacy. *Science Teacher*, *62*(9), 28 – 31.

Coffey, A., & Atkinson, P. (1996). *Making sense of qualitative data. Complementary Research Strategies*. California: Sage Publications.

Costa, V.B. (1995). When science is another world relationship between worlds of family, friends, school and science. *Science Education*, *79* (3), 313-333.

Crawley, F.E. (1988). *Determinants of physical science teachers' intention to use investigative teaching methods: A test of the theory of reasoned action.* Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Ozark, MO.

Crawley, F.E., & Coe, A.S. (1990). Determinants of middle school students' intention to enroll in a high school science course: an application of the theory of reasoned action. *Journal of Research in Science Teaching, 27*(5), 461 – 476.

Cross, R.T. (1999). The public understanding of science: Implications for education. *International Journal of Science Education, 21*(7), 699- 702.

Curriculum Council. (2001). *Science syllabus for 2001- 2003.* Perth, Western Australia: Curriculum Council,

Davison, W., & Hewitt, C.N. (1993). Environmental chemistry comes of age. *Education in Chemistry, 3*, 48- 50.

Devonshire, J. (1996). Heavy metals in Bristol Channel. *Education in Chemistry, 7*, 13-15.

Dillon, J. (2002). Editorial – Perspectives on environmental education related research in science education. *International Journal of Science Education. 24* (11), 1111 – 1117.

Dove, J. (1996). Student teacher understanding of the greenhouse efffect, ozone layer depletion and acid rain. *Environmental Education Research, 2*(1), 89 –100.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23* (7), 5-12.

Earth Summit. (2002). [WWW document]. http://www.eathsummit.2002.org/

Education Department of Western Australia. (1998). *Outcomes and standard framework overview, student outcome statements, Science.* Perth, Western Australia: EDWA.

Eijkelhof, H.M.C., Klaassen, K., Schottle, R., & Lijnse, P.L. (1987). *Public and pupils' ideas about radiation: some lessons from Chernobyl to science educators.* Paper Presented at the 5th International Conference on World Trend in Science education, Kiel, FRG, August 1987.

Eijkelhof, H.M.C., & Millar. R. (1988). Reading about Chernobyl: the public understanding of radiation and radioactivity. *School Science Review*, *70* (251), 35 – 41.

Eiser, J.R., Reicher, S.D., & Podadec,T.J. (1995). Global changes and local accidents: Consistency in attributions for environmental effects. *Journal of Applied Social Psychology, 25* (17), 151- 1529.

Erickson, F. (1986). Qualitative research on teaching. In M.C. Wittrock (Ed), *Handbook for research on teaching* (3rd ed). New York: Macmillan, p 119 – 161.

Fensham, P.J. (1988). Approaches to teaching of STS in science education. *International Journal of Science Education*, *10* (4), 346-356.

Fensham, P.J. (1990). Development and challenges in Australian environmental education, *Australian Journal of Environmental Education*, *6*, 15-27.

Fensham, P.J. (1997). Chemistry for tomorrow's public. *Education in Chemistry*, *3,* 43-44.

Fensham, P.J., & Harlen, W. (1999). School science and Public understanding of science. *International Journal of Science Education*, *21*(7), 755 – 763.

Fetherston, T. (1997). The derivation of learning approach based on personal construct psychology. *International Journal of Science Education, 19* (7), 801-819.

Fielding, N.G., & Fielding, J.L. (1986). *Linking data.* Beverly Hills, CA: Sage.

Fisher. B.W. (1998). There's a hole in my greenhouse effect. *School Science Review*, *79* (288), 93 – 99.

Fleming, R. (1988). Undergraduate science students' views on the relationship between science, technology and society. *International Journal of Science Education, 10*, 449 – 463.

Flick, U. (1992). Trianguulation revisited: Strategy of validation or alternative?. *Journal for the Theory of Social Behaviour, 22*, 175 – 198.

Francis, C., Boyes, E., Qualter, A., & Stanisstreet, M. (1993). Ideas of elementary students about reducing greenhouse effect. *Science Education*, *77*(4), 375 – 392.

Gallagher, J.J., & Hogan, K. (2000). Intergenerational, community based learning and science education. *Journal of Research in Science Teaching, 37*(2), 107- 108.

Gambro, J.S., & Switzky, H.N. (1996). A national survey of high school students' environmental knowledge. *Journal of Environmental Education, 27* (3), 28-33.

Garnett, P.J. (Ed). (1996). *Foundations of chemistry, 2nd Ed.* Australia: Longman.

Garnett, P.J., Garnett, P.J., & Hackling, M.W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education*, *25*, 69-95.

Gauld, C.F. (1982). The scientific attitude and science education: A critical reappraisal. *Science Education*, *66* (1), 109-121.

Gayford, C. (1993). Discussion – based group work related to environmental issues in science classes with 15 year old pupils in England. *International Journal of Science Education, 15* (5), 521-529.

Gayford, C. (2002). Controversial environmental issues: a case study for professional development of science teachers. *International Journal of Science Education, 24* (11), 1191 – 1200.

Goodrum, D., Hackling, M.W., & Rennie, L. (2000). *The status and quality of teaching and learning of science in Australian schools. A research report.* Canberra: Department of Education, Training and Youth Affairs, Commonwealth of Australia.

Gough, A. (2002 a). Mutualism: a different agenda for environmental and science education. *International Journal of Science Education. 24* (11), 1201 – 1215.

Gough, N. (2002 b). Thinking / acting locally / globally: Western science and environmental education in a global knowledge economy. *International Journal of Science Education. 24* (11), 1217 – 1237.

Granell, C.G. (1993). Development of conceptual knowledge and attitude about energy and environment *.International Journal of Science Education, 74* (12), 1431- 1433.

Grace, M. M. & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education, 24* (11), 1157 – 1169.

Hackling, M.W. (2002). Assessment of primary students' scientific literacy. *Investigating, 18* (3), 6 – 7.

Hackling, M.W., Goodrum, D., & Rennie, L. (2001). The state of science in Australian secondary schools. *Australian Science Teachers Journal, 47* (4), 6 – 17.

Hakim, C. (2000). *Research design. Successful designs for social and economic research. 2nd Edition.* London: Routledge.

Hand, B., Prain, V., Lawrence, C., & Yore, D.L. (1999). A writing in science framework designed to enhance scientific literacy. *International Journal of Science Education, 21*(10), 1021- 1035.

Hart, P. (2002). Environment in the science curriculum: the politics of change in the Pan – Canadian science curriculum development process. *International Journal of Science Education, 24* (11), 1239 – 1254.

Hewson, P.W., & Thorley, N.R. (1989). Conditions of conceptual change in classroom. *International Journal of Science Education, 11(Special issue),* 541-553.

Hillman, M., Stanisstreet, M., & Boyes, E. (1996). Enhancing understanding in student teachers: The case of auto pollution. *Journal of Education for Teaching, 22* (3), 311 – 325.

Hofstein, A., Aikenhead, G., & Riquarts, K. (1988). Discussions over STS at the fourth IOSTE symposium. *International Journal of Science Education, 10* (4), 357-366.

Holman, J. (1988). Editors introduction; Science technology society education. *International Journal of Science Education, 10* (4), 343-345.

Horning, S. (1992). Gender differences in response to news about science and technology. *Science, Technology and Human Values, 17*, 532 – 542.

Houghton, J.T., Jenkins, G.J., & Ephraums, J.J. (1990). *Climate change: The intergovernmental panel on climate change scientific assessment.* Cambridge, UK: Cambridge University press.

Houghton, J.T., Callander, B.A., & Varney, S.K. (eds). (1992). *Climate change 1992: The supplementary report to the IPCC scientific assessment.* New York: Press syndicate of the University of Cambridge, p 1-22.

Hunt, A. (1988). SATIS approaches to STS. *International Journal of Science Education, 10* (4), 409-420.

Hurd, P.D. (1998). Scientific literacy: new minds for a changing world. *Science Education, 82* (4), 407-416.

IPCC (Intergovernmental Panel on Climate Change). (2001). *IPCC Third assessment report- climate change 2001.* [WWW document]. URL http://ipcc.org.third assessment report/

Isaac, S. & Michael, W.B. (1997). *Handbook in research and evaluation. For education and behavioral sciences. 3rd Edition.* California: EdITS.

Jenkins, E.W. (1999). School science, citizenship and the public understanding of science. *International Journal of Science Education, 21*(7), 703 – 710.

Johnson, P., & Gott, R. (1996). Constructivism and evidence from children's ideas. *Science Education, 80* (5), 561-577.

Johnson, R.T., Johnson, D.W., & Holubec, E.J. (1986). *Circles of learning: Co-operation in the classroom (rev.ed).* Edina, MN: International Book Company.

Juhl, L., Yaserlet, K., & Silva, A.J. (1997). Interdisciplinary project based learning through an environmental water quality. *Journal of Chemical Education, 74* (12), 1431- 1433.

Kee, T.P., & McGowan, P.C. (1997). Chemistry within chemistry without. *Education in Chemistry, 7*, 102-104.

Kelly, R.J. (1997). Research traditions in a comparative context: A philosophical change to radical constructivism. *Science Education, 81* (3), 355-375.

Kelter, P.B., Grundman, J., Hage, D.S., & Carr, J.D. (1997). A discussion of water pollution in Unites States and Mexico: with high school laboratory activities for analysis of Lead, Atrazine, and Nitrate. *Journal of Chemical Education, 74*, 1423-1421.

Koballa, T.R.Jr. (1984). Teaching hand on science activities: Variable that moderate attitude- behaviour consistency. *Journal of Research in Science Teaching, 23*, 493 – 502.

Koballa, T.R.Jr. (1988). *The determinants of eight-grade students intention to enrol in elective science courses in high school.* Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Ozark, MO.

Koballa, T.R.Jr. (1992). Persuation and attitude change in science education. *Journal of Research in Science Teaching*, 29 (1), 63-80.

Kolsto, S.D. (2001). Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimensions of Controversial Socioscientific Issues. *Science Education, 85*, 291 – 310.

Kornberg, H. (1991). Science and environmental awareness. *School Science Review, 72*, 7 – 14.

Kortland, K. (1996). An STS case study about students' decision making on the waste issue. *Science Education, 80* (6), 673- 689.

Koulaidis, V., & Christidou, V. (1999). Models of students thinking concerning the greenhouse effect and teaching implications. *Science Education, 83*, 559 – 576.

Krathwohl, D. R. (1998). *Methods of educational and social science research: An integrated approach*. New York: Longman.

Krynowsky, B.A. (1988). Problems in assessing student attitude in science education: A practical approach. *Science Education, 72* (4), 575 – 584.

Kurup, P.M. (1995). Third world chemistry curriculum: Need for the linking with social, environmental and technological issues. *Proceedings of the International Conference on Industry Initiatives in Chemistry*. York: The University of York, p 230.

Lagowski, M. (1988). Is curriculum enough?. *Journal of Chemical Education, 65*, 559.

Laugksch, C.R. (2000). Scientific literacy: a conceptual overview. *Science Education, 84*, 71 – 94.

Law, N., Fensham, P.J., Li, S., & Wei, B. (2000). *Public understanding of science as basic literacy*. Paper Presented at Australian Science Education Research Association, 31, Fremantle, WA, 29 June-01 July, 2000.

Layton, D. (1988). Revaluing T in STS. *International Journal of Science Education, 10* (4), 367-378.

Layton, D. (1992). Science technology teacher training and quest for quality. In Layton, D (Eds). *Innovations in science and technology education, Vol, IV*. Paris: UNESCO.

Leharane, S., & Chowdhry, B. (1995). Environmental concerns an acid problem. *Education in Chemistry, 7*, 106-108.

Lucas, A.M. (1987). Public knowledge of radiation. *Biologist*, *34*, 125 – 129.

Lucas, A. M. (1988). Public knowledge of elementary physics. *Physics Education*, *23*, 10 – 16.

Lucas, A.M. (1991). "Info-Tainment" and informal sources for learning science. *International Journal of Science Education, 13*, 495 –504.

Lyons, E., & Breakwell, G. (1994). Factors predicting environmental concern and indifference in 13 to 16 years old. *Environmental Behaviour*, *26*, 223 – 238.

Malcom, C. (1987). *The science framework P-10: science for every student.* Melborne: Ministry of Education, Victoria Government.

Manazal, F.R., Barreiro, R.L.M., & Jimenez, C.M. (1999). Relationship between ecology fieldwork and student attitudes toward environmental protection. *Journal of Research in Science Teaching, 36* (4), 431 – 453.

Mason, L., & Santi, M. (1998). Discussing the greenhouse effect: Children's' collaborative discourse reasoning and conceptual change. *Environmental Education Research, 4* (1), 67 – 85.

Millar, R., & Wynne, B. (1988). Public understanding of science: from contents to process. *International Journal of Science Education*, *10* (4), 388 – 398.

Morris, M. & Schagen, I. (1996). *Green attitude or learned responses?. Global environmental education.* Borkshire: National Foundation for Educational Research.

Munson, B.H. (1994). Ecological misconception. *Journal of Environmental Education, 25* (4) , 30-34.

Musser, L.M., & Malukus, A.J. (1994). Childrens' attitude toward the environmental scale. *Journal of Environmental Education, 25* (3), 22- 26.

NCERT (National Council for Educational Research and Training). (1999.a). *Science- A Textbook for Class X.* New Delhi: NCERT Publication.

NCERT (National Council for Educational Research and Training). (1999.b). *Chemistry for Class XI and XII, Vol I and II.* NewDelhi: NCERT Publication.

NCERT (National Council for Educational Research and Training). (2000). *English – A Textbook for Class X.* NewDelhi: NCERT Publication.

NRC (National Research Council). (1996). *National science education standards.* Washington, DC: National Academy Press.

NRC (National Research Council). (1999). *How people learn; brain, mind, experience and school.* Washington, DC: NRC.

NSTA (National Science Teachers Association). (1982). *Science, Technology and Society: Science Education for the 80's. Position Statement.* Washington, D.C: NSTA.

Olson, J., James, E., & Lang, M. (1999). Changing the subject: the challenge of innovation to teacher professionalism in OECD countries. *Journal of Curriculum Studies, 31*, 69 – 82.

Osborne, R.J., & Wittrock, M.C. (1983). Learning science a generative process. *Science Education, 67* (4), 489- 508.

Ponting, C. (1993). *A green history of the world.* London: Penguin Books.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1992). Accodomation of a scientific conception toward a theory of conceptual change; In M.K. Persall, *Relevant Resarch Vol III.* Washington, DC: National Science Teachers Associattion, p 253 – 270.

Potts, A., Stanisstreet, M., & Boyes, E. (1996). Childrens ideas about the ozone layer and opportunities for physics teaching. *School Science Review*, *78* (283), 57 – 63.

Power, C. (1981). Contribution of research to educational policy and practice. *Australian Education Research*, *8,* 5- 19.

Randall, J. (1997). Integrating high school chemistry with environmental studies and research. *Journal of Chemical Education*, *74* (12), 1409-1411.

Roberts, D.A. (1996). What counts as quality in qualitative research? *Science Education. 80* (3), 243 – 248.

Robinson, M., & Kaleta, P. (1999). Global environmental priorities of secondary students in Zabre, Poland. *International Journal of Science Education*, *21*(5), 499 – 514.

Ross, S. (1991). Physics in the global greenhouse. *Physics Education*, *26*, 175 – 181.

Roth, K.J. (1992). Science education : it's not enough to do or relate. In M.K. Pearsall.(Ed). *Relevant Research Vol II.* Washington, DC: National Science Teachers Association.

Royal Society. (1985). *The public understanding of science*. London: Royal Society.

Rye, A.J., & Rubba, A.P. (1998). An exploration of the concept map as an interview tool to facilitate the externalization of students' understanding about global atmospheric change. *Journal of Research in Science Teaching, 35* (5), 521-546.

Rye, A.J., & Rubba, A.P., & Weisenmayer, R.L. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19* (5), 527 – 551.

Schibechi, R.A. (1983). Selecting attitudinal objectives for school science. *Science Education, 67* (5), 595 – 603.

Scott, P., Asoko, H., & Driver, R. (1991). Teaching for conceptual change: A review of strategies. In Duit, R., Goldberg, F. and Neidderer, H. (Eds). *Research in Physics Learning: Theoretical issues of empirical studies.* Kiel, Germany: University of Kiel, p 310 - 329.

Scott, D., & Willits, S. (1994). Environmental attitudes and behaviors: a Pennsylvania survey. *Environmental Behavior, 26* (2), 239 – 260.

Shrigley, R.L. (1990). Attitude and behaviour are correlates. *Journal of Research In Science Teaching, 27* (2), 97 – 113.

Shrigley, R.L., Koballa, T.R.Jr. (1992). A decade of attitude research based on Hovland's learning theory model. *Science Education, 76* (1), 17 – 42.

Simpson, R.D., Koballa, T.R.Jr., Oliver, J.S., & Crawley, F.E. (1994). Research on the affective dimensions of science learning, in *Hand book of research on science teaching and learning*, edited by, Gabel, D.L. (1994).New York: McMillan.

Solomon, J. (1988). Science technology and society courses: tools for thinking about social issues. *International Journal of Science Education, 10* (4), 379-387.

Solomon, J. (1993). The social construction of children's scientific knowledge. in *Children's informal ideas in science*. (Eds). P.J. Black & A. M. Lucas. London: Routledge.

Solomon, J. (1999). Op-Ed: Meta- Scientific criticisms, curriculum innovation and propagation of scientific culture. *Journal of Curriculum Studies, 31*, 1 – 15.

Somerville, C.J.R. (1996). *The forgiving air: understanding environmental change*. California: University of California Press. p 31 – 55.

Staver, J.R. (1998). Constructivism: sound theory for explaining the practice of science and science teaching. *Journal of Research in Science Teaching*, *35* (5), 501-520.

Summers, M., Kruger, C., & Childs, A. (2001). Understanding the science of environmental issues: development of a subject knowledge guide for primary teacher education. *International Journal of Science Education, 23* (1), 33 – 53.

Their, H.D., & Hill, T. (1988). Chemical education in schools and community: the CEPUP project. *International Journal of Science Education*, *10* (4), 421-430.

Tobin, K., & Tippins, D. (1993). Constuctivism as a referent for teaching and learning in Tobin (Ed). *The practice of constructivism in science education*, Washington, DC: AAAS Press.

Trakina, M. (1993). Gender differences in attitude towards sciences. *Psychological Reports, 73*, 123 – 130.

Trumbull, J.D., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen science project. *Science Education*, *84*, 265 – 275.

UN (United Nations). (1992). UN Conference on the Environment and Development. *Agenda21*: *Rio Declaration, Forest Principles*. New York: United Nations.

UNEP (United Nations Environment Programme). (2001). [WWW document] URL http://UNEP.Information unit for conventions (IUC)/. Climate Change Information Sheets, 1 – 30.

Von Glaserfeld, E. (1992). Questions and answers about radical constructivism. In M.K.Pearsall. (Ed). *Relevant research, Vol II*. Washington, DC: National Science Teachers Association.

Wals, A.E.J. (1992). Young adolescent's perceptions of environmental issues: implications of environmental education in urban settings. *Australian Journal of Environmental Education, 8*, 454- 459.

Weelie, D., & Wals, A.E.J. (2002). Making bio diversity meaningful through environmental education. *International Journal of Science Education, 24* (11), 1143 – 1156.

Yager, R.E. (1991). The constructivist learning model. *The Science Teacher*, *10,* 53-57.

Yager, R.E. (1993). Science-Technology–Society as reform. *School Science and Mathematics*, *84* (3), 189 – 198.

Zimmerman, L.K. (1996). Knowledge, affect and environment: 15 years of research. (1979-1993). *Journal of Environmental Education*, *27* (3), 41- 44.

Zoller, U., & Weiss, S. (1983). The issue of 'sensitive' interdisciplinary science-oriented curricula in the social science. *European Journal of Science Education, 5*, 147 – 155.

Appendix 1

Prepositional Knowledge Statement

The Greenhouse Effect

1. The Greenhouse Effect is a natural process in which some gases in the Earth's atmosphere cause the atmosphere to act like a greenhouse, letting the Sun's energy in, but preventing some of the Earth's radiation from escaping to space.

2. Were it not for this natural effect, the Earth's climate would be much colder (by about 33 degrees Celsius), and life as we know it would not exist.

3. Solar radiation reaching the Earth consists mainly of infra-red, visible and ultra-violet radiation. Some of this solar radiation is reflected back into space, mainly by clouds. As solar radiation passes through the atmosphere most ultra-violet radiation is absorbed by ozone in the stratosphere and a small portion of the infra-red and visible radiation is absorbed by other constituents of the atmosphere. The solar radiation that passes through the atmosphere is absorbed by the Earth's surface.

4. The Earth emits infra-red radiation (heat). Some of this infra-red radiation is absorbed by gases in the atmosphere and the rest escapes into space. The absorption of infra-red radiation emitted by the Earth has an important role in maintaining the Earth's average temperature of 16 degrees Celsius.

5. The gases in the atmosphere that absorb infra-red radiation are called greenhouse gases. Greenhouse gases include carbon dioxide, methane, ozone, nitrous oxide, water vapour and CFCs.

6. With the exception of water vapour, the other greenhouse gases constitute less than 1% in total of the atmosphere.

7. Sources of greenhouse gases are as follows: (i) carbon dioxide, which is produced by the combustion of fossil fuels, and is also increased in the atmosphere by deforestation; (ii) methane, which is produced by ruminant animals such as cows and sheep, rice paddy fields, natural gas fields and landfill garbage dumps; (iii) nitrous oxide, which is produced as a by-product of combustion processes and from fertiliser use; (iv) chlorofluorocarbons (CFCs), which are used as refrigerants, foaming agents, solvents and aerosol propellents escape into the atmosphere; (v) ozone, which is produced in the lower atmosphere as a component of photochemical smog; and (vi) water vapour which is produced mainly by evaporation from the sea.

8. Over the last 100 years, the concentrations of greenhouse gases have increased in the atmosphere due to increased human activities.

9. Increased concentrations of greenhouse gases in the atmosphere have resulted in warming of the Earth's atmosphere, sometimes described as an enhanced greenhouse effect.

10. Climate change, caused by increased concentrations of greenhouse gases in the atmosphere, is now widely recognised as a major issue with the potential to cause significant damage to natural ecosystems, national and global economies, and human welfare.

11. Scientists from the Intergovernmental Panel on Climate Change (IPCC) consider that: (i) atmospheric carbon dioxide concentrations have increased by 30% since the industrial revolution; (ii) sea levels have risen by 10 to 25 cm since 1860; (iii) the mean global temperature has increased by 0.4 to 0.8 degree Celsius since 1860; and (iv) several of the warmest years in the last 10,000 years occurred in the last 10 years.

12. Scientists from the Intergovernmental Panel on Climate Change (IPCC) predict the following impacts of the Greenhouse Effect during this century: (i) an increase in the Earth's temperature by about 0.2 degree Celsius in each decade; (ii) sea levels will rise between 40 cm to 1 metre as oceans expand and glaciers melt; and (iii) there will be changes in weather patterns, such as changes in rainfall and more severe droughts and floods.

13. The increase in greenhouse gas concentrations has been clearly established, however the extent of climate change cannot be predicted accurately.

14. The reduction of greenhouse gas emissions is increasingly being recognised as an important issue by governments, industry and the community. Every person can play a role in reducing greenhouse gas emissions.

15. In recognition of the seriousness of the Greenhouse Effect, many countries signed a treaty in December 1997 (Kyoto Protocol), which is an international obligation to limit greenhouse gas emissions.

Appendix 2

Questionnaire about the Greenhouse Effect

Your Name____

School____________________________________

Year______________________________

Thank you for agreeing to complete this questionnaire on the Greenhouse Effect. Many of the questions do not have a right or wrong answer; we are interested in your beliefs and ideas. Please explain your answers as fully as possible.

This is not a test and your answers will not affect your grades in science.

The information you provide will be used to improve the way this topic is taught in school science. Your answers will remain confidential and any aspects about this research will not name any students, teachers or schools.

Part. A

1. Some issues of concern to people all over the world are listed below. Please rank the issues according to their impact in your daily life in a **1** to **7** order of importance (**1** for most important and **7** for least important).

ISSUE	RANK
Economic issues and poverty	
The Greenhouse Effect	
Increasing crime	
Terrorism	
Health and diseases like AIDS	
Family breakdown	
Increasing drug use	

2. Indicate your views about the Greenhouse Effect in terms of the following statements by drawing a circle around one of the boxes.

2.1. There is now, no doubt that the Greenhouse Effect is affecting our climate.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree

2.2. The Greenhouse Effect will change the climate of this planet in the future.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree

2.3. What I do has an effect on the Greenhouse Effect.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree

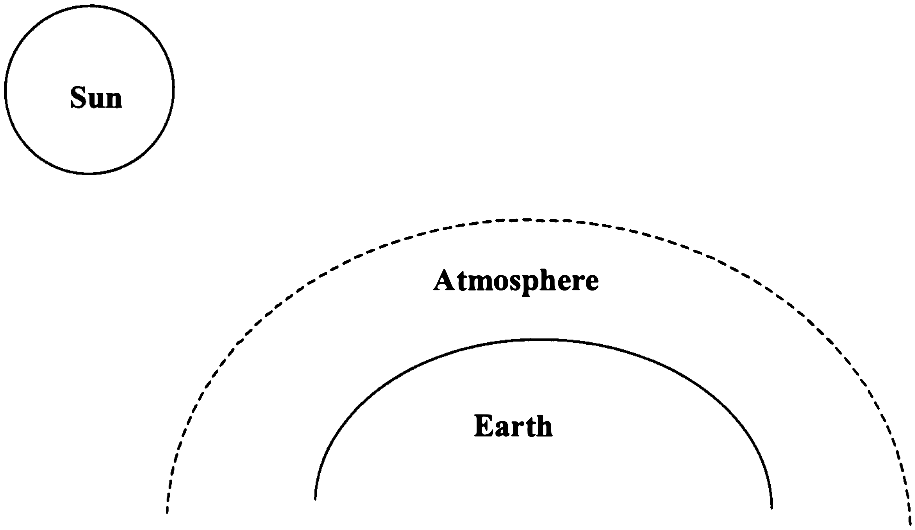
2.4. Governments should conduct programmes to raise the community's awareness of this issue.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree

2.5. Governments should enact strict laws to reduce the release of greenhouse gases to the atmosphere.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree

Part. B



1. Illustrate the Greenhouse Effect by drawing arrows on this diagram to show what happens to solar radiation from the Sun.

2. Explain your diagram

____

____

____

____

____

____

____

____

3. What are the greenhouse gases?

____

____

____

4. Answer the following questions **TRUE** or **FALSE** or **DON'T KNOW.**

Circle one choice and give reasons if **TRUE** or **FALSE.**

4.1. The Greenhouse Effect is keeping our planet **habitable.**

True	False	Don't know

Reason.

____

____

4.2. The **enhancement** of the Greenhouse Effect is causing global warming.

True	False	Don't know

Reason.

____

____

4.3. We **cannot** conclude, based on the available scientific evidence, that human activities cause the changes in global climate.

True	False	Don't know

Reason.

____

____

4.4. Burning fossil fuels like coal, oil or gas can contribute to the **enhancement** of the Greenhouse Effect.

True	False	Don't know

Reason.

____

____

4.5. Deforestation (cutting down trees) **reduces** the Greenhouse Effect.

True	False	Don't know

Reason.

____

____

4.6. The surface of the Earth **absorbs** solar radiation and **emits** infra red radiation.

True	False	Don't know

Reason.

____

____

4.7. Greenhouse gases do **not** absorb infra red radiation.

True	False	Don't know

Reason.

____

____

4.8. Cattle and sheep farming **reduces** the Greenhouse Effect.

True	False	Don't know

Reason.

____

____

4.9. Oxygen, nitrogen and argon **don't** cause the Greenhouse Effect.

True	False	Don't know

Reason.

____

____

4.10. The concentrations of most greenhouse gases are **increasing** in the atmosphere because of human activities.

True	False	Don't know

Reason.

____

____

Part. C

The following are some widely accepted ways of reducing the Greenhouse Effect by individual and collective actions.

- Which of the following are you or your family already doing?
- Which are you or your family considering doing?
- Which are you or your family not interested in taking any action?

Circle **1** if you or your family is already doing this, **2** if you or your family is considering taking action and **3** if not interested in taking any action.

1. Walk, cycle or use public transport rather than using a car.

1	2	3

2. Use compact fluorescent lights in place of normal globes.

1	2	3

3. Reduce hot water consumption, by washing clothes in cold water or by fitting a water efficient showerhead.

1	2	3

4. Insulate your home to reduce electricity used for heating and cooling.

1	2	3

5. Replace an electric hot water system with a solar or high efficiency gas system.

1	2	3

6. When buying a new car, choose one that is fuel-efficient rather than high powered.

1	2	3

7. Conserve existing trees and plant new trees.

1	2	3

8. Switch-off the lights and electrical appliances when they are not needed.

1	2	3

9. When purchasing electrical appliances, choose one that is high-energy star rated rather than a cheaper one.

1	2	3

10. Use manual mechanical devices wherever possible instead of using electricity, eg. Avoid using electric can openers, electric knife, etc.

1	2	3

Part. D

Cars produce large quantities of greenhouse gases and contribute to air pollution in cities.

A political party has developed a proposal to restrict the number of cars that can enter your capital city by imposing very high parking fees and reducing the number of parking bays in the city centre. The Party also proposes to double the price of petrol and car licensing fees to discourage car use.

How do you feel about this proposal? (Circle one choice)

Strongly support	Support	Undecided	Strongly oppose	Oppose

I hold this position because:____________________________________

____

____

____

____

____

____

____

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____

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____

____

Part E

1. How much information do you get regarding the Greenhouse Effect from the following sources.

Circle one of the choices.

1.1. Parents

Mostly	Some	None

1.2. Teachers

Mostly	Some	None

1.3. Textbooks

Mostly	Some	None

1.4. Friends

Mostly	Some	None

1.5. Media reports (TV news/documentaries, Newspapers, Magazines, etc.)

Mostly	Some	None

2. What steps do you feel your state and national governments should take to reduce the release of greenhouse gases?

- ____
- ____

Appendix 3

Interview Questions
(Students)

1. Would you explain your diagram, which shows what happen to solar radiation from the Sun?

2. Do you think the Greenhouse Effect is real and affecting our climate or is it just another scientific theory?

3. Regarding the predictions by scientists about the Greenhouse Effect:

(i) By how much is the average global temperature expected to rise in the next 50 years?

(ii) By how much is the sea level expected to rise in the next 50 years?

(iii) How will ecosystem be affected?

(iv) What changes will we notice in Trivandrum/Perth?

4. If you were the Premier/Chief Minister of your state government and the Minister for the Environment proposed that your government put a 25% tax on electricity to fund research and development to reduce greenhouse gas emission from electricity generation, would you approve this proposal?

5. The Minister also proposes banning the sale and use of air conditioners to reduce electricity consumption and greenhouse gas emission. Will you approve this proposal?

6. Have you been taught about the Greenhouse Effect in science / chemistry at school? Has it been taught in any other school subject? What aspects of the Greenhouse Effect were discussed in class?

Appendix 4

Interview Questions for Head of Science

1. What are lower secondary students taught about the Greenhouse Effect in science at your school?

2. There is no mention of the Greenhouse Effect in the WA Yr 11 and 12 chemistry syllabuses. Are you aware of any aspects of Greenhouse Effect taught to chemistry students in your school?

3. Are aware of any other learning areas taught about the Greenhouse Effect? Society and Environment for example?

4. Should your school do more to ensure your students have a better understanding of the Greenhouse Effect?

5. How do you think the Greenhouse Effect should be taught, to be effective?

6. Do you think an understanding of the Greenhouse Effect is an important aspect of scientific literacy? What responsibility do schools have for improving the public understanding of science issues like the Greenhouse Effect?

Appendix 5

Coding Manual

Spread Sheet Headings

A-10 - Australia Year 10

A- 12 – Australia Year 12

I – 10 – India Year 10

I – 12 – India Year 12

ROWS

Numbers A – 12 - 1 to 15 Year 12 School 1 Australia

16 to 30 School 2

31 to 45 School 3

46 to 60 School 4

61 to 75 School 5

Numbers A – 10 – 1 to 30 Year 10 School 1 Australia

31 to 60 School 2

61 to 90 School 3

91 to 120 School 4

121 to 150 School 5.

THE NUMBERING OF INDIAN DATA ALSO IN SAME WAY TO 5 SCHOOLS

COLUMNS

A 1

1. EIP
2. TGE
3. IC
4. TE
5. HD
6. FB
7. IDU

The rank assigned by students will be put in each column

(EIP- Economic issues and poverty, TGE- The greenhouse effect, IC – Increasing crime, TE – Terrorism, HD – Health and diseases, FB – Family breakdown, IDU – Increasing drug use)

A 2

A2. 1 to A2. 5

(5 for Strongly Agree, 4 for Agree, 3 for Not Sure, 2 for Disagree, and 1 for Strongly disagree)

B 1 & 2

Coding will be done in five levels 1 to 5.

5 for Level – The mechanism of the GHE was explained correctly and represented accurately in a diagram

4 for Level 2 - The mechanism of the GHE was represented accurately in the diagram, however, the explanation of the mechanism was not complete. Students did not differentiate between natural and enhanced GHE.

3 for Level 3 - The mechanism of the GHE and diagrammatic representations were not complete, however, students did understand that CO_2 was involved in trapping reflected rays and causing global warming.

2 for Level 4 – Confused ozone layer depletion with the GHE

1 for Level 5 – Minimal understanding of the GHE

B 3

B3 CO_2

B3 CH_4

B3 H_2O

B3 N_2O

B3 O_3

B3 CFC

B3 CO

B3 O_2

B3 N_2

B3 H_2

1 if written and 0 if not written

(The gases other than GHE gases are based on the response give by the students)

B 4

B 4 . 1 to B 4 .10

3 if True, 2 if False and 3 if Don't Know

Reason code 1 for Valid reason, 2 for Not valid reason, 3 if Misconception regarding the GHE, and 0 if not written.

C

C 1 to 10

3 if Already doing

2 if Considering doing

1 if Not interested in doing

D

D 1

5 if Strongly Support, 4 if Support, 3 if Undecided, 2 if Oppose, and 1 if Strongly Oppose

Reason Codes

5. Strong reason for the support of the proposal to discourage car use to reduce the GHE
4. Concerned with the GHE but not supporting the proposal
3. Undecided because the lack of flexibility of the proposal regarding the public transport and not having faith in political parties and governments
2. Not supporting the proposal due to reasons other than the GHE
1. Not supporting the proposal and not concerned about the GHE

E . 1

E 1. 1 to E 1.5

3 for Mostly, 2 for Some, and 1 for None

E. 2

Categories

1. Research for alternate energy sources and funding for alternative fuel research
2. Cut down less trees and plant more tress
3. Not at all concerned with governmental actions and not believing in governmental efforts
4. More propaganda about the issue including educational activities
5. Restricting greenhouse gas emission by law including signing the Kyoto protocol
6. Restricting use of private vehicles and fines for more emissions from the vehicles.

(These categories are based on the overall responses given by the students answered the questionnaire)