PERCEPTIONS OF ENVIRONMENTAL SCIENCE STUDENTS ON GLOBAL WARMING AND OZONE DEPLETION

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ABSTRACT

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Perceptions of Environmental Science Students on Global Warming and Ozone Depletion

This research analysed post-secondary Environmental Science students' perceptions of global warming and ozone depletion. The aim was to investigate what students, who had already tackled these issues during Environmental Science lessons, had actually understood. The study intended to find out what sources of information students use to acquire knowledge about these issues and also whether this is resulting into environmentally aware attitudes and behaviour. A mixed quantitative and qualitative approach was used. A questionnaire was set to students to gauge their perceptions regarding these two issues, to explore their sources of information and their behaviour regarding the environment in certain life situations. Four groups of students were subsequently interviewed to gain deeper insight about the causes and possible remedies of these global issues and what link exists between the two. Students were also probed to reveal what practices they perform to decrease these problems. The research outcomes demonstrated that students have constructed logical but erroneous conceptual frameworks, through a hybrid between fragmented knowledge and mental models about these environmental issues. Students tended to think in a general way in that anything environmentally friendly decreases global warming and ozone depletion and vice-versa. The conclusive chapter highlights suggestions that might help change the strategies used to expose environmental issues to the students.

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ENVIRONMENTAL SCIENCE **PERCEPTIONS** **CONSTRUCTIVISM**

ENVIRONMENTAL EDUCATION **ACTION COMPETENCE** **CONCEPTUAL FRAMEWORKS**

This work is dedicated to my husband Stephen and my two precious daughters Francesca and Michaela who are my *raison d'etre.*

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Chapter 1 Review of Literature

1.1 Introduction

Two major problems that are significantly challenging sustainability are Global Warming and Ozone Depletion. The scientific community has gained extensive knowledge about the scope and causes of global warming and ozone depletion, putting them in a more legitimate position than ever to alert governments. Meanwhile, public opinion is paying increasing attention to the problems. But, as Benjamin Dessus, a French expert and member of the Intergovernmental Panel on Climate Change (IPCC), has been quoted in The UNESCO Courier of June 2001:

> "we're standing before a real paradox: public will is still falling short, as though knowledge cripples action instead of prompting it." (UNESCO, 2001)

1.2 Developing Environmental Concepts

1.2.1 Investigating Organisation of Knowledge

Leighton & Bisanz (2003) focused on how environmental concepts are developed. The researchers have explored the acquisition of theory-based representations, often referred to as informal or naïve theories and concepts are assumed to embody the theoretical beliefs individuals hold about the world and the relations between entities individuals perceive in the world (e.g. Siegler 1998, Wellman & Gelman 1998).

Organisation of knowledge has been an issue of debate among researchers, who study concept development as some believe it happens through,

1. the construction of cohesive **mental models** for reasoning about a variety of topics (Vosnidou and Brewer 1992),

2. **fragmented knowledge** when individuals reason initially about a topic in a cursory and fragmented manner (DiSessa, 1988). According to this 'fragments' view, mental models do not emerge until enough facts have been gathered to support the construction of cohesive and meaningful knowledge forms,

3. a **hybrid** of these two. How we reason about a topic depends on the **contextual domain** (Lawson, 1988).

Lawson (1988) and Vosniadou & Brewer (1992) imply that conceptual understanding and reasoning follows a path of increasingly evolving models. According to Lawson (1988), the child is free to form naïve beliefs about physical phenomena, which will then form the basis for cohesive models. Naïve models can evolve into more sophisticated models, and form hybrid models, which Vosniadou & Brewer (1992) term 'synthetic' models. With time these models evolve into scientific models as children learn more about the physical world and integrate new knowledge with existing beliefs.

This proposal is concordant with the view that individuals are active learners who attempt to understand their environment (Piaget 1928, 1969, Ausbel 1968, Nussbaum & Novak 1976, Driver & Easley 1978, Nussbaum 1979, Solomon 1983, Lawson 1988, McCloskey & Kargon 1988, Vosniadou 1991). In particular, Vosniadou (1991) suggests that mental models, which are initially constructed from a child's underlying knowledge of the world, serve as tools for understanding and predicting events. However, it is unclear from Vosniadou's (1991) account whether, in some cases, intuitive knowledge about concept is structured simply as a collection of facts.

Investigations of children's mental models [Vosniadou & Brewer's (1992) and Samarapungavan *et al.*'s (1996)] have focused on concrete concepts - the earth, the sun, and moon with which children have direct experience: they live on earth, feel and see the sun, and see the moon. However, children and adults have no direct experience with the ozone layer and ozone 'hole'. As a result it is not clear whether

Vosniadou & Brewer's (1992) mental models are useful in describing how people's knowledge of the ozone layer is structured. Perhaps people's knowledge of the ozone layer might be better described as a collection of facts and not as reflecting cohesive models.

Leighton & Bisanz (2003) examined children's and adults' knowledge of the ozone layer and its depletion and whether this knowledge increases with age. They concentrated on how the 'ozone layer' and 'hole' might be structured as scientific concepts. The analysis revealed that adults have more knowledge than children, on these topics but both exhibited little knowledge about protecting themselves from the dangers that ozone depletion causes.

Moreover, only a small number of participants exhibited mental models in their perceptual understanding of the topic. The researchers implied that if reasoning on this issue involved models exclusively, then more evidence of full models should have resulted among the participants. Instead more partial models or the complete absence of models were found. Consequently, the results indicated that reasoning about the ozone layer might follow a hybrid path – a path in which reasoning about this issue is more likely to begin in a fragmented knowledge but followed by eventual construction of full models.

A search of the research literature has uncovered that school-age children are frequently exposed to issues related to global warming. Yet, according to Meadows & Wiesenmayer (1999) their conceptions regarding the scope and nature of this phenomenon are often incomplete or even inconsistant with predominant scientific understandings. The researchers imply that the complex conceptual knowledge required to understand issues related to global warming create learning situations that harbour the development of incomplete or inaccurate ideas related to global warming.

1.2.2 Bruner's Constructivism

The tool necessary to achieve concept development through the hybrid model is Brunner's constructivism. A major theme in the theoretical framework of Bruner (1973) is that learning is an active process in which learners construct new ideas or

concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure (i.e., schema, mental models) provides meaning and organization to experiences and allows the individual to "go beyond the information given".

As far as instruction is concerned, the educator should try and encourage students to discover principles by themselves thus develop a predisposition towards learning. Together they should engage in an active dialogue (i.e., Socratic learning). The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding. The curriculum should be organized in a spiral manner so that the student continually builds upon what has been already learnt. Good methods for **structuring** knowledge should result in simplifying, generating new propositions, and increasing the manipulation of information (Bruner 1966).

1.3 Scientific Understanding

In 1992 a European Community – wide opinion survey carried out on behalf of the European Commission concerning public understanding of, and attitudes towards science and technology (Eurobarometer, 1992), showed that even though the European population believes that protecting the environment and fighting pollution are immediate and urgent problems they do not have a clear understanding about major environmental problems such as acid rain, the hole in ozone layer, air pollution, the greenhouse effect and global warming. These findings vary a lot between the different countries.

Students, who are still in the process of establishing their attitudes, will have some difficult decisions to make later on in life related to global warming and ozone depletion. Education, about such matters with the use of the correct educational strategies is therefore becoming increasingly essential. Such strategies are best designed if there is an appreciation of students' preconceptions and any misconceptions they might have cultivated while learning was occurring. Unfortunately, still little is known about students' ideas in this area.

Though students may already have the idea that an increase in the greenhouse effect will cause changes in the weather patterns, an appreciation of the mechanism of global warming by the retention of solar energy, takes much longer to be retained (Boyes & Stanisstreet 1993).The understanding of the greenhouse effect is scientifically complex for children. The greenhouse effect is a natural phenomenon and is indeed essential to life on Earth. It is the **increase** in the greenhouse effect caused by atmospheric pollutants that is the problem. Furthermore, the greenhouse effect is imperceptible to individuals, unlike some other problems of pollution (Francis *et al.*, 1993). As a consequence, it is virtually impossible for teachers to demonstrate the increase in global warming to students. It requires a small rise against a fluctuating background. Due to this, some scientists are still sceptical about the existence of the problem (Gribbin 1990) which leads to further complications in asserting the reality of the problem. In addition, an understanding of the causes of the greenhouse effect requires an appreciation of some aspects of the generation and efficient use of electrical energy, concepts which are usually found difficult to assimilate as they are thought to be abstract (Boyes & Stanisstreet, 1990a, 1990b).

Overcoming these difficulties is a major task which can be done through education. Education in this area is utterly important not just because the issues themselves are significant but also because global environmental problems may necessitate, by social engineering, great changes in human behaviour patterns. Educating future adults who shall be tomorrow's decision-makers would be setting the foundations for a more environmentally informed generation ready to undergo such changes. Moreover, the lifestyle they are choosing today is already impacting the environment. It is therefore extremely important to start by understanding the perceptions and misconceptions held by students and appreciate the ideas they already have so as to be able to design and execute effective teaching strategies (Francis et al., 1993).

1.3.1 Students' Perceptions

Skamp *et al.* (2004) conducted a large scale cross-sectional (Years 6, 8 and 10) study of students' ideas about air pollution and the greenhouse effect. A range of persistent alternative conceptions were identified, in some instances with increasing frequency across grades. Students' attitudes towards education, obligation, legislation or

taxation as a way of reducing air pollution were determined; the first two being the most favoured.

Another study conducted by Daniel *et al.* (2004) explored school students' ideas, both scientific and idiosyncratic, about the extent to which various actions might contribute towards reducing global warming. Many students appreciated that a decrease in industrial and vehicle emissions and producing energy from renewable sources would play an important role in this aspect. However, fewer students appreciated that individual actions, such as "saving" electricity and recycling paper, might play; perhaps suggesting that young people feel disempowered about this issue or even disengaged.

In a study, Gomez-Granell & Cervera-March (1993) investigated the awareness of a sample of university and pre-university students about environmental issues and the causes related to energy consumption. The majority of the sample attributed a much higher number of negative environmental consequences to actions related to industrial production than to actions of a more individual nature. With regard to dumping dangerous waste, such as oil slicks, excess of CO_2 and SO_2, acid rain etc. the respondents considered the consequences of such actions even worse than the dumping itself. A direct association was established between what the respondents understood as 'dangerous waste' and any other concept which incorporated the connotation of being 'dangerous' or 'harmful'.

Children have their own understanding of how the world functions prior to receiving formal scientific knowledge. Consequently, the information they gather allows them to build frameworks which though these can be valued as incorrect by the scientific community, are the perceptions or understandings the students managed to structure with the knowledge they possessed at that particular moment. Many researchers refer to these as misconceptions. Much research has been done to determine pupils' misconceptions related to environmental issues such as the ozone layer and global warming.

Table 1.1 Misconceptions Reported in Previous Research

AUTHORS	UNCOVERED MISCONCEPTIONS
Boyes & Stanistreet (1993)	• all environmentally friendly actions help to overcome all problems. • the use of lead-free petrol will reduce global warming • ozone layer depletion contributes to global warming • global warming will cause an increase in skin cancer
Boyes & Stanisstreet (1994)	• confusion of the depletion of the ozone layer with the greenhouse effect and other forms of atmospheric pollution
Daniel *et al.* (2004)	• reducing nuclear power would diminish global warming
Groves & Pugh (1999)	• a consequence of an increasing greenhouse effect will be more earthquakes • the greenhouse effect is worsened by the ozone holes • the greenhouse effect is worsened by too many sun's rays getting to the Earth • a bigger greenhouse effect will cause an increase in skin cancer • the greenhouse effect is made smaller by using unleaded fuel • reduction of nuclear stockpiles reduces the greenhouse effect • nuclear power plants rather than coal plants would not reduce the greenhouse effect • protecting rare plants and animals would help decrease the greenhouse effect • keeping beaches clean would help decrease the greenhouse effect
Cordero (2001)	• ozone hole occurs during summertime • ozone depletion causes skin cancer
Summers *et al.*, (2001)	• holes in the ozone layer are responsible for global warming • there is no natural greenhouse effect which supports life, only that due to pollution by humans • no idea of the necessary balance between energy received from the Sun and that radiated into space. • no understanding of relationship between trees and the amount of CO_2 in the atmosphere • ozone layer confused with atmospheric CO_2 • global warming is definitely due to human activities - no idea of the uncertainties about its causes • burning of fossil fuels produce ozone directly • confuse destructive effect of CFCs on ozone in stratosphere with the production of ozone at ground level from pollutants • ozone is non-toxic

	• ozone layer holes are not naturally repaired • the sun has no role in ozone formation • confusion between ozone as a pollutant and effect of pollutants on ozone high up
Francis *et al.*, (1993)	• the use of unleaded petrol would reduce ozone depletion and global warming • reduction of global nuclear arsenal reduces global warming • protection of rare species reduces global warming • keeping beaches clean reduces global warming • damage to ozone layer integrity causes global warming
Brody (1994)	• anything natural is not pollution • biodegradable materials are not pollutants • solid waste in dumps is safe
Gomez-Granell & Cervera-March (1993)	• energy production and consumption is related to all human activities • low awareness on human's ecological impact • atmospheric pollution is the result of motor transport in cities
Boyes *et al.*, (1999)	• smoke from factories and cars causes damage to the ozone layer • ozone layer as a layer of dust, presumably also located on the ground • the ozone layer helps keep the world warm • the ozone layer protects the Earth from acid rain • skin cancer and eye cataracts are linked with the greenhouse effect
Christidou & Kouladis (1996)	• general pollution harmed the ozone
Leighton & Bisanz (2003)	• all pollution harmed ozone layer in the atmosphere
Chukran *et al.*, in Francis *et al.*, 1993	• confusion and amalgamation of the major environmental problems of global warming and ozone depletion
Fisher (1998)	• confusion about the relationship between the ozone hole and the greenhouse effect
Jeffries *et al.* (2001)	• global warming is caused by increased penetration of solar radiation that is connected with holes in the ozone layer • global warming will lead to more skin cancer • the use of unleaded petrol will reduce global warming • global warming has no effect on distribution of crop pests • ground level ozone not considered as a greenhouse gas

Andersson & Wallin (2000)	• not understanding fully the societal implications of actions such as a drastic reduction in CO_2 emissions
Koulaidis & Christidou (1999)	• greenhouse effect is due to solar radiation that heats up the Earth and the atmosphere, while getting trapped by certain atmospheric gases

The studies outlined in Table 1.1 reveal the existence of the following common elements in children's and adults' thinking about the greenhouse effect (Boyes & Stanisstreet, 1993; Dove, 1996; Francis *et al.*, 1993; Hann *et al.*, 1992; Koulaidis & Christidou, 1993; Rye *et al.*,1994):

(a) the tendency to confuse the greenhouse effect with ozone depletion, or to causally attribute the former to the latter;
(b) the tendency to understand and interpret the greenhouse effect exclusively as an environmental problem, ignoring the fact that it is the result of a natural mechanism;
(c) the tendency to attribute the greenhouse effect to specific gases over others, or
(d) the reference to specific expected consequences of the manufactured greenhouse effect, such as an increase in the planet's mean temperature and sea level;
(e) the suggestion of 'solutions' without considering the societal and economic repercussions.

It is well accepted that such alternative cognitive frameworks are robust and persistent to modification (Ausubel, 1968). In fact a study carried out by Jeffries *et al.* (2001) concludes that despite media publicity and inclusion of the issue of global warming in the formal curriculum of the country in question, insecure knowledge and misconceptions still persist among students.

Subsequent to the misconceptions reported by the study conducted by Koulaidis & Christidou (1999) (Table 1.1) the researchers imply that students' age does not make any difference in the internalised misconceptions. This demonstrates the importance

of the availability of appropriate knowledge from the correct sources, otherwise it seems that misconceptions shall be carried all along throughout one's lifetime.

Misconceptions concerning environmental issues can be overcome if they are identified and understood. One of the main goals of educators is to better understand how the individual constructs their own conceptual frameworks in relation to environmental information. Naturally, a better understanding of students' ideas and how they develop can lead to better teaching/learning methods and potential improvements in the public understanding of environmental information and therefore the environment. Cordero (2001), who focused on identifying student misconceptions about ozone depletion, admitted that further studies were required to thoroughly investigate why these particular misconceptions exist, so as to be able to suggest more effective teaching methods.

1.3.2 Meaningful Learning Through Construction

Learning is an active process of construction as explained previously in section 1.2.2. in which meaning is accomplished on the basis of experience. This view of knowledge does not necessarily reject the existence of the real world, and agrees that reality places constrains on the concepts that are, but asserts that all we know of the world are human interpretations of our experience of the world. Concept development begins from the revelation of various perspectives and the consequent change of our mental models in response to those perspectives as well as through cumulative experience (Bednar *et al.*, 1995).

Constructivism puts the student at the centre of control. Learning is placed in a rich context that reflects the real world. This would enable the constructive process to occur and transfer of knowledge beyond the classroom to be achieved. This can be accomplished if learning happens through cognitive apprenticeship, mirroring the collaboration of real world problem solving, and using the tools available to solve authentic problems. Learning can then be assessed by measuring the effectiveness of the learner's knowledge structure in facilitating thinking in the content field (Bednar et al. 1995).

The learner must construct an understanding or perception and the content cannot be prespecified. Only the knowledge domain may be specified but the student is encouraged to search for other knowledge domains that may be relevant to the issue. Information on the issue is gathered from many sources and learners must be encouraged to seek new perspectives and to consider alternative sources. It is necessary to define a central or core body of information, but it is difficult to define the boundaries of what may be relevant from all the information collected (Bendar, *et al.* 1995).

The constructivist views learning as not being independent of the content and context of learning. It is not possible to isolate units of information or make priori assumptions of how the information will be used. Facts are not simply facts to be remembered in isolation. Instead of dividing up the knowledge domain based on a logical analysis of dependencies, the constructivist view turns toward a consideration of what real people in a particular knowledge domain and real life context typically do (Bendar *et al.*, 1995). The main goal of such an approach is to make the learner think how an expert of that particular knowledge domain would think in that particular circumstance.

(a) A Focus on the Learner

The constructivist approach focuses on skills of reflexivity not remembering, it focuses on the process of knowledge construction and the development of reflexive awareness of that process: the possibility of alternative sign systems, the imaginative aspects of much of our knowledge, the development of self-conscious manipulation of the constructive process, etc. Because every learner will have a unique perspective going into and leaving the learning experience, the concept of the global learner is not a part of the constructivist perspective (Bendar et al, 1995).

(b) Specification of Objectives

Constructivists do not have learning and performance objectives that are internal to the content domain, but rather they seek for authentic tasks and let the more specific objectives emanate and be realised as they are suitable to the learner in solving the real task.

(c) A Conducive Environment

Constructivists stress the importance of the learning environment which should encourage understanding from multiple perspectives.

(d) Strategies for Constuctivism: Situated Cognition

By real world contexts, Bendar et al, (1995) suggest that:

- **The task is not isolated, but a part of a larger context.** Students are not asked to learn about problems from books. Projects and environments that capture a larger context in which that problem is relevant need to be created.

- **The task of the learner and the surrounding environment or the information base have to be real** (Brown, Collins, & Duguid, 1989; Resnick, 1987). This is not done by simply talking about critical and incidental attributes of the environment. The reason for solving a problem must be authentic to the context in which the learning is to be applied. Learning and performance objectives are not only internal to the content domain, but there must be a search for authentic tasks so as the more specific objectives are realised.

- The environmental context is critical. The information cannot be remembered as independent, abstract entities. Learning always takes place in a context and the context forms an inexorable link with the knowledge embedded within it. Most simply stated, an abstract, simplified environment (school learning) is not just quantitatively different from the real world environment, but also qualitatively different. The reason that so much of what is learned in school fails to transfer to non-school environments or even from one subject matter to another is attributable, in part, to the fact that the school context is so different from the non-school environment. Spiro

> *et al.*, (1988) argue that environments do not have to be simplified as it is typically done in school settings, but rather maintained in their complexity and the student helped to understand the concept embedded in the multiple complex environments in which it is found. Salomon & Perkins (1989) make a similar point in their discussion of high-level transfer:

> "Authentic learning environments may be expected to vary in complexity with the expertise of the learner. That is, the child would not be confronted with the complexity of the adult's world-indeed, the child's world is not that complex. ...when we propose an authentic environment and a complex environment, we are referring to authenticy and complexity within proximal range of learner's knowledge and prior experience" (p.107).

It has been the tendency in traditional designing that we learn about something so that we can use that knowledge later. From the constructivist view it is necessary that the learning of the content is embedded in the use of that content. In their design of basic electricity training Sticht & Hickey (1988) demonstrated this approach. The traditional way to this particular course had been to prepare an electricity curriculum based on an analysis of the facts, procedures, concepts, and procedures in the knowledge domain and taught in the traditional textbook fashion. When this was learned students were expected to be able to go to their particular specialities and apply the knowledge.

On the contrary, Sticht & Hickey (1988) concentrated on the functional context of the electricity knowledge. They recognised authentic tasks and provided instruction in the context of those tasks. In their design, students were asked to diagnose why a flashlight would not light. Then the class discussed how different diagnoses might be represented in an overall picture (i.e., a functional analysis). From context to context, they transferred the students to more complex and less familiar systems, but always maintaining the functional context of the task.

(e) The Strategy of Multiple Perspectives

From the constructivist standpoint it is essential that students learn to construct multiple perspectives on an issue and that they can make the best case possible from each one.

The method for achieving these perspectives is to make a collaborative learning environment so that students can develop, compare, and understand multiple perspectives on an issue. Co-operative learning is nothing new but constructivists emphasise that sharing a workload or coming to a consensus is not the goal of collaboration. Instead the goal is to search for and evaluate the evidence for a viewpoint. Different sorts of evidence and different reasoning will keep up the differing views. In addition, this is not a competitive exercise, where groups debate on who is right. It is rather seen as a co-operative effort where students are coming to understand each perspective and even contributing to the development of each perspective.

The use of examples is another factor important in achieving multiple perspectives and a rich understanding. In traditional instructional approaches the examples are selected to stress critical characteristics and students are expected to systematically manipulate the complex of irrelevant attributes in the quest for one solution for a problem. This is not what happens in real life as there is never a clear cut answer to any problem. Conversely, the constructivist approach to the use of examples would be in using a real authentic situation resulting in a supply of alternative views generating a construction of understanding as well as supporting the development of multiple perspectives (Bendar et al, 1995).

(f) Evaluating Constructively

With a constructive view of knowledge, the goal is to improve the ability to use the content domain in authentic tasks (Brown, Collin, Duguid, 1989). The evaluation must examine the thinking process. This is not to suggest, however, that the issue of thinking is independent of the content domain. Researches on expert and novice strategies indicate that effective problem solving strategies are intimately tied to the content domain (Bendar et al, 1995).

Possible ways of evaluation would for example be in asking students to address a problem in the field of content and then defend their decision, or to reflect on their own learning and document the process through which they have constructed their view of the content.

There are two elements that seem important so that the perspectives that the students develop in the content area are effective in working in that area and that the students can defend their judgements.

- The first element might be referred to as **instrumentality**; to what degree does the learners' constructed knowledge of the field, permit them to perform efficiently in the discipline? The most apparent application of the concept of instrumentality might be problem solving. Can students come to a reasoned solution to problems in the field?
- The second element, i.e., the ability to **clarify and defend decisions**, is connected to the development of metacognitive skills, i.e., thinking about thinking. Reflexive awareness of one's own thinking means monitoring both development of the structure of knowledge being studied and the process of constructing that knowledge representation.

However, operating the concept of instrumentality is not an easy task as no two students would be expected to make the same interpretations of the learning experience nor to apply their learning in exactly the same way to real world problems that do not have one best answer (Bendar et al, 1995).

The theory of learning does not in principle lead smoothly and unambiguously to generalisable prescriptions for practice. Instead, instructional designers must use theory as a "point of view" or as a means for forming expectations of how real world problems will behave.

1.4 Concept Classification

Lawson *et al.*, (2000) have conducted a study based on the classification of scientific concepts. Previous research has found that scientific concepts can be meaningfully classified as:

- **descriptive** (i.e., concepts such as "predator" and "organism" with directly observable examples) or
- **theoretical** (i.e., concepts such as "atom" and "gene" without directly observable examples).

Developing understanding of descriptive and theoretical concepts is linked to students' developmental levels, presumably because the procedural knowledge structures (i.e., reasoning patterns) that define developmental levels are needed for concept construction.

Lawson *et al.*, extend this theory and research by studying an intermediate class of concepts called:

- **hypothetical** (i.e., concepts such as "subduction" and "evolution" with exemplars that cannot in practice be observed due to limits on the normal observational time frame).

The hypothesis that three kinds of scientific concepts exist was tested by constructing and administering a test on concepts introduced in a college biology course. It resulted that, descriptive concept questions were easier than theoretical concept questions and these were easier than hypothetical concept questions. Furthermore, a significant relationship ($p < 0.001$) was found between conceptual knowledge and developmental level. This demonstrates that procedural knowledge skills associated with levels of intellectual development play an important role in declarative knowledge acquisition and in concept construction. It also seems to highlight why educational programmes particularly those which are dependent on assessment through examinations, tend to focus on descriptive concepts.

Another study on concept formation conducted by Österlind (2005) presented the work of three 14-year old pupils who were learning about the intensified greenhouse effect and the depletion of the ozone layer. The pupils' work demonstrated a need for certain domain-specific knowledge; for example, understanding such concepts as photosynthesis, radiation and catalyst. The pupils experienced difficulty in distinguishing between the different meanings attached to individual concepts in their theoretical and practical contexts. They were often unable to clearly explain a specific environmental problem due to an incapability to differentiate between the environmental concepts. Thus, Österlind (2005) concludes that it is a question of appropriate conditions for concept formation or conceptual change to occur.

1.5 Education for Sustainable Development

A sustainable society is one that meets its needs without compromising the ability of future generations and other species to meet theirs (WCED, 1987). Underlying this definition is an environmental ethic captured in the Kenyan proverb:

> "We do not inherit the earth from our parents, we borrow it from our children." (Pezzoli, 1997)

Since the report of the World Commission on Environment and Development (WCED 1987) and the United Nations Conference on Environment and Development (UNCED, 1992) in Rio de Janeiro, sustainable development has been widely recognized as a common goal. This has led to a need for information and most of all education about it. Besides an improved knowledge base, education for sustainable development develops better skills and pro-environmental attitudes and values that will lead people to take action towards adopting sustainable lifestyles. This is particularly important considering that the UN Decade of Education for Sustainable Development is underway. The outcomes to be reached between 2004 and 2015 through education for sustainable development include the:

- promotion and improvement of basic education focusing on imparting knowledge, skills, values and perspectives throughout a lifetime that encourage and support citizens to lead sustainable lives.
- reorienting existing education programmes which should include more principles, knowledge, skills, perspectives and values related to sustainability in each of the three realms – social, environmental, and economic. This should be done in a holistic and interdisciplinary manner.
- developing public awareness and understanding of sustainability since informed citizenry and knowledgeable consumers can help communities and governments enact sustainability measures and move towards more sustainable societies.
- training all sectors of the workforce who can contribute to local, regional and national sustainability. (UNESCO, 2002)

Consequently, it can be implied that an increased recognition of the importance of education for sustainable development provides an important reason for developing every person's understanding of environmental issues. One understands that the concept of sustainable development is multifaceted, and involves environmental, economic and social consequences of humanity's activities. The following is how the Council for Environmental Education in the UK defined it in 1998:

> "Education for sustainable development enables people to develop the knowledge, values and skills to participate in decisions about the way we do things individually and collectively, both locally and globally, that will improve the quality of life now and without damaging the planet for the future." (Defra, 1998)

According to the International Union for the Conservation of Nature (IUCN), environmental education (EE) is:

> "... the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among men, his culture and his biophysical surroundings. EE also entails practice in decision-making and self-formulation of a code of behaviour about issues concerning environmental quality". (IUCN; 1970)

The 1977 Tbilisi Conference (UNESCO – UNEP, 1977), known to have spearheaded the environmental education movement, resulted in a declaration which listed seven directive principles for environmental education (EE) programmes. These are summarized as follows:

- EE is a lifelong educational process that occurs at all levels of education.
- EE is about the interactions which occur in the natural, the built and social environment. It should lead to the understanding of human interactions and political processes, together with the nature of socio-economic issues and the effect of these on environmental degradation or enhancement.
- EE is for developing attitudes and value systems which lead to socio-economic improvement through positive social interactions and the maintenance and improvement of the natural and built environment.

- EE aims to develop an individual's understanding, skills and the feelings of empowerment that are necessary for both positive behaviour towards the biophysical and social environment in everyday living, and for active participation in group efforts to find the optimal solutions for environmental problems.

- EE requires a holistic and preferably interdisciplinary approach to teaching with opportunities for diverse learning experiences, but with particular emphasis on direct experiential learning in natural, built and social environments.

Environmental education is therefore not only the concern of natural scientists, but draws from the tools and resources of a wide range of disciplines in order to demonstrate the root of current problems and suggest ways in which learners could either prevent or remedy these. Leal Filho (1996) argues that environmental education is a process directed towards increasing the general level of public concern about environmental dynamics as well as fostering awareness of the need for public participation in order to promote environmental conservation.

1.5.1 Teaching About, Through and For the Environment

This planet is facing an environmental crisis and as has been reported by environmental experts in a UN conference held in Rome in September 2007, climate change is affecting Europe faster than the rest of the world and rising temperatures could transform the Mediterranean into a salty and stagnant sea. It is unclear why this region is more sensitive to climate change, but experts are convinced that in the next decades, temperature increases hitting Europe during the summer months could be 40 to 50 percent higher than elsewhere. Experts said changes are also being felt at sea level, with a surface temperature increase of six-tenths of a degree Celsius. These temperature rises could wipe out up to 50% of the species in the region (Castelfranco, 2007).

Worldwide educators have begun to move away from teaching approaches that stress 'wildlife experience' or 'nature study' (i.e. teaching merely about the scientific aspects of nature). As previously explained constructivism encourages learners to understand

and transform authentic problem environments. This leads to EE being defined as education **about, through** and **for** the environment. Ten years ago EE would have been equated with the environmental sciences, a field which is dominated by the conventions and traditions of the scientific method. This has been the case with Malta when Environmental Science was introduced as an Intermediate level option subject for higher education students. However, education about, through and for the environment is now seen as a holistic field that draws from the tools of both the social and natural sciences.

Educators should adopt the approach that stresses holism when addressing environmental issues. This means that planet Earth should be seen as a super-organism consisting of interrelated and interdependent biophysical entities that are undergoing continuous transformation. Humans are located within a technologically-orientated sphere (techno-sphere), which in turn is located within a broader social and biophysical environment. This approach requires educators to encourage learners to think in terms of systems theory, which sees the whole (the super-organism) as greater than the sum of its individual parts. Thus, positive actions in specific parts (or individual life-worlds, e.g. the economy) should work to the benefit of the whole. This form of 'inclusive' thinking encourages learners to develop associations between various constituents (life-worlds) of a system and demands that learners develop proficiency in a range of subject areas or disciplines (O'Donoghue 1996).

Most educators also agree that environmental education is not a separate discipline. It is a systematic process in which learners are empowered to critique a problem environment, through direct experience and the communication of information. Learners are also encouraged to engage in practical activities that ultimately benefit the biophysical environment. This process must result in three outcomes:

1. learners must understand their relation to other interlinking chains of natural systems and socio-ecological processes.

2. learners must interpret conditions into their own frameworks, since much of what we learn about 'reality' is determined and shaped by our individual worldviews and backgrounds.

3. learners must be able to critique conditions and uncover hidden ideologies or assumptions underlying specific problems. That which is learned must drive the learner towards transformation. Knowledge of environmental issues must be built for the ultimate objective of action and practical change.

Programmes differ in the extent to which they are able to achieve all of these outcomes. Some succeed in creating the awareness and knowledge of environmental problems, while others culminate on renewed actions that benefit the natural environment. Yet, with our environmental problems still worsening after more than 30 years of debate, it's not hard to understand why many educators are insisting that learners embark on practical, action-geared projects.

The latest term in international documents concerning the environment from this perspective is Education for Sustainable Development rather than Environmental Education. Though the term has changed, the aims have remained the same. As Pace (2005) argues, the emphasis should be put on the aims and achievements not on the labels given as long as sustainable development remains the main focus.

1.5.2 The Provision for Environmental Education in the Maltese Education System

The misconceptions held by students and teachers as revealed in previously discussed literature suggest the importance of environmental education in the educational process. As Knapp (2000) suggests,

> "Environmental Education must look upon itself as a sequential learning process, which was the original intent of the Tbilisi Doctrine."

Environmental education as a standard part of the educational curriculum could increase environmental consciousness, ecological knowledge, knowledge of environmental issues, from primary school age through adulthood, thus forming citizens capable of making decisions for sustainable development which will improve the life of future generations. Such a strategy could motivate students to take personal responsibility towards the resolutions of the environmental problems, empower them to use responsible positive actions for helping resolve environmental issues and contributing to sustainable development in the process (Dimitriou, 2001).

Environment awareness in Malta has to be attributed to a number of enthusiastic individuals, many of whom happened to be school teachers or NGO members or researchers. They passed on their knowledge and passion for the various areas of the natural environment to others. They were in fact the first environmental educators. Consequently a number of provisions in the education system were taken by those entities that tried and could make a difference in the mentality of the generations to come.

Table 1.2 Provisions taken towards Education for Sustainable Development

YEAR	EVENTS
1991	Unofficial setting up of Environmental Education Unit (EEU) that developed EE courses for teachers. The EEU of the Faculty of Education insists that personal development components are integral features in efforts to promote sustainable lifestyles. The EEU initiated a research programme producing several environmental education resoursces. The EEU, MEPA and the Education Division organized several in-service courses to help teacher apply environmental education principles in their teaching strategies (Briguglio & Pace 2004).
1992	The Matriculation and Secondary Education Certificate (MATSEC) Examinations Board was set up. Consequently new subject syllabi were drawn, relevant for the Maltese context. Incidence of environmental topics and issues have been given increasing importance.
1992	The introduction of Environmental Studies in secondary schools, combining elements of geography, social studies and history.
1994	Environmental Science was introduced targeting post-secondary students (Pace, 1997).
1995	2nd National Training workshop on Environmental Education in Malta where an Action Group has been set up to co-ordinate the formulation of a National strategy for environmental education (NEES) and to ensure the participation of all the parties interested in this strategy. Its aim was to exploit the resources available, to develop new ones, to propagate the concept of environmental education, in a formal and informal way, to all sectors of the population (Mugliett 1998). Unfortunately, NEES had limited resources and for some of its target groups Education for Sustainable Development was not a priority resulting in inadequate participation in the consultation process (Briguglio & Pace 2004).

1999	The new National Minimum Curriculum has no provisions for ESD but proposes measures such as interdisciplinarity, a learner-oriented pedagogy, the development of critical thinking and participatory skills, interaction with the community and autonomy for schools that, if adopted would facilitate ESD's infusion in the educational system (Ministry of Education, 1999).
2001	A National Commission for Sustainable Development was set up. Aiming at promoting sustainable development, it acknowledges the importance of education (Briguglio & Pace 2004).
2002	The Eco-Schools programme was introduced in Malta with the aim of instituting ESD principles within a school's management policy progressively incorporating an environmental ethic within the school ethos. The programme empowers students to adopt an active role in environmental decision-making and action in their school and their community.
2004	The setting up of CEER, a Centre for Environmental Education and Research. It seeks to provide training and research programmes for Malta and the rest of the Euro-Med region that promote environmental education and develop a cohort of environmental educators to address the ever-increasing need for expertise in this field. It is the main environmental education agency in the country.(CEER 2004)
2006	The National Commission for Sustainable Development drew A Sustainable Development Strategy for Malta 2006-2016. It included how education could make a difference. It aimed at enabling people develop the knowledge, values and skills to participate in decisions affecting the quality of life of current and future generations. (NCSD 2004)

The events summarised in Table1.2 seem to corroborate Mifsud's (1998),the then Permanent Secretary of the Environment, claim that

> "We are committed to forge a stronger relationship with the educational process in Malta. We wish to steer away from the simple dissemination of information to a somewhat neutral public currently more concerned with the emotional, aesthetic or superficial aspects of environmental sustainability, towards the provision of up-to-date scientific based information which a better educated public can assimilate and react to." (Mifsud 1998)

Unfortunately, however after ten years from Mifsud's speech, the task force formed by the NCSD in 2006 to draw A Sustainable Development Strategy for Malta noted that a proper policy regarding education for sustainable development was and still is

lacking in Malta. As a result such education in schools is rather sporadic. The approach remains one of providing environmental information and a scientific background about all aspects of the environment. However, the NCSD (2004) stresses that the fostering of pro-sustainability values is not given due importance in educational programmes. A clear policy needs to be adopted about education for sustainable development in the National Minimum Curriculum. Environmental education policies provide a sense of direction as to the path a country wishes to follow, enabling periodical checks to be made along the way (Filho in Pace, 1998)

Therefore the discourse now changes to

> "... there is a clear need for a consolidated and integrated approach at a national level. There is also a need to shift the emphasis from environmental protection onto sustainability, and from communication of scientific information to that which will create a change in values." (NCSD 2004)

Education is the tool that can be used to raise public awareness which will help communities identify important issues, problems, as well as opportunities and solutions. Awareness raising initiatives can provide people with the knowledge and insights to enable them to make responsible and informed choices in their behaviour and lifestyle.

1.6 Internalising New Attitudes and Behaviour

Psychological traditions recognise two different conceptions about social attitudes and behaviour. On the one hand, the behaviourist theories defend the idea that an individual's behaviour and attitudes are the result of interiorisation of norms and prohibitions which were socially sanctioned or accepted. Thus the individual's behaviour and attitudes could be externally regulated, by way of norms imposed from outside.

On the other hand, we have structural-cognitive perspectives (Kohlberg, 1976, 1981). Here, moral development is not seen as a process of internationalising social norms. Quite the opposite: individuals build autonomous principles of social and moral justice. The behaviour of individuals depends on their cognitive development and on their logical and conceptual capacity for understanding social and scientific

phenomena. Thus, according to these theories, the individual's moral conduct would be extremely consistent and would be strongly affected by their level of cognitive development.

Turiel (1975, 1978), Keasey (1978) and Grueneich (1982) questioned the existence of a logical rationality which guides an individual's behaviour as well as the idea that this behaviour is consistent in all situations. Thus, behaviour would be determined by a more pragmatic rather than a strictly logical kind of rationality. This rationality would have both cognitive and affective components which maintain a degree of consistency and a balanced relationship between them, and therefore a change in one would bring about changes in the other and vice versa. Consequently, various investigators have also confirmed that: an individual's moral conduct is not universally consistent. It depends on cultural and contextual conditioning; an individual's attitudes and behaviour are not strictly determined by beliefs or theoretical knowledge.

Gomez-Granell & Cervera-March, (1993) believed that in order to change people's attitudes and behaviour it is necessary to have a conceptual framework that allows one to understand the reasons that justify their behaviour. It is not enough to internalise exterior norms, we must understand their justification. At the same time this conceptual knowledge is not sufficient if it is not related to affective components and conditions of use. It is not enough for a scientist to know in detail about the harmful greenhouse effect, what causes it and what causes ozone depletion. Knowledge must also be linked to behaviour and daily interests of the people who share the same environment with the scientists that study these issues scientifically.

1.7 Conclusion

> "a basic aim of environmental education is to succeed in making individuals and communities understand the complex nature of the natural and the built environments resulting from the interaction of their biological, physical, social, economic and cultural aspects, and acquire the knowledge, values, attitudes and practical skills to participate in a responsible and effective way in anticipating and solving environmental problems and the management of the quality of the environment"(UNESCO-UNEP, 1977).

Nowadays, after the Tbilisi Conference on Environmental Education (1977), this basic aim is still basic and public participation is an important element of Agenda 21 because it is a basic concept of sustainable development (UNEP, 2000).

Communities and individuals have to acquire an awareness and understanding of the total environment and its problems or issues. It is widely approved that the key element in improved environmental management is public participation. The foundation on which environmental policies are built is the general public's knowledge of the environment (UNEP, 2000).

However, is the public's knowledge of the environmental issues or problems sufficient for them to be able to make decisions from which they will benefit? Can individuals explain the factors involved in the environmental issues or problems? Does the individual understand his/her participation in producing environmental problems? Although public awareness and concern about the environment has grown the public's knowledge of the environment is seriously deficient (UNEP, 2000).

This definitely involves the employment of effective educational strategies. It is clearly advantageous if these begin early, before complex alternative conceptual frameworks are established and before attitudes and prejudices based on those alternative ideas are set (Kornberg 1991). For this reason, the already existing conceptual frameworks on global warming and ozone depletion of students shall be studied and analysed so as to be able to recommend how to construct concepts which will hopefully lead to an attitude and behaviour inextricably linked with sustainable development.

Chapter 2 Issues of Methodology

2.1 Aims of Research

The literature manifested striking evidence that scientific and technical concepts regarding global warming and ozone depletion are handled by the majority of students with a high degree of confusion and uncertainty (Gomez-Granell and Cervera-March 1993). Moreover, it emphasises the importance of understanding and grasping such concepts due to the important decisions students will have to make during their lifetime that affect environmental sustainability for future generations.

This study sets out to investigate Maltese students undergoing a post-secondary course in Environmental Science, who have already studied a topic about Air Pollution that includes global warming and ozone depletion. These could provide the necessary information about the perceptions and misconceptions held on these environmental issues, accentuating the conceptual framework built and its implications.

Consequently, the research aims to illustrate how these perceptions and misconceptions impact on the choices that students do in their everyday life. The study will try to elicit present practices performed by students that give evidence as to whether they are influenced by what they know on climate change.

This study aims to identify the main sources of information through which students are learning about the environment. Knowing where the problem lies will enable educators counteract misconceptions and provide insights into possible ways in which environmental science lessons might be taught to address the misconceptions (Christidou and Koulaidis 1996, Koulaidis and Christidou 1999).

Therefore, the results obtained from the data collected shall throw light as to whether greater consideration should be given to environmental education as a primary source

of information and what strategy could be adopted to provide not only greater awareness but also the adequate attitude necessary to achieve sustainability.

Adolescents' understanding of global warming and ozone depletion is of interest not only to those who might be curious about the development of scientific understanding, but also to those interested in fostering lifestyle change. This study will include a critical analysis of how the scientific part found in the Intermediate Environmental Science syllabus can be integrated with action-competence to achieve pragmatic conceptualization from students and how this could start at school and proceed when the students leave formal education.

Finally, this study shall provide concrete and practical recommendations on how to provide the foundations through which students can acquire a basis on which to make informed decisions about environmental issues and to develop the willingness to do so. Other recommendations that can be implemented by the whole school community to generate an enhanced environmental mentality and culture among the young shall be proposed.

Thus, the areas of concern shall be the development of correct concepts regarding global warming and ozone depletion possibly through environmental education in schools and environmental education projects and programmes. The latter is not yet a well-established area, but since environmental education is well established as both a requirement (WCED 1987) and a tool for sustainable development (Schneider 1993) it will form part of this study. Indeed environmental education has been consistently mentioned in the international literature (e.g. Bain 1994, Hardy 1992, McCormick 1995) as an item that needs to be taken into account in promoting sustainable development.

2.2 Research Questions

Climate change has become an international concern and most of all a political issue as the general public has become increasingly aware of the problems facing the world (Boyle 1989, Houghton *et al.* 1990, Mitchell 1990, Tickell 1991, Leighton & Bisanz 2003).

The study shall be designed to address the following questions:

- Do students recognise terms associated with global warming and the ozone layer and its depletion?
- To what extent do students have factual knowledge about global warming, and the ozone layer and its depletion?
- Do students think there is a link between ozone layer depletion and global warming?
- What are the perceptions held by students about global warming and ozone depletion?
- From where are students getting their perceptions?
- How much do students' feel that global warming and ozone depletion affect them personally?
- How can the Intermediate Environmental Science syllabus change from tackling these issues factually to providing insight and increasing awareness and responsibility?
- Are students prepared to change their lifestyle towards a more sustainable future?
- What can be done to gear students for a sustainable lifestyle?
- What can be done by the educational system to ensure that future generations are more environmentally responsible and adopt a more sustainable lifestyle?

2.3 Philosophical Foundations

The methodology used in this study needs to be put into perspective of the philosophies that regulate it. Research being it quantitative or qualitative, is established on underlying assumptions about what constitutes 'valid' research and which research methods are appropriate. In order to conduct and/or evaluate quantitative and qualitative research, it is therefore important to know what these assumptions are.

The most pertinent philosophical assumptions are those which relate to the underlying epistemology which guides the research. Epistemology refers to the assumptions about knowledge and how it can be obtained (Hirschheim, 1992).

In attempting to address the research design, two methods have been identified, as no single method is able to endow enough insight to unveil concepts and practices that have so far been latent. No method possesses an intrinsic and canonical superiority over another, conversely, they all have their merits and weaknesses, such that each method shall grant its valid contribution and shall be an important vehicle to conceptualise that portion of the study which it suits best.

Ackroyd and Hughes (1992) justify such an orientation claiming that research scientists do not make use of the same instruments. As they deal with different matters, they need to use or develop instruments of research suited to their respective subject matters. However, it is also argued that the research instruments devised for collecting the data need to be sensitive to the nature of the subject matter of the discipline.

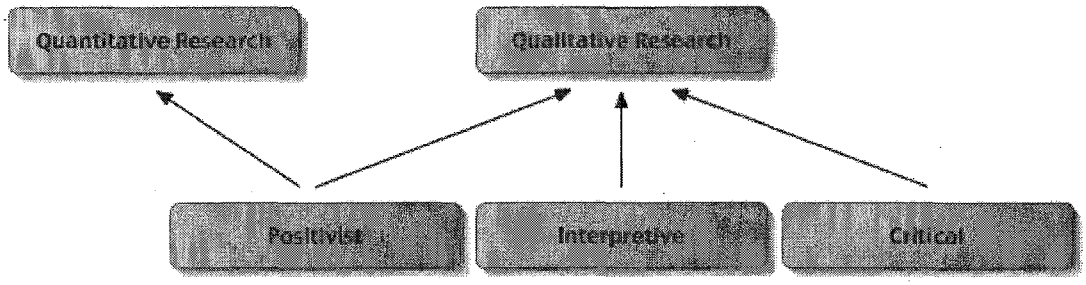
Multi-method research designs do not only secure better understanding but also enhance the process of triangulation where the subject is studied from different points of view. Denzin (1970) clarifies that,

> "No single method is free from flaws – no single method will inadequately handle all the problems of casual analysis – and that no single method will yield all the data necessary for a theory's test. Consequently, the researcher must combine his methods in a process termed triangulation; that is empirical events must be examined from the vantage provided by as many methods as possible." (pp.3)

2.3.1 Quantitative Research

As Figure 2.1 clearly depicts, quantitative research is based on a positivist epistemology dealing only with observed and measured knowledge. The tool used to obtain this kind of information is the survey. It is a scientific method that provides numeric data and that is able to distinguish between what is considered to be true and what is considered to be false. The aim is to classify features, count them, and construct statistical models in an attempt to explain what is observed.

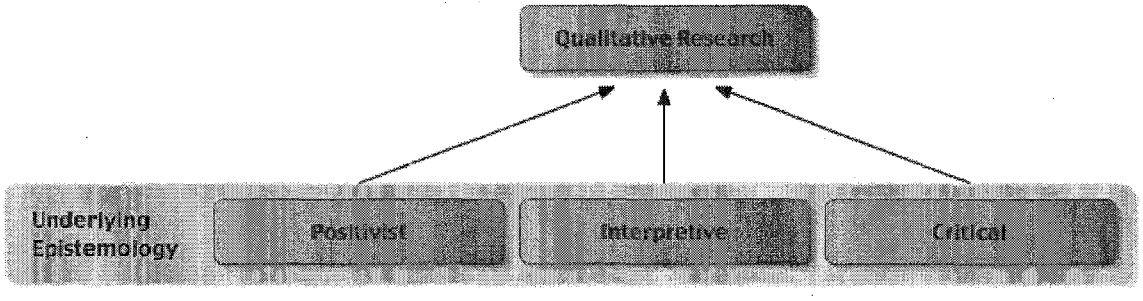
Figure 2.1 Epistemological Assumptions for Qualitative and Quantitative Research (Myres, 1997)



In theory, it is enough, for one observation that contradicts the prediction of a theory to falsify it and render it incorrect. Furthermore, even after being tested, a scientific theory is never verified because it can never be shown to be true, as some future observation may yet contradict it. Accordingly, a scientific theory is, at most, extensively corroborated, which makes it accepted until proven otherwise. Of course, in reality, measurement is never perfect and is always based on theory.

2.3.2 Qualitative Research

Figure 2.2 Epistemological Assumptions for Quantitative Research (Myres, 1997)



Qualitative research provides an effective way to understand any phenomenon by viewing it in its context. The researcher needs to understand what's going on through immersion. Flexibility in an inquiry of people in context elicits more information than any other rigid tool. Qualitative research also operates under different ontological assumptions about the world; there is not a single unitary reality apart from our perceptions. Since each of us experiences from our own point of view, each of us experiences a different reality. Conducting research without taking this into account violates their fundamental view of the individual. Consequently, they may be

opposed to methods that attempt to aggregate across individuals on the grounds that each individual is unique.

Orlikowski and Baroudi (1991), following Chua (1986), suggest three categories, based on the underlying research epistemology: positivist, interpretive and critical. While these three research epistemologies are philosophically distinct, in the practice of social research these distinctions are not always so clear cut (Lee, 1991). There is considerable disagreement as to whether these research "paradigms" or underlying epistemologies are necessarily opposed or can be accommodated within the one study.

- **Critical Research**

Qualitative research for the present study shall be conducted by interviewing focus groups. Critical research is considered since it reflects the aim of conducting these interviews. Critical researchers assume that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognize that their ability to do so is constrained by various forms of social, cultural and political domination. The main task of critical research is seen as being one of social critique, whereby the restrictive and alienating conditions of the status quo are brought to light. Critical research focuses on the oppositions, conflicts and contradictions in contemporary society, and seeks to be emancipatory i.e. it should help to eliminate the causes of alienation and domination. Popkewitz (1984) refers to critical science as a manner to understand rapid social changes in the world as well as responding to certain social problems that changes bring about.

Thus, paraphrasing Habermas (1973), individuals get to know themselves and their situation through retrospection, bringing to consciousness the process of social formation which provides conditions in which questions of ethics, morality and politics orient individuals to what is right and just in a given situation. So, a theory shall not be viewed as absolute knowledge, but more simply as an orientation for practice.

Consequently, perceiving that the positivist epistemology deals only with observed and measured knowledge, it has to be recognized that such an approach on its own would result in excluding many important aspects of psychology because feelings, perceptions and attitudes cannot be readily measured. Hence triangulation becomes a necessity. This means that observations and measurements are inherently imperfect and hence the need to measure phenomena utilizing more than just one method.

2.4 The Research Instruments

The survey is the main instrument that shall be used in this research. It can be described as being like an onion, with data from questionnaires similar to peeling off some outer layers of skin, but being supplemented by interviews to get to the in-depth layers.

Surveys are useful in describing the characteristics of a large population. No other method of observation can provide this general capability and in fact a big representative sample aims at generalizing the findings. Having a large sample implies statistically significant results even when analyzing multiple variables. Therefore, many questions can be asked about a given topic giving considerable flexibility to the analysis. Furthermore, standardized questions make measurement more precise by enforcing uniform definitions upon the participants. Standardization ensures that similar data can be collected from groups then interpreted comparatively (between-group study). Moreover, usually, high reliability is easy to obtain—by presenting all subjects with a standardized stimulus, observer subjectivity is greatly eliminated.

The researcher must conduct the survey with a large sample to ensure that a large number of that selected sample will reply to obtain a reliable result.

The survey will take the form of:

1. a questionnaire with a number of close-ended questions
2. followed by a structured interview with a number of open-ended questions

2.4.1 The Questionnaire as a Research Instrument

It is expected that the questionnaire reveals the students' understanding of what is implied by global warming and ozone depletion, whether students think that the two issues are interlinked and in what ways, what causes global warming and ozone depletion, whether they are contributing to their increase and how they can change their attitudes to stop doing more harm to the environment. The answers to the questionnaire will provide information about the students' perceptions. The aim is to collect numerical data, classify features, count them, and construct statistical models in an attempt to explain what is observed. The objective is to seek precise measurement through the questionnaire to analyse target concepts.

If the questionnaire is utilised as the only tool in a study, the researcher can draw misleading conclusions because of a limited range of options offered to the respondents. Another limitation in this technique is that the participants cannot qualify their responses and the answers are quite limited.

2.4.2 Design of the Questionnaire

At the outset of this study, it is hypothesised that the reason why Environmental Science students exhibit low responsiveness to environmental issues, in particular global warming and ozone depletion, is due to the misconceptions and formulation of incorrect concepts that has occurred during the experiences lived.

The questionnaire (Appendix 1) was designed to procure quantitative data as to what extent this supposition could be significant, while the interview constructed afterwards was intended to complement and gain further insight into some of the underlying ideas of the students. The questionnaire was based on a previous one used on British school children aged 11-16 (Boyes & Stanisstreet 1993) to explore the ideas of elementary school students about actions that would reduce the greenhouse effect, a study conducted by Summers *et al.*, (2001) that investigated the understanding of environmental issues among primary teachers and on another research that examined children's and adults knowledge and models of reasoning about the ozone layer and its depletion (Leighton & Bisanz, 2003). However, the statements used in the present questionnaire were adapted to the Maltese situation

and statements that were thought to be ineffective in eliciting any information regarded useful for this research, such as, " The Greenhouse Effect can be made smaller by eating healthy foods", were eliminated. Statements that in the other studies were targeted for a younger age group were eliminated. Moreover, this questionnaire included statements aimed at revealing Environmental Science students' attitudes towards the environment.

The questionnaire was divided into four sections;

- Part 1 had to draw out individual information about their gender, school and whether they were in possession of an O-level in Chemistry.
- Part 2 constituted of 21 statements that elicit information about the knowledge students have on Ozone Depletion.
- Part 3 constitutes of 35 statements that elicit information on what students know about Global Warming.
- Part 4 elicits information from students about their attitudes towards the environment and tries to investigate the sources from where they are getting the information about these issues.

The number of statements making up part 2 and part 3 of the questionnaire reflects the information that needs to be elicited. 21 statements regarding ozone depletion and 35 statements on global warming were regarded to be enough to understand the perceptions Environmental Science students hold without boring them with repetition that would not lead to the revelation of further information. Students were asked to respond **True**, **False** or **Don't Know** to each statement by ticking the appropriate box.

The principle of triangulation was used within the questionnaire itself as the student was asked questions reflecting his/her attitude towards the environment after having previously answered questions relating to the causes and effect of certain behaviour towards the restoration or depletion of the environment.

Reliability within the questionnaire is accounted for by testing the questionnaire for internal consistency. This refers to the degree to which the items that make up the scale fit together. It checks whether all the statements are measuring the same

underlying construct. Cronbach's alpha coefficient is one of the indicators of internal consistency. Ideally, the Cronbach alpha coefficient of a scale should be 0.7. This reliability test was run with the data of the questionnaire used for this research and the alpha value corresponded to 0.793, so the scale can be considered reliable within the sample.

Previous investigations made use of the Likert scale that ranged from 1 to 5 starting from strongly agree and moving to strongly disagree. Nevertheless, in the analysis performed afterwards, the 'strongly agree' was aggregated to the 'agree' and the 'strongly disagree' was aggregated with the 'disagree' (Boyes and Stanisstreet 1993, Leighton and Bisanz 2003, Francis *et al.*, 1993). For this reason, statements in the present questionnaire had only three options from which students could choose since adding more seemed to be useless. Moreover, the statements presented in the questionnaire were not intended to investigate the opinion of students but rather what they were certain of and what not.

The advantage of a questionnaire is that prevalence can be established with confidence (assuming that the sample is not unduly biased). However, validity is less certain as the researcher cannot be sure that the respondents understood the questions in the way intended, or indeed that they responded seriously. Apart from this, knowledge statements are tested in isolation rather than as elements of an elaborated explanation.

2.4.3 The Pilot Study

The questionnaire was piloted with 32 Environmental Science second year sixth form students attending the Junior College. The students were asked to write comments on the format of the questionnaire and on individual statements were they retained necessary. The pilot study was carried out:

- to check for clarity of the questionnaire items, instructions and layout;
- to gain feedback on the validity of the questionnaire items, the operationalization of the constructs and the purposes of the research;
- to eliminate ambiguities or difficulties in wording;

- to gain feedback on the attractiveness and appearance of the questionnaire;
- to gain feedback on response categories;
- to identify commonly misunderstood questions;
- to check the time taken to complete the questionnaire;
- to check whether questions are too long or too short, too easy or too difficult;
- to gain feedback on the layout , sectionalizing, numbering and itemization of the questionnaire.

As Oppenheim (1992) remarks, everything about the questionnaire should be piloted. All the comments were scrutinised and found to be constructive and therefore the necessary amendments were done. This sample of students participating in the pilot study did not form part of the cohort of students that responded to the final version of the questionnaire.

2.4.4 The Interview

Consequently, the analyses of the questionnaire led to the construction of an interview. It is a qualitative method to find out about another person's feelings, thoughts, or experiences. Open-ended questions were used to catch authenticity, richness and depth of responses, honesty and candour which are the hallmarks of qualitative data.

The interview was conducted with four groups of ten Environmental Science Sixth form students chosen randomly from three schools. This depended on the number of students that were ready to offer their time to participate in the interview. The sample of students from one of the schools was too small to form an appropriate focus group and therefore was not considered for this part of the study. The interviews were concerned with their practices in relation to, and views about global warming and ozone depletion. The interview consisted of a number of open-ended questions to encourage an amplification of students' spontaneous thoughts and answers. The typical interview lasted around 40 minutes. These students had previously formed part of the cohort of students that had answered the questionnaire administered.

Open-ended questions allow respondents to include more information than in a questionnaire, including attitudes and understanding of the subject. This allows the researcher better access to the respondents' true know how on the issues. Due to the simplicity and the number of limited answers of closed-ended questions in the questionnaire that would have been previously administered, the respondents might have felt they had not enough choices that actually reflected their real feelings.

The advantage of an interview is that students can provide in-depth information of high validity (Summers, et al., 2001). Open-ended questions cut down on two types of response error; respondents are not likely to forget the answers they have to choose from if they are given the chance to respond freely, and open-ended questions simply do not allow respondents to disregard reading the questions and just "fill in" the survey with all the same answers (such as filling in the "no" box on every question).

Whereas the questionnaire tends to give importance to the frequency, open-ended responses give the researcher space to handle ideas that belong to just one person. One of the great advantages of the open-ended question is that it can discover uncommon but intelligent opinions of which the researcher would otherwise have remained unaware.

2.5 Ethical Issues

Kimmel (1988) pointed out that when attempting to describe ethical issues, it is important to recognize that the distinction between ethical and unethical behaviour is not dichotomous but it lies on a continuum ranging from the clearly ethical to the clearly unethical. The point to be borne in mind is that ethical principles are not absolute but must be interpreted in the light of the research context and of other values at stake.

The Guidelines for UoM Research Ethics Committee (University of Malta, 2004), BERA ethical guidelines (2006), BSA guidelines for professional conduct (1997) and Kelman (1982) remark that while the whole purpose of research is to learn something about the other, this aim should not be achieved to the detriment of those investigated or some other third party.

Kelman (1982) identifies the following criteria in an attempt to ensure the researcher's obligation to minimize harm and these were followed in the present research;

- Confidentiality and privacy are designed to protect participants against foreseeable and unforeseeable future circumstances as major threat comes from public exposure of information about identifiable individuals. Guarantees of confidentiality and anonymity given to research participants must be honoured.
- Research should be based on the freely given informed consent of those studied. The researcher explains as fully as possible, and in terms meaningful to participants, what the research is about, who is undertaking it, why it is being undertaken, and how it is to be promoted.
- Participants have the opportunity to decide for themselves what is in their best interest and whether they want to make part of the investigation. Participants are made aware that they can choose to reject the use of data-gathering devices such as tape recorders.
- There is a commitment to present all findings in published form and to present the main findings to all those who participated in the research as acknowledged in the terms of agreement prior to informed consent.
- Research shall not intrude in the lives of those studied.

Participants under investigation have to be respected to the utmost and absolutely nothing must be done to damage any part of their aspects or even feel disturbed. It is understood that the subjects being investigated are already complying with the researcher in lending themselves to be observed and therefore it is expected that they be treated with great respect and consideration during the investigation.

2.6 Participants

The sample for the final version of the questionnaire consisted of 280 Environmental Science second year sixth form students coming from all over Malta.

As shown in Table 2.1 the Junior College contributed with the largest number of students since it has the biggest intake of students. 23.9% of the students came from Giovanni Curmi HSS while the smaller groups came from Church Schools.

Table 2.1 Percentage Number of Students in Each School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Junior College	181	64.6	64.6	64.6
	Giovanni Curmi HSS	67	23.9	23.9	88.6
	De La Salle College	8	2.9	2.9	91.4
	St. Aloysius Sixth Form	24	8.6	8.6	100.0
	Total	280	100.0	100.0	
Total		280	100.0		

Respondents have been further categorized when they were asked whether they were in possession of Chemistry at SEC level. This was done to find out whether students in possession of this subject were better-off in concept formation than other students who lacked it. Table 2.2 demonstrates that the majority of the students did not possess this subject as was expected since Environmental science is usually chosen by non-science students.

Table2.2 Students with Chemistrv at SEC Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	260	92.9	92.9	92.9
	Yes	20	7.1	7.1	100.0
	Total	280	100.0	100.0	
Total		280	100.0		

The interviews were conducted with four groups of ten students from the above sample coming from three schools:

- 1 group from the Junior College
- 1 group from St. Aloysius College
- 2 groups from Giovanni Curmi HSS

The number of groups from the different schools reflects the number of students that made themselves available to form part of the focus groups.

2.7 Conclusion

The research questions were the guide used in gathering the information. While the information collected was perceived to be an important aspect of this research, it was never intended to be the ultimate aim. In fact the student was central and his/her rights were always respected as the study may have lost its credit if it had done otherwise. The results were to be made known to those schools that participated in the study and to those who believed that this study could help better understanding of what are the students' perceptions and misconceptions on important environmental issues. Thus, students' already formulated concepts about global warming and ozone depletion and their attitudes towards the environment have been studied and the results obtained shall be analysed to portray the real magnitude of the influence of the former on the latter.

Chapter 3 Perceptions of Maltese Environmental Science Students

3.1 Aims and Hypothesis

This chapter shall present results obtained from the research conducted about Maltese Environmental Science post-secondary students' perceptions of global warming and ozone depletion. The results will:

(a) highlight the main perceptions;

(b) investigate how these perceptions impact on the choices that students do in their daily life;

(c) identify the main sources of information regarding these issues.

3.2 Students' Perceptions about Ozone Depletion

The data collected showed that Environmental Science students still lack scientific knowledge regarding ozone depletion since out of 21 statements about the issue only 10 were answered correctly by the majority.

57.9% of the students were conscious that ozone is not only found in the atmosphere at high altitude (OD1) and 85.4% appreciated that over the past years the amount of ozone in the atmosphere has changed (OD 3). However, 50.7% were unaware that at present the amounts of ozone at ground level are already harming the environment (OD 2) and this was accentuated by the fact that only 43.6% of Environmental Science students realized that there is now more ozone at ground level than before (OD 7). Most of the students (67.1%) appreciated that at high altitude levels, ozone is beneficial to living things (OD 4).

Table 3.1 Distribution of Responses of Maltese Post-Secondary Environmental Science Students to Statements Concerning Ozone Depletion.

	Ozone Depletion [OD]	% True	% False	% Don't Know
	Statement			
1.	Ozone is only found in the atmosphere at high altitude.	34.3	**57.9**	7.9
2.	There is too little ozone at ground level to cause any environmental problems.	32.5	**49.3**	18.2
3.	Over the past years the amount of ozone in the atmosphere at high altitude has remained the same.	5.4	**85.4**	9.3
4.	The ozone in the upper atmosphere is beneficial for living things.	**67.1**	13.2	19.6
5.	Holes in the ozone layer let too much heat from the Sun get through to Earth.	**83.9**	11.8	4.3
6.	Pollution from burning fossil fuels is destroying the ozone layer.	**90.7**	7.5	1.8
7.	There is now more ozone at ground level than before.	**43.6**	18.9	37.5
8.	Pollution has reduced the amount of ozone at ground level.	16.1	**58.6**	25.4
9.	Ozone at ground level is toxic to living things.	**62.5**	17.1	20.4
10.	The Sun has nothing to do with the ozone formation in the atmosphere.	25.7	**45.0**	29.3
11.	Before human intervention, the amount of upper atmosphere ozone naturally changed a lot all over the world.	28.9	**38.9**	32.1
12.	Car engines emit lots of ozone into the air.	31.8	**60.0**	8.2
13.	The thinning out of ozone can slowly be 'repaired' by natural processes.	**59.3**	23.9	16.8
14.	Industrial processes in factories emit lots of ozone directly into the air.	**43.9**	41.8	14.3
15.	The Sun acting on air pollution makes ozone at ground level.	27.9	27.9	**44.3**
16.	Ozone is a pollutant which thins the atmosphere to let more ultra-violet light through.	41.1	**47.5**	11.4
17.	Increased amounts of ultra-violet light entering through the thinner parts of the ozone layer adversely affect human health.	**92.1**	2.9	5.0
18.	Holes in the ozone layer will never be repaired naturally.	32.1	**51.8**	16.1
19.	The thinning out of the ozone layer is contributing to global warming.	**83.9**	10.7	5.4
20.	Ozone depletion is a major cause of skin cancer.	**83.2**	8.6	8.2
21.	Ozone produced at ground level will help replace ozone high up in the atmosphere.	10.7	**48.6**	40.7

Bold figures show the highest frequency.
Shaded box denotes the correct answer to the statement

Consequently, the vast majority (OD 17, 92.1%) understands that the amounts of ultra-violet light entering through the thinner parts of the ozone layer adversely affect human health and that the depletion of this gas is a major cause of skin cancer (OD 20, 83.2%).

59.3% of Environmental Science students realized that the thinning out of the ozone layer can slowly be repaired by natural processes (OD 13). However, 51.4% of the students were unaware that ozone produced at ground level will not help replace ozone high up in the atmosphere (OD 21). There seemed to be great misunderstanding between the beneficial ozone layer and ozone at ground level. 52.5% of Environmental Science students thought of ozone as a pollutant which thins the atmosphere to let more ultraviolet light through (OD 16). While students were divided about whether the sun has to act on air pollution to produce ozone at ground level (OD 15), another statement revealed that 55% think that the sun has nothing to do with the ozone formation in the atmosphere (OD 10).

Students also appreciated that pollution does not decrease the amount of ozone at ground level (OD 8, 58.6%) and that car engines do not directly emit ozone into the air (OD 12, 60%). They did not think the same for factory emissions where only 41.8% are convinced that emissions from industries do not include ozone (OD 14).

Summers *et al.*, (2001) reported a large number (88%) of practicing teachers who had the wrong impression that pollution from fossil fuels is destroying the ozone layer. The data from the present study also revealed that 90.7% of the Environmental Science students believed that pollution from the burning of fossil fuels is destroying the ozone layer (OD 6), and 88.2% thought that the holes in the ozone layer let too much heat from the sun get through to the Earth (OD 5). Hence, only 11.8% understood that the thinning out of ozone layer is not directly connected to global warming.

Figure 3.1 Perception by Gender

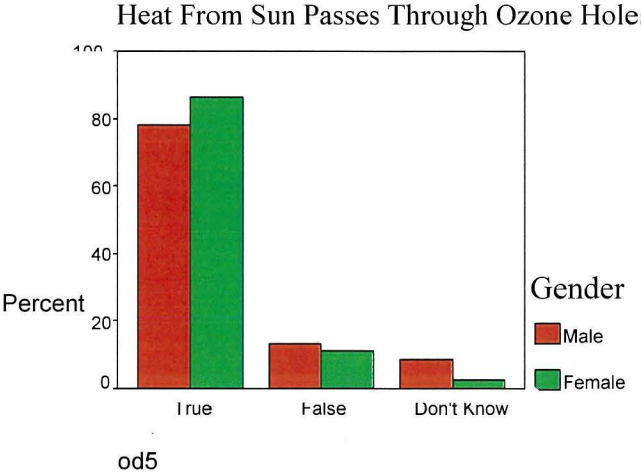


Figure 3.1 illustrates the difference between male and female Environmental Science students in assuming that holes in the ozone layer let too much heat from the Sun get through to Earth. As Table 3.2 shows, this perception persisted more in females while more males have showed

greater uncertainty (i.e. have answered "don't know") about the subject. However, this assumption was not significant (p=0.67).

Table 3.2 Perception OD5 by Gender

			Gender		
			Male	Female	Total
od5	True	Count	65	170	235
		% within gender	78.3%	86.3%	83.9%
	False	Count	11	22	33
		% within gender	13.3%	11.2%	11.8%
	Don't Know	Count	7	5	12
		% within gender	8.4%	2.5%	4.3%
Total		Count	83	197	280
		% within gender	100.0%	100.0%	100.0%

62.5% of Environmental Science students understood that ozone at ground level is toxic to living things (OD 9). However, only 45% knew that the Sun is participant in the formation of ozone in the atmosphere (OD10). 51.8% of the students realised that holes in the ozone can be repaired naturally (OD18). Students knew that ozone is present at ground level and also as the ozone layer high in the atmosphere, however, they had difficulties in understanding how both are formed and whether they are related.

Another strong perception among students was that the thinning out of the ozone layer is contributing to global warming (OD 19). 83.9% of the sample believed this was true. Figure 3.2 demonstrates that such a perception was equally persistent in both genders. However, results show no significant differences (p=0.874).

Figure 3.2 Perception by Gender:

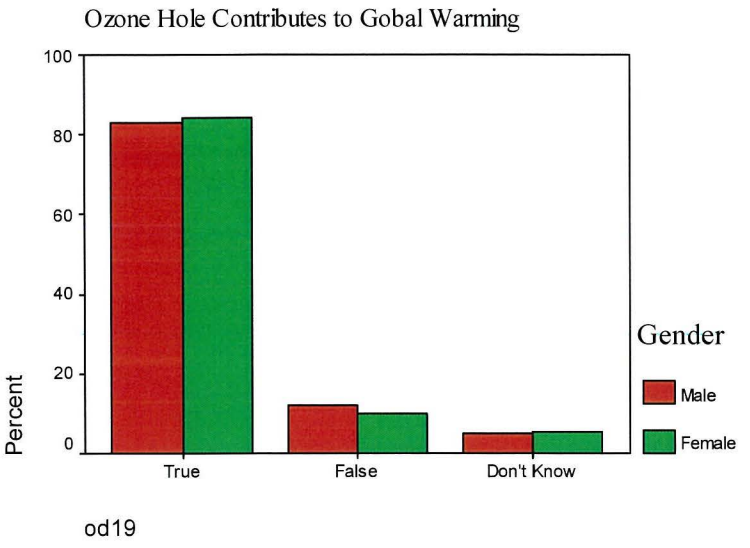
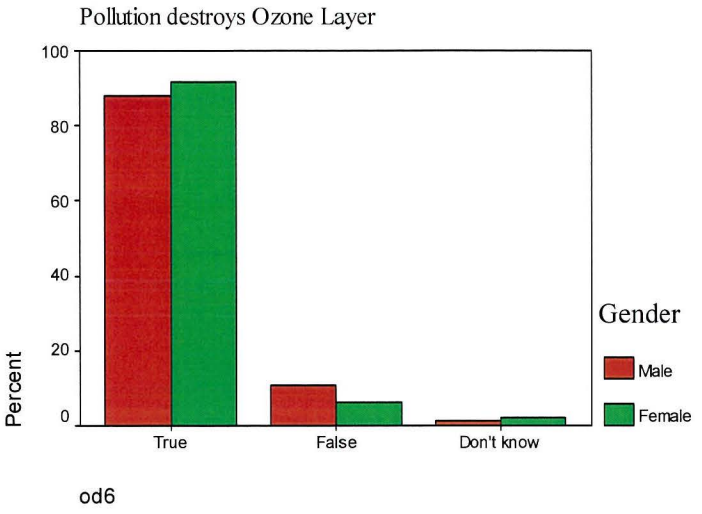


Table 3.3 Perception OD16 by Gender

			Gender		
			Male	Female	Total
od16	True	Count	17	98	115
		% within Gender	20.5%	49.7%	41.1%
	False	Count	56	77	133
		% within Gender	67.5%	39.1%	47.5%
	Don't Know	Count	10	22	32
		% within Gender	12.0%	11.2%	11.4%
Total		Count	83	197	280
		% within Gender	100.0%	100.0%	100.0%

As table 3.3 shows, 49.7% of the females were sure that ozone is a pollutant that thins the atmosphere and consequently allows more ultraviolet light to pass through while 67.5 % of the males did not think this is possible. This showed that a higher proportion of males than females held the correct perception. The result is significant (p=0.000).

Figure 3.3 Perception by Gender



More than half of Environmental Science students (OD 21, 51.4%) didn't know that ozone at ground level cannot replace ozone high up in the atmosphere.

Figure 3.3 shows another perception that students held regarding how pollution from burning fossil fuels is destroying the ozone layer (OD 6). However, the fact that more females than males hold this perception is not significant (p=0.353).

The first part of the questionnaire revealed that overall Environmental Science students seemed to be confused between ozone as the protective layer that is beneficial to all living things and ozone as the pollutant found at ground level. There was also a predominance of non-scientific ideas about the agents that cause 'holes' and the relationship of ozone depletion with global warming.

3.3 Students' Perceptions about Global Warming

3.3.1 Understanding Global Warming

From the second section of the questionnaire, it was clear that the majority of the students appreciated the fact that during the past 100 years the Earth has become warmer (GW 22) and this was confirmed by the focus groups interviews. Similarly, the majority of the students (93.9%) understood that global warming will be the cause of climate change (GW 23) and changes in the world's weather patterns (92.1%, GW 43).

Table 3.4 Distribution of Responses of Maltese Post-Secondary Environmental Science Students to Statements Concerning Global Warming.

Global Warming [GW]	% True	% False	% Don't Know
Statement	6.8	**87.1**	5.7
22. Overall, the Earth has not become warmer during the past 100 years.			
23. Any warming of the earth that occurs in future won't have much effect on the climate.	2.5	**93.9**	3.6
24. Pollution traps heat entering through holes in the ozone layer to cause global warming.	**60**	23.6	16.4
25. Certain gases in the atmosphere act on the planet like the glass in the greenhouse.	**82.9**	5.7	11.4
26. CO_2 level in the atmosphere is an important factor in global warming over which humans have control.	**66.1**	19.3	14.6
27. Gases produced by humans make the Earth warm enough to support life.	13.2	**60.7**	26.1
28. The Earth is warm enough to support life because of a natural greenhouse effect.	**73.6**	13.2	13.2
29. All the energy the Earth gets from the Sun is retained by the planet and its atmosphere.	31.1	**51.4**	17.5
30. Gases produced by humans cause more of the Sun's energy to be trapped in this atmosphere.	**71.4**	11.4	17.1
31. Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'.	52.9	34.3	12.9
32. Before Human intervention, the Earth radiated enough of the Sun's energy back into space to remain at the same temperature, on average.	**63.9**	15.0	21.1
33. Burning fossil fuels has increased the amount of CO_2 in the atmosphere.	**90.7**	5.4	3.9
34. Cutting down forests has no effect on the amount of CO_2 present in the Earth's atmosphere.	8.2	**87.9**	3.9
35. By planting new forests, the amount of CO_2 in the atmosphere will be reduced.	**80.0**	13.6	6.4
36. Global warming is caused by a layer of high altitude CO_2.	**41.4**	26.4	32.1
37. Natural global warming may be increased by the CO_2 produced by humans.	**70.0**	15.0	15.0
38. It is certain that present global warming is caused by human activities.	**71.8**	18.6	9.6
39. Global warming may be due to a natural cycle of warming and cooling of the Earth.	**37.9**	36.8	25.4
40. Since global warming may be a natural effect there is no need to take precautions against it.	7.5	**84.3**	8.2
41. If global warming gets worse there will be more flooding.	**78.9**	10.4	10.7
42. If global warming gets worse more people will die of skin cancer.	**74.6**	16.1	9.3
43. If global warming gets worse there will be changes in the world's weather patterns.	**92.1**	5.0	2.9
44. If global warming gets worse there will be more deserts in the world.	**49.6**	25.0	25.4
45. If global warming gets worse some of the ice at the North and South Poles will melt.	**91.8**	4.3	3.9
46. Global warming is made worse because too many of the sun's rays get to the Earth.	**70.0**	21.1	8.9
47. The greenhouse effect is made worse by too much CO_2 in the air.	**80.7**	7.5	11.8

48.	The greenhouse effect is made worse by too much ozone near the ground.	26.4	35.4	**38.2**
49.	The greenhouse effect is made worse by gas from rotten waste.	**55.7**	16.4	27.9
50.	Global Warming is made worse by acid in the rain.	35.0	**42.5**	22.5
51.	Global Warming is made worse by holes in the ozone.	**79.3**	13.9	6.8
52.	The greenhouse effect is decreased if renewable energy sources are used instead of power stations running on fossil fuels.	**82.5**	6.1	11.4
53.	Global Warming can be decreased if unleaded petrol is used.	**81.1**	9.3	9.0
54.	Global Warming can be decreased if more trees are planted.	**82.5**	8.2	9.3
55.	Global Warming can be decreased if recycled paper is used.	**70.7**	15.4	13.9
56.	Global Warming can be decreased if electricity is not wasted.	**81.4**	8.6	10.0

Bold figures show the highest frequency.
Shaded box denotes the correct answer to the statement.

Thus, 91.8% understood that if global warming gets worse some of the ice at the North and South Poles will melt (GW 45) and 78.9% thought that there will be more flooding (GW 41). This created an amount of uncertainty among students as regards an increase in desertification as only 49.6% believed this is possible (GW 44). In addition, the majority of Environmental Science students (82.9%) were aware that there are certain gases in the atmosphere that act on the planet like glass in a greenhouse (GW 25).

Students (66.1%) were aware that Carbon Dioxide is one of the gases that cause global warming and that humans have control over it (GW 26). Moreover, the number of students that were uncertain about the agents that enhance the greenhouse effect has increased.

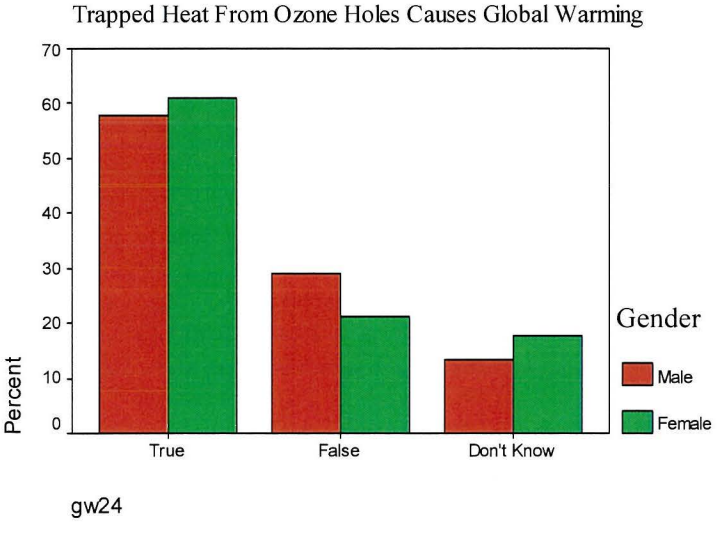
A greater number of the students (90.7%) knew that Carbon Dioxide results from the burning of fossil fuels (GW 33) and that the cutting down of forests does effect the amount of this gas present in the Earth's atmosphere or that planting new forests would reduce the amount of this gas (GW 34, 35).

70% of the students were aware that natural global warming can be altered by the Carbon Dioxide produced by humans (GW 37). Students (71.8%) were certain that global warming is caused by human activities (GW 38). They (84.3%) also knew that even though global warming is a natural effect, precautions have to be taken against increasing it (GW 40).

Furthermore, few (37.9%) knew that global warming is a natural cycle through which the Earth passes (GW 39). Nevertheless, to think that this is the only cause of global warming is an error according to the IPCC Fourth Assessment Report (2007) since human intervention was certainly recognized as the main reason behind it. Students considered humans as the culprits for producing gases that cause Sun's energy to be trapped in this atmosphere (71.4%, GW 30). They also considered this fact as unnecessary to keep the Earth warm enough so as to support life (60.7%, GW 27). Students (73.6%) understood that life on Earth is supported by a natural greenhouse effect (GW 28). Though Environmental Science students knew that human intervention has enhanced the natural greenhouse effect and that this was caused by the gases produced when burning fossil fuels, mainly Carbon Dioxide, a high percentage is uncertain about the amount of Sun's energy that is retained. Only 51.4% of Environmental Science students understood that not all the energy the Earth gets from the sun is actually retained (GW 29).

3.3.2 Causes of Global Warming

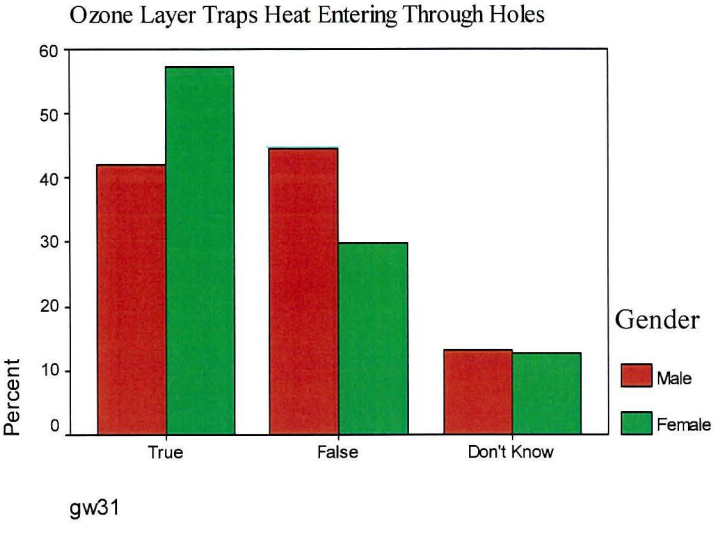
Figure 3.4 Perception by Gender



The fact that students (70%) believed that global warming is caused by too many sun's rays reaching the Earth (GW 46) is slightly related to OD 5 [Pearson Correlation $r=0.142$, $p<0.05$]. This relationship was also noticed in the study conducted by Groves and Pugh (1996) and also by Boyes, Chuckran & Stanistreet (1993) who suggested that students believed that too many sun's rays are reaching the Earth because of holes in the ozone layer. The reasoning behind this concept is that pollution traps heat entering through holes in the ozone layer to cause global warming (60%, GW 24).

52.9% believed and 12.9% were uncertain that global warming is caused by the ozone layer trapping extra heat entering through is holes (GW 31). 29.9% of the females and 46.6% of the males gave correct answers showing that a higher proportion of males held a correct grasp of the concept (p=0.045).

Figure 3.5 Perception by Gender



This reasoning was also confirmed by 79.3% of the students implying that global warming is made worse by holes in the ozone layer (GW 51). There is a slight correlation between the two statements [Pearson Correlation r=0.217, p=0.000].

Moreover, the present research showed that Environmental Science students (80.7%) considered solar input as just one of the causes of global warming; other causes being heat entrapment due to the gases (mainly Carbon Dioxide) released by the burning of fossil fuels (GW 47).

There is a connection between the idea that skin cancer will increase if global warming gets worse and that global warming will get worse due to many sun's rays reaching the Earth (also found in Boyes, Chuckran & Stanistreet, 1993) . Students were aware that ozone depletion contributes to increases in skin cancer (OD 20) and since most confused ozone depletion with global warming, they probably developed a general belief that ozone depletion, global warming and skin cancer are related (GW42). There was a small correlation between the two variables [Pearson Correlation r=0.120, p=0.046].

Confusion about causes of global warming was also evident by a high percentage of incorrect responses to statements regarding the gas produced by rotten waste (GW 49, 46.3%), acid rain (GW50, 57.5%) and holes in the ozone layer (GW51, 86.1%).

Results showed that students considered anything that is environmentally wrong as the cause of any environmental problem. Students tended to relate the causes together and the problems together as well.

3.3.3 Ways to Reduce Global Warming

Similarly to the findings of Groves and Pugh (1996), students scored better here than for the rest of the questionnaire. 82.5% of Environmental Science students knew that the use of renewable sources of energy instead of fossil fuels (GW 52), planting more trees (GW 54), the use of recycled paper (GW 55, 70.7%) and not wasting electricity (GW 56, 81.4%) would lead to a decrease in global warming.

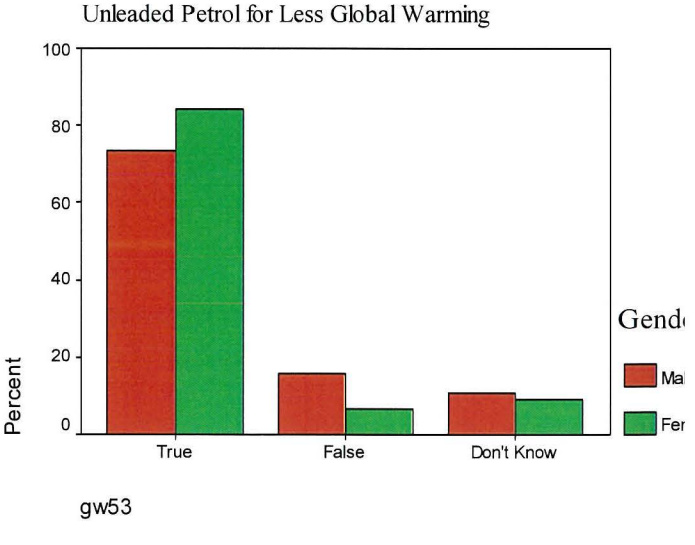
It could be another example of "whatever is good for the environment is good against global warming".

3.3.4 Perceptions Held by Students about Global Warming

Students also revealed a significant misunderstanding being that the use of unleaded petrol would decrease global warming (GW 53, 81.1%). Figure 3.6 shows that only 6.6% of the females and 15.7% of the males knew that the statement was not correctly explaining how global warming can be reduced. This proportion is significant (p=0.046).

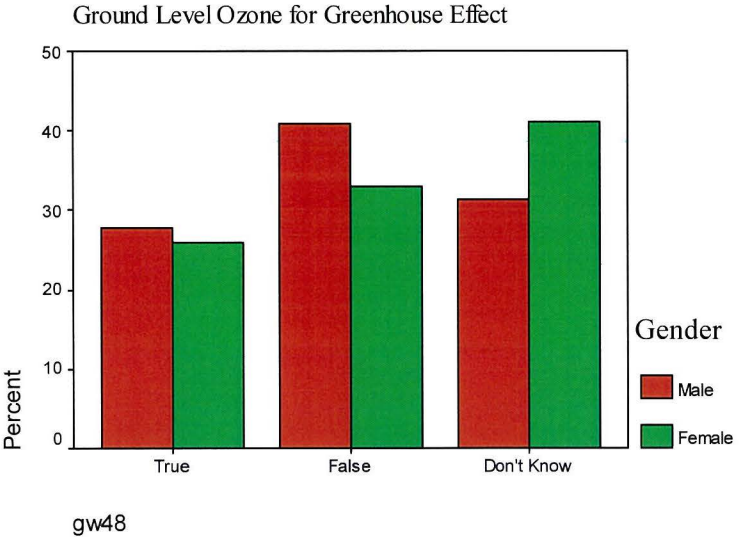
As in the studies conducted by Boyes and Stanistereet (1993) and Groves and Pugh (1996), the results of this research were not encouraging. These results implied that a number of alternative conceptions, were being formulated.

Figure 3.6 Perception by Gender



Another perception held by these students was that global warming is caused by a layer of high altitude Carbon Dioxide (GW 36, 73.5%) while 64.6% thought or were unsure whether the greenhouse effect is made worse by too much ozone near the ground (GW 48). Figure 3.7 depicts how the majority of those that were not certain about how ozone at ground level affects the greenhouse effect were females. However, the results were not significant (p=0.274).

Figure 3.7 Perception by Gender



3.4 Is Chemistry at SEC Level a Help?

Environmental Science students were asked whether they were in possession of the MATSEC O-level equivalent for Chemistry. This was done since the section from the Environmental Science syllabus (Appendix Three) regarding ozone depletion and global warming includes a number of chemical issues. It was hypothesized that students with a background in Chemistry would understand better both issues and formulate correct concepts.

The percentage number of students in possession (7.9%) of Chemistry at SEC level was much lower than those who were not in possession (92.9%) of this qualification. Correlation between being in possession of this qualification and the statements was worked out together with their statistical significance.

Table 3.5 Correlation and Statistical Significance between Chemistry at Sec Level and the Responses for the Statements about Global Warming and Ozone Depletion

Statement	Correlation (r)	Significance (p)
OD 5	0.165**	0.006
OD 8	0.156**	0.009
OD 14	0.196**	0.001
GW26	0.156**	0.009
GW52	0.152*	0.011
GW55	0.198**	0.001

***Correlation is significant at 0.05 level (2-tailed)**

****Correlation is significant at 0.01 level (2-tailed)**

Being in possession of Chemistry at SEC level did not seem to affect much the responses of Environmental Science students apart from the responses for the statements listed in Table 3.5. The six statements showed a small positive correlation with the possession of a qualification in Chemistry and the results obtained were significant. The issues tackled in the statements listed in Table 3.5 are matters that form part of the Chemistry at SEC level syllabus.

From the data collected, it can be concluded that a background in Chemistry did not really put Environmental Science students at an advantage over the others in constructing the correct concepts.

3.5 Sources of Information

Table 3.6 presents the main sources of information about environmental issues. The students' primary sources are Environmental Science lessons (94.6%). Television (62.9%) is a secondary source while the internet (41.1%) and newspapers (33.2%) follow. Only 9.3% of the students felt that they were learning about environmental issues from their home and therefore from the people that can transmit persisting values and a pro-environmental mentality.

Table 3.6 Sources of Information by Percentage Number of Students

Source of Information	Percentage Number of Students
Environmental Science lessons	94.6
Television	62.9
Internet	41.1
Newspapers	33.2
Magazines	12.1
Home	9.3
Others	7.9

3.6 Students' Attitudes and Behaviour

The final part of the questionnaire was constructed with the aim of investigating students' attitudes and behaviours towards the environment and find out whether what they are being exposed to is producing the desired results. The tables below indicate the kind of responses that were given by the Environmental Science students.

Table 3.7 Reasons for Walking by Percentage Number of Students

I'd rather walk than use cars:	Percentage number of students
to save money	16.8
for good health	**58.8**
for cleaner air	25.0

Bold figures indicate largest percentage.

Table 3.8 Reasons for Switching off TV by Percentage Number of Students

I switch off the TV when I not watching it:	Percentage number of students
to save money	37.5
for cleaner air	18.6
to concentrate more on my work	**43.9**

Bold figures indicate largest percentage.

Table 3.9 Attitude Towards Packaging by Percentage Number of Students

When I buy things:	Percentage number of students
I choose things with least packaging	25.0
I choose things with nicest packaging	12.1
I don't bother	**62.9**

Bold figures indicate largest percentage.

Table 3.10 Reasons for Recycling by Percentage Number of Students

I'd rather buy recycled products:	Percentage number of students
as they cost less	14.6
less energy was used to produce them	**47.9**
I don't buy these products	37.5

Bold figures indicate largest percentage.

Table 3.11 Reasons for Buying Energy-Saving Appliances by Percentage Number of Students

I'd rather buy energy saving appliances:	Percentage number of students
to burn less fossil fuels	39.6
as these last longer	14.3
as they are more efficient	**46.1**

Bold figures indicate largest percentage.

The responses exposed the students' passive attitude towards the environment. 62.9% did not bother about the kind of packaging of objects. Only 18.6% switch off the television when not in use. Furthermore, the majority of the students did not consider buying recycled products. Walking is considered to be an exercise done to improve their health. Only 25% felt that by so doing they harm the environment less. Only 39.6% opt for energy-saving appliances to reduce in the burning of fossil fuels. Students tended to put themselves and their immediate needs in the first place. The environment was not given adequate importance.

3.7 Varimax Rotated Factor Analysis

The 56 statements of the questionnaire on ozone depletion and global warming were subjected to Principal Components Analysis (PCA) using SPSS. Prior to performing PCA the suitability of data factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of 0.3 and above. The Kaiser-Meyer-Oklin value was .672, exceeding the recommended value of .6 (Kaiser, 1970, 1974) and the Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance, supporting the factorability of the correlation matrix.

Principal components analysis revealed the presence of 21 components with eigenvalues exceeding 1 (Appendix Four), explaining a total of 64.145% of the variance. An inspection of the screeplot revealed a break after the seventh component. Using Catell's (1966) scree test (Appendix Four), it was decided to

retain seven components for further investigation. To aid in interpretation of these seven components, Varimax rotation was performed. The rotated solution presented in Table 3.12 revealed the presence of simple structure (Thurstone, 1947) with the seven components showing a number of strong loadings, and all variables loading substantially on only one component. The seven factor solution explained a total of 32.9% of the variance with Component 1 contributing 6.82% and Component 2 contributing 5.5%.

The statements associated with high loadings (0.35 and higher) were examined in an attempt to identify the common conceptual themes for each factor (Childs 1979). The interpretation of the seven components was consistent with previous research on Ozone Depletion and Global Warming as in Boyes and Stanistreet (1993).

Rotated Component Matrix [a]

	Component						
	1	2	3	4	5	6	7
gw45	.531	.307					
od21	.518						
gw25	.508						
gw51	.505						
gw42	.504			.383			
gw35	.457	.441					
gw31	.440			.326	.355		
gw32	.431						
gw41	.430						
gw46	.426			.314			
gw30	.379						
gw24	.342						
gw55		.693					
gw56		.580					
gw53	.445	.504					
gw53		.440					
gw47		.435					
gw43	.401	.432					
gw33	.392	.407				.327	
od17		.368					
gw49		.334					
od7			.661				
od21			.586				
gw48			.520				
od9			.451				
od15			.416				
gw36			.336				
od4							
gw44							
od14				.619			
od12				.430			
od16				.425		.342	
gw38				.374			
od6				.349			
od5				.341			
gw40					.536		
gw37					.475		
gw23					.474		
od3					.472		
gw26					.384		
gw22					.356		.3
OD1			-.313		.337		
od19							
gw29				.310		.497	
gw39						.448	
gw52		.345				.445	
gw28	.351					.440	
OD2							
gw27							
od11							.5
gw34							.5
gw50				.321			.3
od10							.3
od13							.3
od18							
od8							

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 15 iterations.

Table 3.12 Varimax Rotated Factor Matrix for the responses to statements concerning Ozone Depletion and Global Warming

Table 3.13 Total Variance Explained

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	3.819	6.820	6.820
2	3.083	5.504	12.324
3	2.619	4.678	17.002
4	2.524	4.507	21.509
5	2.368	4.228	25.737
6	2.092	3.735	29.472
7	1.952	3.486	32.958

Extraction Method: Principal Component Analysis.

Table 3.14 Factor Names and Pertaining Statements

Factor	Name	Statements
1	Causes and Consequences of Global Warming	GW25: Certain gases in the atmosphere act on the planet like the glass in the greenhouse. GW30: Gases produced by humans cause more of the Sun's energy to be trapped in this atmosphere. GW31: Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'. GW32: Before Human intervention, the Earth radiated enough of the Sun's energy back into space to remain at the same temperature, on average. GW35: Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'. GW41: If global warming gets worse there will be more flooding. GW42: If global warming gets worse more people will die of skin cancer. GW45: If global warming gets worse some of the ice at the North and South Poles will melt. GW46: Global warming is made worse because too many of the sun's rays get to the Earth. GW51: Global Warming is made worse by holes in the ozone.

2	Personal Responsibility	OD17: Increased amounts of ultra-violet light entering through the thinner parts of the ozone layer adversely affect human health. GW33: Burning fossil fuels has increased the amount of CO_2 in the atmosphere. GW43: If global warming gets worse there will be changes in the world's weather patterns. GW47: The greenhouse effect is made worse by too much CO_2 in the air. GW53: Global Warming can be decreased if unleaded petrol is used GW54: Global Warming can be decreased if more trees are planted. GW55: Global Warming can be decreased if recycled paper is used. GW56: Global Warming can be decreased if electricity is not wasted.
3	Ground Level Ozone	OD7: There is now more ozone at ground level than before. OD9: Ozone at ground level is toxic to living things. OD15: The Sun acting on air pollution makes ozone at ground level. OD21: Ozone produced at ground level will help replace ozone high up in the atmosphere. GW48: The greenhouse effect is made worse by too much ozone near the ground.
4	Pollution	OD6: Pollution from burning fossil fuels is destroying the ozone layer. OD12: Car engines emit lots of ozone into the air. OD14: Industrial processes in factories emit lots of ozone directly into the air. OD16: Ozone is a pollutant which thins the atmosphere to let more ultra-violet light through. GW38: It is certain that present global warming is caused by human activities.
5	Skepticism	OD3: Over the past years the amount of ozone in the atmosphere at high altitude has remained the same. GW22: Overall, the Earth has not become warmer during the past 100 years. GW23: Any warming of the earth that occurs in future won't have much effect on the climate. GW26: CO_2 level in the atmosphere is an important

		factor in global warming over which humans have control. GW37: Natural global warming may be increased by the CO_2 produced by humans. GW40: Since global warming may be a natural effect there is no need to take precautions against it.
6	The Greenhouse Effect	GW28: The Earth is warm enough to support life because of a natural greenhouse effect. GW29: All the energy the Earth gets from the Sun is retained by the planet and its atmosphere. GW39: Global warming may be due to a natural cycle of warming and cooling of the Earth. GW52: The greenhouse effect is decreased if renewable energy sources are used instead of power stations running on fossil fuels.
7	Excluding Human Intervention	OD11: Before human intervention, the amount of upper atmosphere ozone naturally changed a lot all over the world. GW34: Cutting down forests has no effect on the amount of CO_2 present in the Earth's atmosphere.

3.7.1 Factor 1: Causes and Consequences of Global Warming

The statements indicate the causes and consequences of global warming. They produce a scientific explanation to this phenomenon and reveal the global outcome if global warming gets worse.

3.7.2 Factor 2: Personal Responsibility

This factor groups statements that point out how changes in the present atmospheric composition due to human practices contribute to the increase or decrease of global warming. Such practices may have a repercussion on human health and on weather patterns. Therefore these statements seem to highlight the personal responsibility towards the environment.

3.7.3 Factor 3: Ground Level Ozone

The highest loading values on this factor underlie general knowledge about ozone at ground level. This factor creates a distinction between stratospheric ozone and the ozone gas produced at ground level and which is toxic to living organisms.

3.7.4 Factor 4: Pollution

The statements pertaining to this factor are concerned with the pollution mainly ozone, produced by human activity and that are giving rise to multiple problems such as global warming and ozone depletion.

3.7.5 Factor 5: Skepticism

Statements pertaining to factor 5 are those that make students contemplate as to whether issues like ozone depletion and global warming are in fact natural phenomena that usually occur in the world's cycle or else are caused by other matters like human intervention. Therefore it seemed appropriate that this factor be called skepticism.

3.7.6 Factor 6: The Greenhouse Effect

These statements deal with the knowledge about the greenhouse effect. These statements infer an idea of a natural greenhouse effect needed to make life possible on Earth. The statements impart the idea of energy loss and gain from the Earth's part and that there is an interaction with the energy radiated from the Sun.

3.7.7 Factor 7: Excluding Human Intervention

The statements belonging to this factor exclude that human intervention may have an effect on ozone depletion or global warming. The grouped statements imply that both issues are natural changes that have always occurred and human interference is not worsening the situation.

3.8 The Interviews

3.8.1 The Causes and Consequences

From the first part of the interview, it is clear that the students tend to believe that the most dangerous and harmful actions are the ones carried out on a large scale by industries.

> *"it's factories and industries that emit the most harmful gases."* SG 1.1
> **(SG 1.1 is Student Group 1, Student 1)**

> *"industries emit a lot of Carbon Dioxide during the production of the things on which their economy is based."* SG 2.1

> *"the government...like in America is not really interested in imposing a reduction in the emissions as this might entail a reduction in the production and therefore the economy would experience a downfall."* SG 2.2

Students consider that actions carried out by themselves as individuals do affect the environment but have a minimum effect when compared to what can be done by industries.

> *"Large developed countries like America do not want to sign a commitment that would reduce emissions; this is not a single person as a single person is not going to make a difference. One can make a contribution but these large countries have to begin to do what is right."* SG 3.1

In addition, analogous to Gomez-Granell and Cervera-March's (1993) findings, most of the harmful actions mentioned were those mostly publicized by the media such as,

> *"deforestation, burning of fossil fuels by industries, car emissions, use of sprays."* SG 2.3

Apart from this, these practices are vastly highlighted during Environmental Science lessons when the sections about Air Pollution and Sustainability are tackled.

The respondents were well aware of the practices that cause global warming and ozone depletion and they were similarly conscious of what could be done to reduce this crisis. However, it is interesting to note that almost all the students, considered global warming and ozone depletion as being linked. They implied that "it was obvious" because,

a) they were both environmental problems related to the climate and
b) the holes in the ozone layer allowed more heat from the sun to enter and this enhances global warming.

> *"I think one leads to the other because global warming leads to ozone depletion."* SG 4.1

> *"I think holes are forming in the ozone layer due to gases and other things. Now, since the ozone hole is becoming bigger more rays from the sun are getting in."* SG 3.2
>
> *"Global warming is leading to ozone depletion."* SG 1.2

However, one student did not think there is a link between the two issues and tried to explain why. However many confusing ideas emerged.

> *"I think they're a bit different because even though they're caused by the same things, ozone depletion will lead to more of the incoming u.v. light and infra red being absorbed in our atmosphere. We will get the harmful u.v. from the ozone depletion and the greenhouse effect is from increase absorption of infra red light, no?... So, we'll get more light when our ozone is depleted. The two things are happening because of the increase of certain amount of chemicals in the atmosphere and both are equally bad. I'm not sure if one directly leads to another, or if both are the consequences of what we are doing."* SG 3.2

The student started with one idea but finished with another. While talking she seemed to have realised that what she thought she had clear ideas about, were not so clear after all. Trying to explain the issues by herself without any help exposed the true framework she had built from the information acquired.

The majority of the students interviewed believe that anything that damages the environment is harmful for global warming and ozone depletion alike. Some students specifically mentioned CFCs as being the cause of ozone depletion, but then all the other gases and all kinds of pollution resulting from the burning of fossil fuels were thought to be responsible both for global warming and ozone depletion.

The majority of students retained that any practice that reduces global warming is able to reduce ozone depletion. While they were expressing themselves on this issue a certain feeling of uncertainty was felt.

3.8.2 Personal Responsibility

Becoming aware of what is occurring globally places responsibility on the individual to perform actions and take decisions that reflect this knowledge. The students interviewed confirmed that the main source of all their information were the

Environmental Science lessons. They also mentioned the news and newspapers which are readily available everyday.

The questionnaire revealed that students know that there are ways of reducing global warming and ozone depletion. So the interviews were utilized to understand what were the prevailing approaches and whether any of these were being performed. The practices mentioned were:

a) The use of Catalytic converters
b) Separation of waste and the use of bring-in sites
c) Reduction in the use of fossil fuels
d) The use of alternative energy resources
e) Sustainable forest use
f) Recycling
g) Reduction in the use of aerosol sprays

The students interviewed admitted that they do carry out some of these practices like:

> *"There is no need to use the car every morning, you can get a lift from someone going the same way."* SG 1.3
>
> *"We should have better waste management, organizing waste and more light economy. You will get lower electricity bills in this way too."* SG 1.3
>
> *"Yes the park and ride system is very helpful to reduce the amount of cars and maybe congestion."* SG 3.3
>
> *"Separation of waste and disposal of appliances containing toxic waste in the correct way."* SG 3.4

All the groups commented about switching off the lights and not wasting electricity. Another student from another group mentioned the economic enforcement the government imposed as part of the electricity bill and other students in this group agreed and suggested measures to reduce global warming and ozone depletion such as producing less carbon emissions, and separating waste.

The majority of the students declared that most of the practices they perform are a consequence of their present situation. This means that they use public transport because they do not have a car licence but as soon as they become of age, they affirmed that they will do anything to get their own car as it gives them a higher status.

> *"A car is freedom. You want to drive. I would want to drive my own car."* SG 2.4

> *"Right now we do it (car sharing), ok its not us its our parents, and right now we catch buses as well but I suppose we'll drive our own car when we get to buy a car."* SG 2.5

> *"But again... We do it (car sharing) not because we're environmentally aware but because of expenses and efficiency, that's it!"* SG 4.2

> *"It could be we're doing things for the wrong reasons but it is still good for the environment."* SG 3.5

As regards recycling and the use of bring in sites, students stated that their parents have to do that. Yet, a small number of students implied that they were very skeptical about what happens to the waste after being collected from the bring in sites and therefore since they were not sure that it really was a contribution towards a better environment, they simply admitted that they do not do it.

> *"The recycling thing...I've never seen them being actually separated so I say what's the point of separating waste that is going to end up as one whole thing."* SG 3.6

3.8.3 A Passive Attitude

If Environmental Science students know that the problems exist why is it so difficult for them to do something concretely for the environment? Students were asked this question and they answered that:

a) environmental practices are not enforced enough

> *"Practices are publicized but not enforced."* SG 2.6

b) people are not encouraged to perform environmentally aware actions

"No incentives are given to those citizens who perform environmentally friendly actions." SG 2.7

c) they do not really believe that all the calamities explained during the lessons will truly happen, or at least not imminently

"They don't even know what's going to happen, the effect of it and when it is going to strike badly, I don't think they are aware of it." SG 2.8

"I think we're too young to realize what is happening. We're worrying about our exams not about the environment." SG 1.5

d) an egoistic and egocentric nature creates a hurdle which is not easily overcome

"I'ts egoism, I think because for example I don't switch off the lights as I say, well I don't feel like, and so I leave it like that." SG 1.6

e) individual practices do not really make a difference when compared to what could be done by the United States, China, India.

"and then its not fair... Large countries like the US and India and China they contribute to the largest amounts of pollution and there is no intention of stopping. If they do not stop or reduce drastically then our individual contribution will be less than nil." SG 4.3

f) Not everyone understands what the issue of climate change is due to lack of education

"I cannot understand how those housewives are expected to do something when they surely do not understand anything about these issues. I really do not think that they even know that there are environmental problems called global warming and ozone depletion." SG 3.2

g) Theories learnt during lessons cannot be put into practice

"The problem is the bridge between the theory and the practice because we're learning theory and we're treating it like another subject. We have it at school and we leave it there whereas we have to treat it in a practical way." SG 2.3

The students themselves suggested ways that could be used to overcome this passivity.

a) To disseminate clearer information that could be understood by people coming from all walks of life using the media.

"More information about the issues and make it clearer, not just like... there's a hole." SG 2.5

b) Separating waste should be enforced by law and nobody is allowed to find excuses for not doing it.

"Create the right laws...like separating waste must be enforced by law since though it started, I don't think it is that popular." SG 1.4

c) Higher fines for those who perform environmentally unfriendly actions.

"People only learn when they have to pay money." SG 4.3

"People will start learning when they start to face consequences." SG 4.4

d) Apply an eco tax.

"It is all a question of money. If there is an eco tax people will have to change their mentality whether they like it or not. Then it will be a question of votes. Which government will have the guts to do it?" SG 2.6

e) Use education to teach children from the youngest age possible. They suggest that to become environmentally aware children have to grow in this new mentality.

"Education, media, newspapers, posters, involvement in ecological campaigns, living an environmentally aware way of life from a very early age." SG 3.8

f) Education has to start from the family and therefore the greatest responsibility of creating an environmentally aware generation is in the hands of parents.

"First of all, the family has to provide the right education, which means that the parents have to start indicating what is right and wrong." SG 4.3

g) Creating positive incentives to encourage those who perform practices that could result in the reduction of global warming and ozone depletion; such as getting money back if electricity is saved.

"Since we're used to dumping waste, we need more encouragement and incentives that help us change a mentality that has been present for many years." SG 3.2

"Compromising: get money back if electricity is saved; reduction in bills."

3.9 Conclusion

Students who followed a post-secondary course in Environmental Science show a certain amount of knowledge on global warming and ozone depletion. However, they also exhibit a number of wrong perceptions which were not associated with a lack of background in Chemistry. The majority of students believed that the holes in the ozone layer allowed more heat and ultra violet rays from the sun to reach the Earth and therefore enhancing the problem of global warming. Students also assumed that any practice that is considered harmful can be the cause of any environmental problem, and any good practice is beneficial for the environment as a whole.

Students admitted that the main source of information about these issues is Environmental Science, the subject that is tackled at school during a two-year post-secondary course. Yet, students show a passive attitude towards doing something to improve the situation and to create a sustainable environment. It seems that the scientific theory explained during Environmental Science lessons is not being applied in the decision taken in the students' everyday life. The students themselves suggested more action added to the theory learnt, more encouragement and enforcement from the government's side, a more focused lifelong educational programme.

Chapter 4 Discussion of Results

4.1 Introduction

The results obtained in this study demonstrated that post-secondary Environmental Science students have acquired an amount of knowledge regarding global warming and ozone depletion. Yet, a number of perceptions held by students were incorrect. The majority of students had the false impression that ozone depletion is causing global warming and also that ozone formed at ground level is linked with the ozone layer. The disclosure of what students know, what they have wrongly apprehended and what they still do not understand gives educators an insight into what is wrong and where changes need to be implemented. Understanding the problem gives the opportunity to do amends to educational strategies.

Students' perceptions about the environment will influence decisions they make in their daily life. Such decisions will influence their life and that of others. This study showed that the Environmental Science lessons are the major source of information for post-secondary Environmental Science students. Therefore ensuring a good quality educational programme should be part of any strategy to address the environmental problems.

4.2 Perceptions Held by Students

4.2.1 Ozone Depletion

Students failed to distinguish that the same ozone gas could be harmful at ground level but beneficial at stratospheric level. Though they knew the name of the chemical they seemed to be thinking about two completely different gases. Moreover, students were unaware that the Sun played an important role in the formation of this harmful gas at ground level. The questionnaire revealed and the interviews confirmed that they considered ozone as being another polluting gas that

forms during the burning of fossil fuels and that it can harm also harm stratospheric ozone.

The uncertainties revealed demonstrated that students had not really understood the issue. Knowledge seemed to be fragmented when students gave contrasting answers to statements that exposed similar principles (OD 13 and OD18) (OD3 and OD11) (DiSessa 1988).

In a similar study conducted by Leighton and Bisanz (2003) students scored highest in categories encompassing fairly basic science, health risks and technical facts demonstrating their possession of factual information. Similar results were obtained in this investigation in that students showed awareness about stratospheric ozone being beneficial to living things and ground level ozone being toxic when the issues were dealt with separately in the questionnaire. Moreover, the majority of students knew that ozone depletion is the major cause of skin cancer.

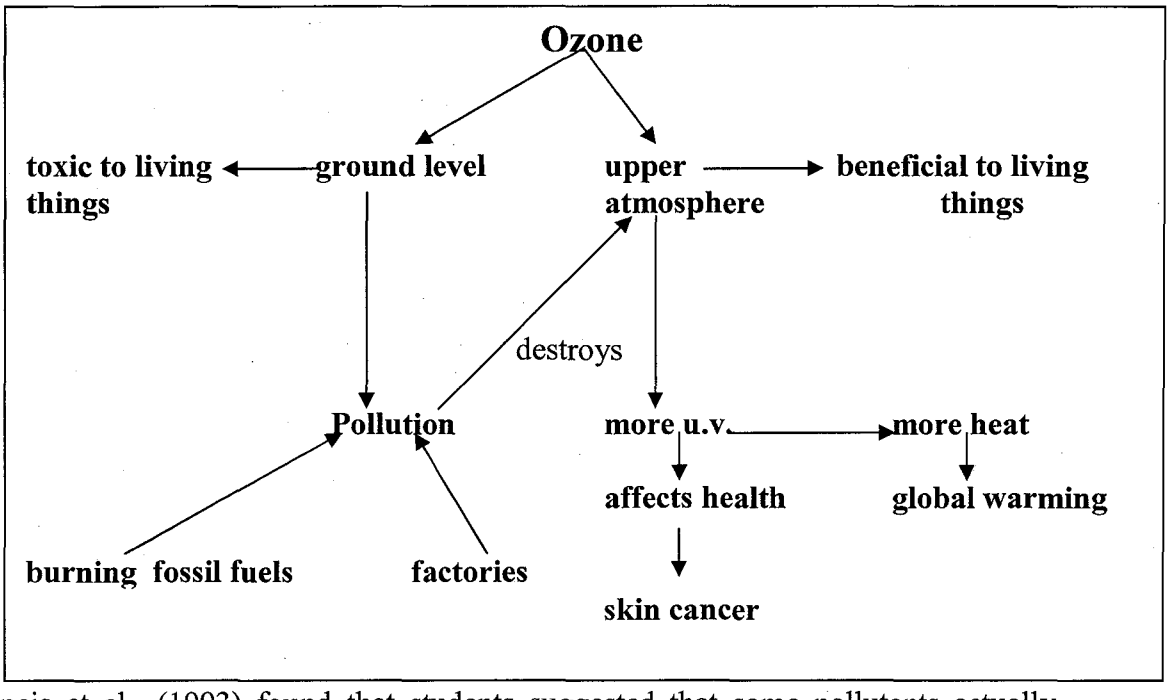
The incorrect or uncertain answers to the statements mainly deal with scientific understanding of how ozone as the pollutant is formed, on whether the thinning out of ozone is affecting global warming and how and what is destroying the ozone layer. It is the difficulty students find in understanding the complex scientific concepts behind these issues that block them from assimilating this knowledge (Meadows and Wiesenmayer, 1999) together with the lack of evolution of the concepts formed.

Conceptual understanding and reasoning follows a path of increasingly evolving models (Lawson, 1988 and Vosniadou & Brewer, 1992). However, this seems not to be happening due to unrelated teaching since different aspects pertaining to the same issue are taught in isolation, inhibiting students from visualizing the whole picture since they are failing miserably when it comes to integrating and applying knowledge. Students should be active learners who need to be helped to reason things out so that their fragmented knowledge evolves into frameworks. Presently, they are expected to link things on their own. Hence, students are gaining fragmented information with a number of lacunae that are being filled with the information they gain from various sources to build a logical but incorrect framework.

4.2.2 Conceptual Framework Based on Students' Perceptions

Overall the conceptual framework in Figure 4.1 gives a 2-dimensional representation of a number of critical concepts related to ozone. The purpose of this graphic was to organise the major concepts that were considered essential to understanding the reasoning of students as regards this environmental issue. It also clearly indicates the supposed link between ozone the pollutant and stratospheric ozone and the perception held by students that associates ozone depletion with global warming.

Figure 4.1 Conceptual Framework on Ozone as held by Environmental Science Students



Francis et al., (1993) found that students suggested that some pollutants actually entered the ozone layer and caused damage. Alternatively Maltese Environmental Science students think that ozone at ground level is a kind of pollution that destroys the ozone layer allowing more sun's rays to enter to the Earth and then accelerate global warming.

4.2.3 Global Warming

The majority of the students understood that global warming will have consequences such as melting of ice at the poles, changes in weather patterns and flooding. Boyes and Stanisstreet (1993) claimed that scientific ideas like the notion that an increase in

the greenhouse effect will cause changes in weather patterns are already present in younger pupils. Alarmingly, some misconceptions found in very young students seem to remain embedded and are in fact found in older students. This perception is also held in the present study. The idea that lead-free petrol will reduce global warming is one of them. This incorrect perception was found at a high level among the Environmental Science students investigated (GW 53, 81.1%). Similarly, Francis *et al.*, (1993) found that students think that leaded petrol contributes to global warming. This perception might create the false impression that using unleaded petrol is considered as a valid strategy to reduce global warming.

This study showed that students probably understand that the use of unleaded petrol is better than the use of leaded petrol but they seem to confuse the reason why, attributing it to lowering global warming, rather than to removing a heavy metal pollutant from the environment (also found in Groves and Pugh, 1996). Students consider this practice as being a positive one for the environment, and therefore according to the logical framework that they have constructed this should correct any environmental wrong.

Students are not effectively transferring acquired knowledge to the "real world" (Groves and Pugh, 1996). Lave (1988) pointed out that knowledge is context-bound, and that "everyday experience is the major means by which culture impinges on individuals". Therefore all the sources of information the students have, including their encounters with media explanations and descriptions, may play a stronger role than their experiences in the Environmental Science classroom even though they feel that the classroom is their main source of information. Student science knowledge related to ecological crises appears to be fairly consistent. Students learn new material in school but do not relate it to previous knowledge or ecological phenomena. Environmental issues are not associated with science concepts taught in classrooms. Formal science instruction does not seem to change conceptions which students have constructed in order to understand the world around them. Brody (1994) emphasised that researchers must continue to find out what the learner already knows. The challenge remains to design instructional strategies which address these conceptions and attempt to alter them in meaningful ways.

About three-quarters of the students thought that more people will die of skin cancer if global warming gets worse (GW42). This persistent misconception shows a hidden link students created in their minds between global warming and an effect of ozone depletion. This was found to be present also in the study carried out by Boyes and Stanisstreet (1993) and they explained that there might be a subconscious mental link between the perils of extensive sunbathing and sunny, warm days-- hence, global warming.

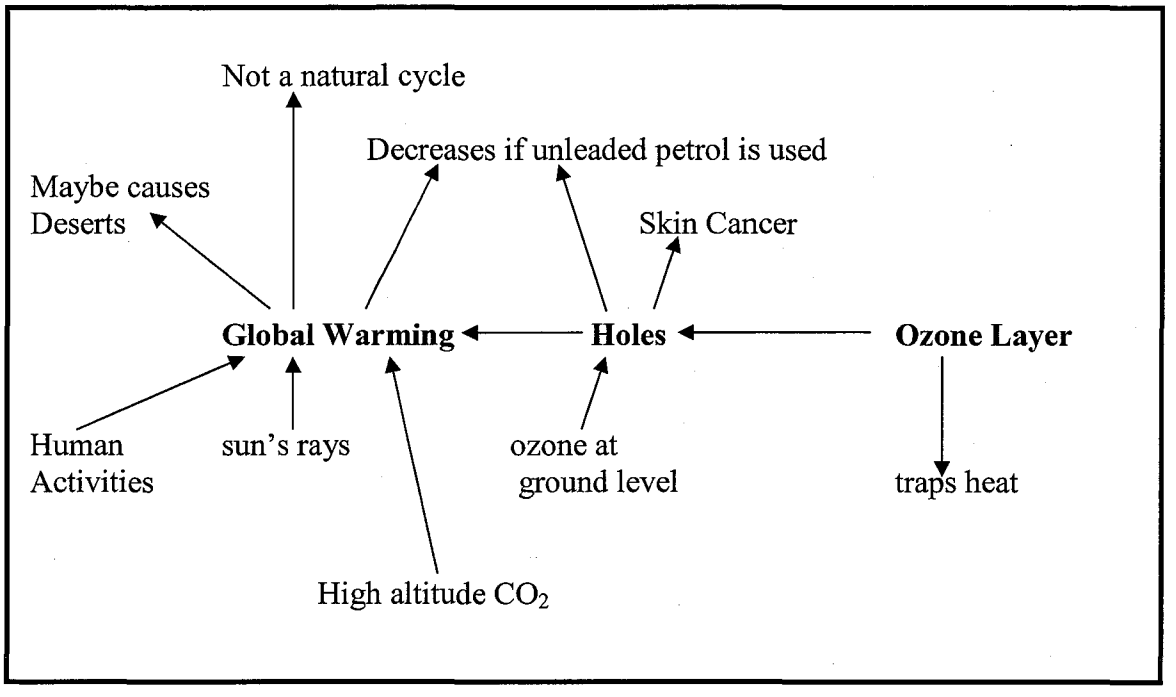
Global warming is a very topical issue that created controversy in the scientific community until the IPCC Fourth Assessment Report (2007) asserted that human action is in fact enhancing climate change. The potential for serious consequences is large and makes this issue a priority to science education (Groves and Pugh, 1996). Consequently, it is extremely important that students are properly guided by all the sources they encounter to the correct understandings (assuming the information being received is correct). However, it is understandable that students find difficulty in understanding such a complex issue.

Interviews carried out by Brody (1994) among students of different age groups showed that a) students learn a few basic science and natural resource concepts relevant to current ecological crises in the elementary grades, b) there is relatively little assimilation of new science concepts or differentiation of existing concepts between students of different age groups, c) the level of understanding of basic concepts and principles related to the environment and the politics surrounding it was low. Furthermore, younger students demonstrated the need for more tangible proof to believe the existence of the crises while in older students, understanding becomes progressively more abstract and their concern for the future of the Earth is more apparent as well as their awareness of the need for global co-operation. It is also true that their pessimism about the future of the Earth increases with age. Results from the present study indicated that post-secondary Environmental Science students possessed very basic knowledge about global warming and hence own the tools they will use to face decisions later on in life.

4.2.4 The Link Between Global Warming and Ozone Depletion

To the majority of students, this link would seem sensible and this apparently logical connection is widely made (Boyes and Stanisstreet 1993, Boyes and Stanisstreet 1994, Groves and Pugh 1999, Summers *et al.,* 2001, Francis *et al.,* 1993, Fisher 1998 and Jeffries et al., 2001). Both issues are environmental problems of global dimensions, both are imperceptible to individuals, both are the results of general over-industrialisation, and both receive considerable publicity.

Figure 4.2 Conceptual Framework that Links Global Warming to Ozone



The perceptions that resulted from the analysis showed that Environmental Science students believed that the depletion of ozone created 'holes' in the atmosphere through which heat from the Sun enters to reach the Earth. This heat is trapped by the pollution of which high altitude Carbon Dioxide and ground level ozone form part, giving rise to global warming.

The interviews confirmed that there was the blending of ideas about global warming and ozone layer depletion. Students identified the consequences of ozone layer destruction (increased solar radiation OD 17, GW 46 and higher incidence of skin cancer OD 20, GW42) with global warming. Furthermore, there was the likelihood of students reaching a conclusion via an erroneous pathway, in that an affirmation

that too many sun's rays getting to the Earth cause global warming may arise from a knowledge that more ultra violet radiation enter due to the thinning out of the ozone layer and a confusion between the two global environmental effects. Boyes and Stanisstreet (1993) explain that a more general logical fault may be operating in the minds of students who are unable to disentangle a whole series of environmental problems from their, sometimes overlapping causes, and therefore assume a generality that all environmentally friendly actions will help all environmental problems.

Students have formulated some apparently logical but quite erroneous frameworks explaining these important global issues. Leighton and Bisanz (2003) implied that students who sustain a cohesive set of beliefs, regardless of scientific accuracy hold a full model. Likewise, Maltese Environmental Science students have collected fragmented information from various sources, added their own intuition and constructed concepts which however, have some wrong implications. Consequently, since students believe that these concepts are correct due to their logical justification, they are reluctant to displace them by more scientifically acceptable ideas.

Cordero (2001) believes that the understanding of science misconceptions by educators leads to the better understanding of how individuals construct their own conceptual frameworks. The particular words chosen by the educator during the explanation of these issues might have triggered the students to understand concepts differently. The understanding of students' ideas and the way these concepts develop can lead to the improvement of teaching methods and this will in time result in a potential improvement in the public understanding of the studied issues.

4.3 A Background in Chemistry

Environmental Science students who were in possession of a qualification in Chemistry at SEC level did not seem to be at an advantage over the others when answering the questionnaire. This suggests that more knowledge does not always mean better understanding. However, further research could be done in this area so as to improve the interdisciplinary approach towards environmental education that should be adopted to construct correct environmental concepts through the structuring of correct physical principles.

4.4 Sources of Information

All the statements regarding ozone depletion and global warming proposed in the questionnaire were previously tackled during the Environmental Science lessons (Appendix Three: Section from Environmental Science Syllabus; Human Activities and Environment). These resulted to be the main source that contributed to students' knowledge.

Students seem also to depend on the information disseminated by the media such as television (62.9%), newspapers (33.2%) and internet (41.1%) It is therefore reasonable to ask whether the message conveyed by the media is correct or not. Studies in this area in the local arena could throw light on what the general public is being continually bombarded with. Therefore the role played by information provided by the media should not be underestimated. This could be a first step to acquire awareness about some aspects of these important issues and also a warning of what shall happen in the future.

4.5 Attitudes and Behaviour

Although students did not choose all the statements that demonstrated an environmentally friendly action, the data collected evidenced that they seemed to understand what harms and what ameliorates the environment. Nevertheless, the attitudes towards a better environment were quite lacking. So it seems that students did not develop environmental values after having undergone a two year course in Environmental Science and obtained information on environmental issues from other sources. In accordance with Turiel (1975, 1978), Keasey (1978) and Gruenich (1982), the fact that logical rationality based on knowledge should guide an individual in decision making, presenting a consistent behaviour, is in reality questionable. The choices identified by the students demonstrated an egocentric attitude where decisions were based on what was thought to be best for the individual at that moment.

The questionnaire indicated that Environmental Science students were aware of environmentally friendly actions. Nevertheless, there is a big difference between

knowing what is right and doing the right thing. Not enough is being done to internalise the latter in learning experiences.

4.6 Linking Factors to Interviews

4.6.1 Factor 1: Causes and Consequences of Global Warming

Statements in this section were issues which apart from being explained during formal Environmental Science lessons, are frequently heard in the media and one can say they are well-publicized phenomena as students confirmed during the interviews. However, unlike what was stated by Boyes and Stanistreet (1993) this study reveals that it cannot be assumed that these are therefore well understood. Data revealed a high percentage of wrong conceptions. There was confusion about the causes and the consequences of both issues and this was further confirmed in the interviews. This factor demonstrated that students knew that there were serious problems regarding the environment but still could not clearly distinguish between them neither in their cause nor in the consequences they produce. The sources procuring information about these two issues were not being effective. While students were allowed to express their ideas about these issues during the interview, they tried to formulate logical arguments on how these global problems are caused. Only while formulating the argument did the students understand that what they were trying to explain could be wrong and that the conceptual framework that they had built in their mind but never had the opportunity to express was full of flaws.

4.6.2 Factor 2: Personal Responsibility

The concept underlying this group of ideas seemed to be that of components which are thought to exacerbate or ameliorate global warming and which are under personal control as they depend on the decisions that are taken everyday.

'Global Warming can be decreased if electricity is not wasted' was answered correctly by 81.4%. Wasting less electricity was high on the Maltese family agenda these last few years since a surcharge on the electricity bill was introduced. The more electricity is used the higher the surcharge one has to pay. There is therefore a kind of personal control that affects finances but also, even if just as a consequence, the environment. During the interviews students from all four focus groups mentioned

this issue, implying that their parents kept reminding them not to waste electricity due to the bill. One student added that though they were not wasting electricity for financial reasons, the environment was benefiting from it as well.

Nevertheless, pupils might be subconsciously distinguishing between solutions which are local that is within their control and those that are global, outside their personal control. This distinction was detected during the interviews when the majority of the students implied that they felt helpless in front of the huge environmental issues, especially when large countries like the United States did not bother to ratify the Kyoto Protocol. This led to the abdication of responsibility for the major, large-scale environmental problems.

Results from the questionnaire showed that students were very reluctant to take individual actions that were pro-environment. This was substantiated during the interviews. Students readily mentioned ways that could be adopted by individuals to decrease global warming and ozone depletion but admitted that in real life they perform very little of them and only because they are made to either by their parents or else due to the context in which they live.

Any statements mentioning environmentally friendly measures were thought by students to decrease global warming. Similarly, all harmful measures were thought to enhance global warming.

4.6.3 Factor 3: Ground Level Ozone

There is a distinction between stratospheric ozone and ground level ozone, even though both are the same gas, yet they play different roles when they are at different levels. The statements here are all about ground level ozone which cannot replace stratospheric ozone. Ground level ozone is a pollutant and students are aware of its toxicity. Nevertheless, they also thought that it enhanced the greenhouse effect and therefore the relationship of this gas with global warming was evident. This also featured in the interviews where the majority of students explained that ozone at ground level enhanced the thinning out of the ozone layer and more Sun's rays were able to reach the Earth as a result.

4.6.4 Factor 4: Pollution

This group of statements indicates an underlying concept held by students which is that pollution including ozone is the main cause for the damage that is being done to the atmosphere. These statements associate ozone with the pollutants that form when fossil fuels are burnt and that altogether are destroying stratospheric ozone and enhancing global warming. Students expressed the same reasoning during the interviews, implying that pollution from burning fossil fuels produced mainly from vehicles and factories is destroying the ozone layer allowing more Sun's rays to reach the Earth and thus enhancing global warming. This confusion of ideas was very persistent and it seemed that the framework they had constructed was deeply embedded since for them it made sense.

4.6.5 Factor 5: Skepticism

Statements pertaining to this factor provide the opportunity to find out whether students are skeptic or not about global warming and ozone depletion being caused by human interference. The results evidenced that Environmental Science students believed that both issues are real problems and that humans are responsible. During the interviews all focus groups agreed that these issues are becoming more and more problematic due to the big countries like United States and China whose emissions are contributing to enhance global warming. However, a feeling of individual helplessness was felt among all groups as they explained that these countries should be concretely doing something to help the environment rather than expect their generation to fix what seemed to be already unsustainable.

4.6.6 Factor 6: The Greenhouse Effect

The ideas that emerge from this factor show the evolution of the concept explaining the greenhouse. The importance of the natural greenhouse effect is emphasized and students are aware that without it life on Earth would be impossible. During the interviews students explained that there is a "good" and a "bad" greenhouse effect, and that human activities are enhancing it so much that its effects are devastating. They attempted to explain scientifically how this effect takes place and why pollution enhances it but many confusing ideas that were previously explained emerged (Figure 4.2). All the students in the focus group agreed that renewable

sources of energy should replace non-renewable once to decrease this effect. Yet, as the results from the questionnaire demonstrated students are too passive to start doing something on an individual basis.

4.6.7 Factor 7: Excluding Human Intervention

Results from the questionnaire and analysis of the interviews demonstrated that students were aware that certain human practices were resulting in global warming and ozone depletion. They did not exclude human intervention for the changes that are being experienced by the Earth. Results from the questionnaire also demonstrated that students were uncertain whether global warming is due to a natural cycle of warming and cooling of the Earth. They were similarly uncertain about the fluctuations of ozone before human intervention. Since, students tended to link both issues in various ways (as they explained during the interviews), they might have thought that what occurred with global warming before human interference could have happened to stratospheric ozone. A logical fault might be operating in the minds of students who are unable to disentangle a whole series of environmental problems.

4.7 A Passive Attitude

Students have demonstrated a passive attitude when faced with decisions that could be in favour of the environment. This was further confirmed during the interviews when students explained that it was not their job to take care of an environment that was being ruined by others. They expressed a feeling of helplessness in front of what was being done by the more developed countries. Moreover, they explained that the expected consequences of global warming and ozone depletion will not happen before a long time. Therefore they declare that they are not interested in actually undergoing a burden will not show the desired results.

The difference between "knowing what to do" and "doing it" shows an inherent flaw in being really aware of the impact of global warming and ozone depletion. These issues are not as real for students as the "economic impact", "peer pressure" and "discomfort" sustainable lifestyles may imply. There is a need to create a youth

culture that is environmentally friendly and it can happen only if students feel a sense of ownership for the solutions adopted.

4.8 Conclusion

As researchers and educators, we have to embrace the important task of educating children about environmental issues of global significance. However, students at this age have apparently already formulated alternative models of the causes and cures of these problems. Furthermore, the Environmental Science they are learning is being considered solely as a subject with no transfer of knowledge to their everyday decision making.

As regards concept development in Environmental Science students, conceptual understanding and reasoning in the abstract domains show that they are following a hybrid path in which fragments characterize initial knowledge followed by the evolution to cohesive models. Moreover, greater effort is needed to educate students about the causes of global warming and ozone depletion and how their own individual behaviour and attitudes do contribute to climate changes.

Chapter 5 The Way Forward

5.1 Introduction

Revealing the perceptions about global warming and ozone depletion that confuse Environmental Science students, puts educators at an advantage as together they can work with a different methodology to formulate correct, meaningful frameworks (Starr and Krajcik 1990). The aim of this chapter is to provide recommendations on how this can be achieved. Moreover, this chapter aims to indicate strategies that might improve the behaviour and attitudes of students and others towards the environment. The goal set is to decrease the extremely passive attitude revealed during the interviews.

Consequently, this would result into more educated, environmentally aware adults that are able to pass on proper information and an environmentally conscious way of life to those that are still to come.

5.2 Developing Correct Concepts

5.2.1 Curriculum Development

An effective Environmental Science curriculum should include a set of organized experiences, which will aid students in developing correct concepts and awareness concerning the environment. The conceptual framework of global warming and ozone depletion revealed by the analysis of the questionnaires and interviews can be used to help the teacher in the selection of concepts and how they can be sequenced in meaningful ways.

The concepts related to current ecological crises should engage students with real life issues that are analysed in social and cultural contexts in order to make valid judgments. Science has implications in everyday life and is not the rote memorisation of meaningless facts from a textbook. It stresses the interrelationship of all life and the factors which affect life on the planet Earth. Brody (1994) explains that in order

to preserve our very complex and fragile ecosystem, a general populace, knowledgeable in the area of both natural and social sciences and how they interact with the world today, is specifically needed. Therefore the design of multidisciplinary curriculum units and appropriate teaching strategies that address student understanding of complex natural phenomena can lead to the development of correct conceptual frameworks which are meaningful.

5.2.2 Practical Strategies

Student understanding of environmental issues is complex. However, it is not often associated with science concepts taught in classrooms. Formal science instruction does not seem to change conceptions which students have constructed in order to understand the world around them. This might be because most of the lesson is dedicated to learning facts rather than understanding them. It is therefore imperative for educators to be familiar with what the students already know. The challenge is to design instructional strategies which address these conceptions and attempt to alter them in meaningful ways. A paradigm shift in science education is necessary; one based on constructivism.

Students need to understand science in the context of society and the future of the human race. The educator can help students

a) identify authentic issues
b) conceptually analyse science knowledge related to these issues
c) determine students' existing knowledge regarding these issues
d) design meaningful environmental courses that aim in formulating correct conceptual frameworks.

This will produce correct links between concepts, and transfer of knowledge from one context to another would be more possible. The outcome will be the creation of more complex meaning in a structured manner.

An incorrect perception could be a point of departure for a constructivist approach, keeping in mind the fragmented knowledge students possess and the mental models they have constructed when this knowledge was put together. Students should be

given the opportunity to construct, discover and explain the links formed between the knowledge accumulated in order to build a correct conceptual framework.

5.3 Towards Environmentally Conscious Behaviour

5.3.1 Where do we start?... Sustainable Schools

It is imperative that young people's experiences of education from nursery school to university equip them with the knowledge, skills and values needed to live and work sustainably. Once they have become adults the learning shouldn't stop. Whether it is in the workplace or in communities, sustainable development is a lifelong learning journey.

This can happen since the country's entire young population travels through primary and secondary schools. There is no other equivalent common experience for all people in Malta than school. Schools have an essential role to play in making a radical impact on children's understanding and experience of sustainable development and to develop the life skills needed to build a sustainable society. Capital investment in Maltese schools presents a key opportunity to the whole population. Schools should be made the liveable models for sustainable development. A capital investment programme that changes the present schools into green schools could offer the opportunity to change not only the fabric of school buildings, but the whole school experience for generations of children (HM Government 2005).

Wu (2002) studied how the establishment of green schools in China facilitated Environmental Education in primary and middle schools. The researcher implied that though Chinese students are well known for grasping book knowledge and passing examinations, they are thought to lack competence in initiative and practice. Consequently, he recommended a transformation in the existing methodology. Wu suggested that a teacher's lecture time should be reduced in favour of a variety of teaching methods to allow more students to participate in classroom study such as debating a local environmental issue.

The formal education system - from early years to university – should provide a continuous opportunity to experience, practise and evaluate sustainable behaviours in recognition that empowering people to find solutions to sustainability problems should be one of its core purposes. Many schools should show the way and have the potential to spark interest, learning and change the behaviour of students and then that of their families into an environmentally aware one. This can start by empowering students and allow them to take responsibility for their own future, help them become part of the solutions to global challenges rather than part of the problem as we view ourselves. Empowerment is possible if:

- children gain first-hand experience of identifying the challenges and finding the solutions in the school, local area and at home, otherwise the issues will remain too abstract and confidence will not be built
- teaching about sustainable development should be mirrored by actions taking place in the school
- parents and the local council can be involved in activities that are organised by the school community.

A whole-school approach to sustainable development is the best way to achieve results. Everyone in the school has a role in advancing sustainable development. Such a programme is already happening in Maltese schools under the title of Eco-schools coordinated by Nature Trust (Malta).

Such a scheme should be given more exposure. All students from all social classes and cultures need to be given the opportunity to live this experience which could lead into the formation of environmentally aware students and families.

Moreover, a holistic approach is taken to school improvement covering the major areas of school life:

- **An Active Curriculum**

Through its focus on issues that matter to young people, sustainable development provides a means of developing pupils' sense of enquiry, enjoyment and interest in

the learning process. By exploring real issues in real places – inside and outside the classroom – it helps to make learning relevant to pupils' lives. Because the range of learning opportunities is so wide – from practical outdoors work to designing projects and writing letters to local councillors – it also creates opportunities for greater personalisation of learning.

The 'Learning Outside the Classroom Manifesto' published by the U.K. Department of Education and Skills (2006) provides a powerful impetus for sustainable schools. It highlights the importance of learning about real issues in real places among real people, helping children to form connections with things that really matter. It is difficult to imagine a child seriously valuing the natural world unless they have experienced it at first hand.

- **Ways of Working**

Schools that manage their operations sustainably provide a powerful example for their staff and pupils to follow. Sustainable schools are efficient schools that consume less energy, water and materials, and produce less waste. Efficient management of school buildings can result in lower energy and water bills. A strategy of 'reduce, reuse and recycle' can result in less purchasing, less cost and less waste. The use of a piece of land from the school grounds for nature conservation can lead to exciting learning opportunities and greater environmental appreciation.

- **Influence on Community**

Schools have the power to exert a broader influence on their communities. Through their contact with parents, local organizations and local councils they can advance an extensive environmentally sustainable agenda among local people. Sustainable schools and sustainable communities together would be providing the background and an ongoing experience for students that could result in generating an intrinsic environmentally aware mentality with the positive attitudes and behaviour that would be turn out without having the feeling of doing something out of the ordinary.

5.3.2 Educational Programmes

In accordance with Gomez-Granell and Cervera-March (1993), it is believed that the change of attitudes and of environmental behaviour could be influenced by the conjunction of a greater understanding of the issues discussed and their interrelationship, and by a social and collective awareness which would allow the linking of this knowledge to humanity's actions in the environment. It resulted from this study that though there is a certain level of awareness among students about global warming and ozone depletion, knowledge is not transferred to real life situations. Educational programmes that happen in and out of school might be considered as being part of the solution.

The aim of such a programme would be that the incipient awareness becomes structured knowledge which brings about lasting change in attitudes and behaviour. It is suggested that the practical constructivism strategies previously explained should form the basis of these educational programmes (also suggested by Gomez-Granell and Cervera-March,1993).

5.4 Changing the Way We Teach

5.4.1 What is Offered to the Maltese Students

In Malta students do not tackle environmental issues from a scientific perspective as an academic subject such as Environmental Science in the Primary or Secondary schools. A Sustainable Development Strategy for the Maltese Islands 2000-2016 by the NCSD (2006) implies that the incidence of environmental topics and the range of issues related to the Maltese environment have increased significantly in the curriculum. It also implies that Social Studies and Science are the subjects through which environmental education are tackled at primary level. At secondary level issues related to sustainable development are included in Home Economics, Design and Technology Education, Environmental Studies and certain topics are included in Physics, Chemistry and Biology, only if any one of these is taken as an option. This implies that there exists a good number of students who till the age of 16 would have never studied environmental issues.

In addition, Environmental Science is a subject offered at Intermediate Level only to post-secondary students who do not study any other science subject. This denotes that students taking any other scientific subject at A-level or at Intermediate level are not allowed to take Environmental Science as well. Thus, one asks, why is this subject only offered to post-secondary students who do not choose any other scientific subject at this level or higher? Why should only this particular cohort be exposed to environmental education? Or is this subject serving only as another academic subject needed to fill the lacunae these students have in science?

The introduction to the syllabus of Environmental Science at Intermediate Level explains that it is meant to offer an opportunity for candidates that may not have prior knowledge of science, to study a range of environmental issues from a scientific perspective. Therefore all other students are not considered. They are not given the opportunity to learn about environmental issues and their implications when these are certainly not tackled in any other science subject syllabus at this level or higher. Are these students then expected to be environmentally responsible adults that lay the appropriate foundations for their own children and thus bring about a change in mentality? The syllabus puts emphasis on the provision of scientific knowledge and understanding implying that students are enabled to review environmental issues more objectively. The results from the questionnaire and the interviews clearly indicate that what is being learnt in class is not reflected in the behaviour and attitudes of students. Dispatching scientific knowledge alone is not bringing about a change in the students' lifestyle. Social, cultural, economical and political dimensions may be considered but the programme primarily seeks to provide scientific knowledge that would enable students to assess the dimension of the issue and to consider alternative strategies for its resolution. The programme seeks to provide basic environmental literacy for candidates. Nevertheless, is this knowledge established in the individual's lifestyle?

This research demonstrates that the fact that a very small percentage of Maltese students come across and study the environment in a scientific way and at such a late stage is resulting into the consideration of Environmental Science solely as a subject needed to get to university. Furthermore, as this study indicates, though the subject is providing the students with a certain amount of scientific information it is not

bringing about the desired change in attitudes or behaviour since the link between the knowledge these students are gaining and the utilization of this information in real life situations is not occurring.

5.4.2 Concrete Changes

The development of correct conceptual environmental frameworks requires a continuous opportunity to construct and form links between old and new knowledge. However, currently our educational system does not allow this.

As proposed by Briguglio and Pace (1994) Education for Sustainable Development should permeate all levels of formal education from Primary to Secondary to Tertiary levels. It also proposes to foster public awareness about the advantages of sustainable development, and organise educational activities towards this end. Adult environmental education could be the response to this greatly-felt need. This will divulge a pro-environmental mentality in the whole society. Brigulglio and Pace suggest an interdisciplinary approach in the Primary and Secondary Levels and thus syllabi should refer to and deal with issues related to sustainable development that are relevant to the experiences of the learners. Moreover, they also suggest that a coordinator responsible for the implementation of Education for Sustainable Development should be appointed in the school. Though this is a very sensible suggestion it has not been implemented yet.

- **In-service Courses**

Moreover, all the teachers must gain a sound background in the Sustainable Development. It is extremely important that the educator does not propagate any wrong concepts especially at the lower levels where concepts start to be constructed ready to hold future structures and frameworks. Kornberg (1991) suggests that prejudices form and attitudes harden early. Therefore it is recommended that teachers both at Primary and Secondary level undergo an appraisal in this area that would help eradicate any misconceptions they might hold so as to be able to present correct environmental issues permeated in all other subjects. Cordero (2001) implies that if teachers do not feel comfortable in their own understanding of these topics, their students may never have the opportunity to explore these subjects.

It is suggested that such courses would be on-going and for all teachers as environmental education should permeate through all subjects. Teachers could experience and experiment the constructivist approach in organised workshops while dealing with authentic environmental issues.

- **Adult Education**

Adult learning is a central tool in the process of raising environmental awareness and promoting environmentally supportive action. Many environmental organisations disseminate information, organise community initiatives and practise non-formal adult education.

Adult environmental education should disseminate knowledge about the environment's direct and indirect physical and related social impact, transmit knowledge on the interaction between local activities and their effects which may occur further away. Adult education has often included a political and socially transformative perspective. Since Paulo Freire's work on literacy and its emancipatory potential, the social and political role of adult education has become a central pillar of much of today's practice in this field. With his motto "from reading the word to reading the world", Freire invited people to explore the social and political as well as the physical environment. The environmental factor is now becoming increasingly important and can hardly be ignored in education efforts committed to social and political goals. Such projects go beyond creating understanding and awareness. Adult environmental education aims at developing skills, creating a sense of commitment and stimulating individual and collective action.

Environmental topics can be an important component of community education programmes. Such programmes can provide a frame for linking environmental issues with social and political problems of the community. Environmental learning encourages participation. As suggested for the in-service courses, such programmes could take the form of workshops where groups of people with their mentor, approach a real life environmental issue utilizing constructivist strategies.

5.4.3 Transforming Environmental Science

Science has a significant role to play within an effective environmental education, particularly through the concepts of scientific literacy and scientific capability, both of which seem fundamental to the development of an understanding of science, environmental issues and their inter-relationship. Nevertheless, as Jensen and Schnack (1997) argue action and action competence ought to have a central place within environmental education in schools. Action and action competence are crucial for environmental education because they bring together the purpose of school education and the nature of ecological and environmental crises that are being faced globally. There is a tendency to expect that through Environmental Science alone there will be,

a) some kind of behaviour modification and
b) that society at large is relying on the individual to effect change.

This was explicitly elicited in this study during the interviews with Environmental Science students were they all agreed that it seems that adults are expecting the younger generation to repair for the damage that has been done to the environment.

In accordance with Hungerford and Volk (1990) the possession of knowledge and positive attitudes is insufficient to guarantee positive action for the environment as was in fact demonstrated in the analysis of the questionnaire of the present study. Environmental Science students do possess the knowledge of what harms or is beneficial for the environment but are not bothered to do it. The essential ingredient is the commitment to action (Hungerford and Volk, 1990). This is what seems to be missing in Environmental Science students and is not presently being transmitted through Environmental Science lessons. An overly-academic school curriculum seems to be disempowering due to its tendency to detach the content and praxis of the curriculum from the realities of everyday life.

It is therefore suggested that Environmental Science would be combined with action competence. Jenkins (1994) explored public's understanding of science and remarked that most people find conventional scientific knowledge of "little or no use

as a basis for action in their social context unless it is reworked, restructured and recontextualised." This can be done by integrating relevant scientific knowledge with situation-specific knowledge which is often idiosyncratic and personal, and with various kinds of perspectives. Scientific knowledge needs to be transformed so as to articulate with praxis (Layton, 1991). Knowledge embedded in the context of action severely contrasts with the conventional pedagogy of academic science which as Layton (1991) puts it "stresses the universality and decontextualised nature of scientific understanding." Traditional teaching promotes linear reasoning implying simple solutions to complex problems with little thought about repercussions. Lave and Wenger (1990) argue that the integration of knowledge through action is concerned with cognitive apprenticeship where learners are seen as "novices (who) become part of communities of practice" rather than a group of people striving for mastery of universal principles or concepts. Personal and communal production of new knowledge (scientific or otherwise) through experience and reconstruction is an essential precursor to the acquisition of the predisposition to the adoption of positive environmental behaviour (Posch, 1993).

Scientific knowledge in conjunction with action competence aims to bring about the democratic commitment of individuals to be participants in the continuous shaping of society and for those individuals to have the capability to participate as shapers of future generations.

- **Action Competence**

Action competence is not exactly a new idea. It is similar to practical reasoning and scientific capability and scientific literacy. Brickhouse *et al.*, (1993) contend that practical reasoning is a fundamental competence required for everyday decision-making as well as the production of scientific knowledge. The Scottish Consultative Council on the Curriculum (SCCC) has developed the notion of scientific capability to convey more clearly a flavour of science education for action as well as for personal enlightenment and satisfaction. In this sense, scientific capability is seen as having five aspects which focus on the purposes of science education in schools.

These are:

1. scientific curiosity
2. scientific competence
3. scientific understanding
4. scientific creativity
5. scientific sensitivity

Together these aspects emphasise the thinking and creativity involved in science as a process, a critical awareness of the role of science in society combined with a caring and responsible disposition, in addition to the development of investigative skills and an understanding of the way that the process and practice of science actually works. Furthermore, it empowers students as their individual actions become important and understanding this will produce an active society rather than one that feels helpless in front of environmental problems.

Environmental Science should undergo a reform to become more responsive towards the personal, societal and cultural needs of the population. Shamos (1995) is sceptical of this notion suggesting it is a form of educational utopia but he still agrees that a reform is essential if public understanding of science is to be enhanced and become more widespread through society.

Jensen and Schnack (1997) distinguish between action and activity. The term activity means being actively engaged in a limited task such as data gathering through field work, surveys, measurements, biochemical analysis. These activities are extremely important as they give life to science and hands on activities help students understand concepts better especially if they are focused on the resolution of a problem which students themselves regard as important. Thus, an activity changes to an action if it is being both purposive and of personal worth to the individual, irrespective of weather the action is carried out by an individual or a group. Furthermore, an action must address causes rather than effects or symptoms. The student must therefore be competent to distinguish between cause and effect and the distinction between the two depends on a sound understanding and the correct formulation of scientific concepts. Every action must be justified by a scientific rationale. Jensen and Schnack (1997) imply that scientific investigative actions focused around environmental

problems do have the capability "of influencing causes and not just the effects and symptoms of the environmental problem" through awareness raising and motivation. Thus there is a clear need to explore the local, national, and international issues and find ways of addressing these issues by scientific environmental action.

5.5 Further Research

The appropriateness of amalgamating action competence with Environmental Science in schools needs to be tested so as to evaluate the effectiveness of the revised conception of action in Environmental Science. Schools should be also encouraged to carry out as wide a range of environmental practices grounded in the students' everyday experience in and out of school as possible.

It would be extremely enlightening if a research would be conducted on the words used by the educators while explaining global warming and ozone depletion. The particular words and phrases, such as, "there is a hole" or "there is a layer", chosen by the teacher to help students formulate a framework might in fact be generating misconceptions.

Even the role of the media in the transmission of environmental concepts needs to be studied. Since television, newspapers and internet are sources used by students to develop conceptual frameworks, it would be interesting to know whether what is being explained by these media is correct or being too sensational.

5.6 Concluding Remarks

Environmental Science needs to undergo a transformation to encompass action competence. With the proposed multidisciplinarity, and its groundedness in the development of a value stance, this transformed environmental Science will begin from the position that knowledge is socially constructed, multi-faceted and only partially shared, that there are cognitive, conative, economic, moral, and philosophical aspects to be considered and that there are no certainties, particularly

when it comes to action-taking. The recontextualisation of both social and scientific knowledge offer our future citizens ways of learning that have the reflexivity to bridge the gap between cognition and action.

Students need opportunities which involve the generation of situated knowledge to become scientifically literate and capable in order to develop action-competence. Moreover, scientific concepts taught formally in the classroom should have application in the field in order to help students make sense of whether their actions have the potential to respond to the symptoms of environmental issues, or more importantly, to address the causes.

Such an experience should start from the very early years, therefore in the Primary schools where environmental frameworks will start to form and continue to harden in Secondary schools. For this reason the transformed Environmental Science should be a compulsory programme for all students as without it students would not be exposed to environmental issues. A scientifically literate and environmentally conscious society is a knowledgeable society which has to act responsibly to maintain environmental sustainability. In so doing students would turn into individuals equipped to participate in decision-making processes around societal issues which have a scientific base.

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Appendix One

Global Warming and Ozone Depletion Questionnaire

Put a X where applicable

P1. Gender: **Female** ☐ **Male** ☐

P2. School: **Junior College** ☐ **De La Salle College** ☐ **St. Aloysius** ☐ **Higher Sec.** ☐

P3. Chemistry at SEC Level: **Yes** ☐ **No** ☐

Indicate to what point you agree with the following statements by ticking only ONE box for EACH of the following statements:

Statement	True	False	Don't Know
Ozone Depletion			
1. Ozone is only found in the atmosphere at high altitude.			
2. There is too little ozone at ground level to cause any environmental problems.			
3. Over the past years the amount of ozone in the atmosphere at high altitude has remained the same.			
4. The ozone in the upper atmosphere is beneficial for living things.			
5. Holes in the ozone layer let too much heat from the Sun get through to Earth.			
6. Pollution from burning fossil fuels is destroying the ozone layer.			
7. There is now more ozone at ground level than before.			
8. Pollution has reduced the amount of ozone at ground level.			
9. Ozone at ground level is toxic to living things.			
10. The Sun has nothing to do with the ozone formation in the atmosphere.			
11. Before human intervention, the amount of upper atmosphere ozone naturally changed a lot all over the world.			
12. Car engines emit lots of ozone into the air.			
13. The thinning out of ozone can slowly be 'repaired' by natural processes.			
14. Industrial processes in factories emit lots of ozone directly into the air.			
15. The Sun acting on air pollution makes ozone at ground level.			
16. Ozone is a pollutant which thins the atmosphere to let more ultra-violet light through.			
17. Increased amounts of ultra-violet light entering through the thinner parts of the ozone layer adversely affect human health.			
18. Holes in the ozone layer will never be repaired naturally.			

19.	The thinning out of the ozone layer is contributing to global warming.			
20.	Ozone depletion is a major cause of skin cancer.			
21.	Ozone produced at ground level will help replace ozone high up in the atmosphere.			

		True	**False**	**Don't Know**
Global Warming				
22.	Overall, the Earth has not become warmer during the past 100 years.			
23.	Any warming of the earth that occurs in future won't have much effect on the climate.			
24.	Pollution traps heat entering through holes in the ozone layer to cause global warming.			
25.	Certain gases in the atmosphere act on the planet like the glass in the greenhouse.			
26.	CO_2 level in the atmosphere is an important factor in global warming over which humans have control.			
27.	Gases produced by humans make the Earth warm enough to support life.			
28.	The Earth is warm enough to support life because of a natural greenhouse effect.			
29.	All the energy the Earth gets from the Sun is retained by the planet and its atmosphere.			
30.	Gases produced by humans cause more of the Sun's energy to be trapped in this atmosphere.			
31.	Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'.			
32.	Before Human intervention, the Earth radiated enough of the Sun's energy back into space to remain at the same temperature, on average.			
33.	Burning fossil fuels has increased the amount of CO_2 in the atmosphere.			
34.	Cutting down forests has no effect on the amount of CO_2 present in the Earth's atmosphere.			
35.	By planting new forests, the amount of CO_2 in the atmosphere will be reduced.			
36.	Global warming is caused by a layer of high altitude CO_2.			
37.	Natural global warming may be increased by the CO_2 produced by humans.			
38.	It is certain that present global warming is caused by human activities.			
39.	Global warming may be due to a natural cycle of warming and cooling of the Earth.			
40.	Since global warming may be a natural effect there is no need to take precautions against it.			
41.	If global warming gets worse there will be more flooding.			
42.	If global warming gets worse more people will die of skin cancer.			
43.	If global warming gets worse there will be changes in the world's weather patterns.			
44.	If global warming gets worse there will be more deserts in the world.			

45.	If global warming gets worse some of the ice at the North and South Poles will melt.			
46.	Global warming is made worse because too many of the sun's rays get to the Earth.			
47.	The greenhouse effect is made worse by too much CO_2 in the air.			
48.	The greenhouse effect is made worse by too much ozone near the ground.			
49.	The greenhouse effect is made worse by gas from rotten waste.			
50.	Global Warming is made worse by acid in the rain.			
51.	Global Warming is made worse by holes in the ozone.			
52.	The greenhouse effect is decreased if renewable energy sources are used instead of power stations running on fossil fuels.			
53.	Global Warming can be decreased if unleaded petrol is used.			
54.	Global Warming can be decreased if more trees are planted.			
55.	Global Warming can be decreased if recycled paper is used.			
56.	Global Warming can be decreased if electricity is not wasted.			

57. From where are you getting information regarding global warming and ozone depletion? Mark with an X the three sources mostly used.

Television ☐ Environmental Science lessons ☐ Internet ☐
Newspapers ☐ Magazines ☐ Home ☐ Others☐

Please specify others _____

For questions 58-62, tick ONE statement that you consider the most important.

58. I'd rather walk than use cars...
☐ this may save me money.
☐ it is good for my health.
☐ in this way I keep the air cleaner for everybody.

59. I switch off the television when I'm not watching it....
☐this may save me money.
☐in this way I'm keeping the air cleaner.
☐I concentrate more on other work.

60. When I buy things...
☐I look for those with the least packaging.
☐I look for those with the bulkiest and nicest packaging.
☐I don't bother.

61. I'd rather buy recycled products than new ones...
☐they cost less.
☐less energy was used to produce the recycled products than to produce new ones.
☐I don't do it.

62. I'd rather buy energy saving appliances than normal ones...
☐in this way less fossil fuels are burnt.
☐they last longer.
☐they are more efficient.

63. Any comments...

_____

_____

Thanks for your valuable contribution and good luck in pursuing your studies.

Appendix Two

Interview Questions

1. What can be done to reduce Global Warming and Ozone Depletion?
2. Are they two separate problems or are they linked together?
3. Are the practices that reduce Global Warming the same as those that reduce Ozone Depletion?
4. What can **YOU** do to reduce these problems?
5. Are you doing any of these practices?
6. Why?
7. Why do you think youngsters are so passive about doing something to reduce these problems even though they are conscious that these problems exist?
8. What do you think should be done?
9. Is there anything you would like to add to all this?

Appendix Three

Environmental Science Syllabus Intermediate Level Regarding Global Warming and Ozone Depletion

Part D: *HUMAN ACTIVITIES AND THE ENVIRONMENT*

Human activities have significantly altered the state of the natural environment and possibly some of the processes that sustain it. The following themes are meant to help candidates develop awareness, knowledge and understanding of local and global environmental issues that are related to the impact of humankind on the environment due to emissions of substances from human activities and/or due to the alteration of the environment and the natural processes that sustain life.

The major themes discussed in this section are: 1. Pollution of the Environment; 2. Degradation & Depletion of Natural Resources & Utilisation of Land. Each theme focuses on a number of major issues, which in turn relate to some of the basic concepts in Environmental Science. The themes are complementary to each other and are mainly intended to (a) help candidates view the various perspectives of human environmental impacts, (b) promote an objective and, where possible, quantitative study of the environment, (c) Illustrate ways how people can manage their environment through the use of scientific knowledge, and (d) address the main targets and priorities of sustainable development which relate to the environmental issues listed above.

Theme 1: Pollution of the Environment
Throughout this theme, candidates are expected to be familiar with the following terms and processes: • Pollution: The release of energy or matter into the environment with the potential to cause adverse changes to an ecosystem (ecosphere or biosphere). • Pollutant: A substance or form of energy that when released into the environment may (directly or indirectly) have adverse effects on the biosphere. • General characteristics of pollutants: (*Definition and explanation of each*) i) Mobility. ii) Persistence. iii) Synergistic action. iv) Bioaccumulation. v) Biomagnification. vi) Primary & secondary pollutants. • General characteristics of sources of pollution: (*Definition and explanation of each*) i) Point or diffuse source. ii) Stationary or mobile source.

	warming: a. Salinization b. Rising sea levels c. Flooding of low-lying land d. Species migration and extinction e. Increased evaporation, precipitation & storms f. Change in global climate patterns	lead candidates to acquire knowledge and understanding about the possible scenarios (predictions) which might develop on Earth in the next half century or so. (Since these predictions may change from time to time a specific list would be inappropriate)
Stratospheric Ozone Layer	Ozone depleting gases: a. NO_x b. CFCs	Candidates are expected to be familiar with the sources of these gases and with simple chemical reactions that explain how these react with ozone reducing the ozone shield. Candidates should be capable of comparing stratospheric ozone with ozone in the troposphere as a dangerous pollutant derived from photochemical reactions of primary/secondary pollutants (NO_x) and causing serious damage or death to humans and plants (Impaired lung function; Eye/nose inflammation; Leaf lesions; Impaired photosynthesis).
Smog	Smog formation and composition: a. Formation of smog enhanced by topographic features such as basins or valleys surrounded by highlands. b. The phenomenon of temperature inversion and static air masses. c. Suspended particulate matter from deforestation and incomplete combustion of fossil fuels and organic matter. d. Photochemical smog resulting from formation of secondary pollutants, NOx, VOCs and other hydrocarbons. (*No details of chemical reactions are expected*)	Candidates should become aware of damages caused by smog as well as the chemical reactions that lead to its formation and harmful effects.
	Damages caused by smog: a. Corrosion of buildings. b. Leaf symptoms & reduction in the photosynthetic efficiency. c. Respiratory diseases & reduced lung functions. d. Impacted urban areas, reduction in visibility, damages to vehicles.	A short discussion about the serious problems caused by smog in some major cities and highways/motorways. Candidates should also be aware of abnormal reactions such as the synergistic behaviour of ozone and sulphur dioxide.
Reduction & Control of Air Pollution	Methods of control: a. Alternative fuels b. Catalytic converters	For each method of pollution control, reduction or elimination discussed, candidates should be aware of how the mechanism works (qualitatively) and its major applications. Candidates

Unit 1: Atmospheric Pollution

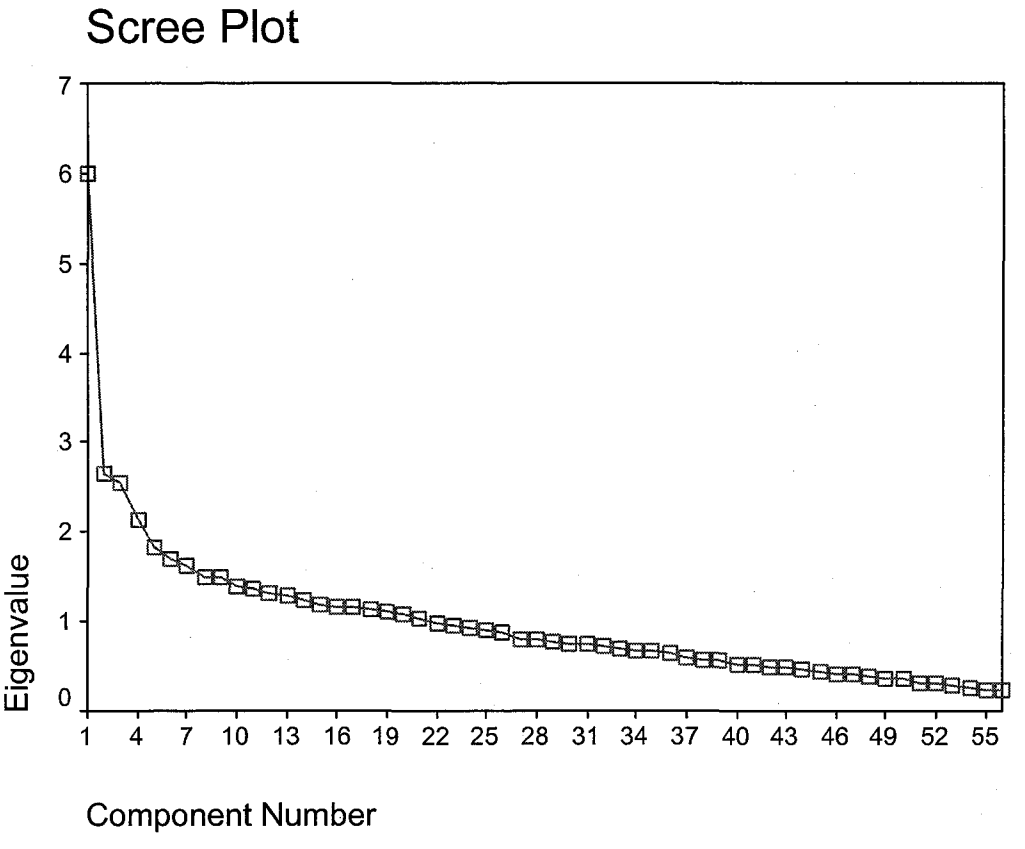
The release of 'wastes', from human activities, that interfere with the dynamic processes occurring in the atmosphere causing problems beyond their source area (long-range transboundary pollution). Consequently, atmospheric pollution must include reference to problems caused on a local, regional as well as global scale.

Topic	*Subject Content*	*Knowledge expected*
Acid Rain	The major acid rain producing substances: a. Nitrous oxides NOx b. Sulphur oxides SOx	The major sources of each pollutant and how it gives rise to acidity in the environment. $SO_3 + H_2O \Rightarrow H_2SO_4$ Atmosphere Lithosphere & Hydrosphere Only a qualitative treatment is required. Knowledge of the intermediate chemical transformations of acid rain will not be assessed. A comparison with natural rainfall acidity highlights the seriousness of the problem.
	The direct and indirect consequences of acid rain: a. Phytotoxicity and damage to vegetation b. Respiratory diseases c. Depletion of plant nutrients d. Acidity in fields, acidification of soils and damage to microbial communities e. Damage to aquatic ecosystems & organisms f. Corrosion of certain building stones (especially limestone), materials & metals (e.g. Aluminium roofs)	Candidates should become aware of the type of damage caused by acid rain and the repercussions of these damages on the environment and on human life. Candidates are expected to know at least one method how to reduce emissions of each of these acidity enhancing agents.
Global climate change as a consequence of atmospheric pollution	Greenhouse gases: a. CFCs b. Methane c. Water Vapour d. Carbon dioxide e. Tropospheric ozone	The greenhouse effect as a natural phenomenon and its importance for life on Earth. Comparison of this phenomenon with the enhanced greenhouse effect due to human activity. Candidates are expected to be familiar with the chemical composition of the greenhouse gases, relative importance to the greenhouse effect and relative quantities expelled into the atmosphere. Candidates should also understand and be able to explain what makes these gases greenhouse gases.
	Sources of greenhouse gases a. Landfills b. Deforestation/fires c. Methane production d. Combustion of fossil fuels e. Propellant, refrigerant gases f. Gut fermentation in intensive livestock production	Candidates should be familiar with the processes which lead to the formation of these gases from the sources mentioned (E.g. Deforestation $C + O_2 = CO_2$)
	Consequences of global	A discussion about consequences of global warming should

	c. Desulphurisation of fuel d. Reduced energy consumption e. Efficiency of energy conversion, improved engines f. Electrostatic precipitators / scrubbers g. Legislation & enforcement	should link the control mechanisms mentioned with specific pollutants (e.g. Electrostatic precipitators for SPM). Since effective controls require legislation & enforcement of law, candidates should be aware of at least one example of an international treaty that has significantly helped to reduce pollution. E.g. Kyoto Protocol, Montreal Protocol, Convention on Transboundary Air Pollution. (*Knowledge of the actual content of the convention/protocol is NOT expected here*) Candidates may also include examples from the local context. E.g. VRT.

Appendix Four

Factor Analysis



Component Matrix

	Component																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
gw33	.571																			
gw53	.555																			
gw45	.519	-.362																		
gw43	.518																			
gw35	.512																			
gw41	.474																			
gw56	.463						-.311											-.428		
gw46	.434								-.307											
gw52	.430			-.303													-.309			
gw42	.426				.381															
gw24	.407										.352									
gw47	.404										.330									
gw30	.395												-.305							
gw51	.385																			
gw32	.384														.341					
od19	.352																			
gw37	.351															.303				
gw26	.350																			
od15	.348	.315																		
od21		.516																		
gw48		.459																		
od9		.318																		
od14			.430		.366	-.326														
gw25	.319		-.383																	
gw50			.376														.314			
od4			-.315																	
od18			.303									.301								
gw55	.460			-.465																
gw31	.364			.438																
gw22				.421				.383												
od7		.404			.476															
gw23					-.403															
gw40					-.354															
od13					-.353															
od11						.447														
gw34						.398		.327		-.351										
gw28	.361						.391													
od16			.336				.386				-.325									
gw29			.338	-.317			.339						.314							
gw27		.305						-.357						.346						
gw44									.386											
gw36	.315									.476										
OD1					-.310					.362										
od21			-.334									.369								
OD2												-.310								
od17	.352												-.431							
od5																				
od12			.341											-.478						
od6			.319					.326						.366						.318
od10															.326	.317				
gw53	.315															.387				
gw38	.335		.303															.463		
gw49	.375																		.423	
od3																			-.338	
od8																				
gw39																				

Extraction Method: Principal Component Analysis.

a21 components extracted.

Factor Analysis Unrotated Loadings of 21 Components

Appendix Five

Common Conceptual Themes for statements in questionnaire elicited by the Varimax Rotated Factor Analysis.

The number in brackets shows the factor loading of each statement (>0.35).

Factor 1: Causes and Consequences of Global Warming

GW25. Certain gases in the atmosphere act on the planet like the glass in the greenhouse. (0.508)

GW30. Gases produced by humans cause more of the Sun's energy to be trapped in this atmosphere. (0.379)

GW31. Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'. (0.440)

GW32. Before Human intervention, the Earth radiated enough of the Sun's energy back into space to remain at the same temperature, on average. (0.431)

GW35. By planting new forests, the amount of CO_2 in the atmosphere will be reduced. (0.457)

GW41. If global warming gets worse there will be more flooding. (0.430)

GW42. If global warming gets worse more people will die of skin cancer. (0.504)

GW45. If global warming gets worse some of the ice at the North and South Poles will melt. (0. 531)

GW46. Global warming is made worse because too many of the sun's rays get to the Earth. (0.426)

GW51. Global Warming is made worse by holes in the ozone. (0. 505)

Factor 2: Personal Responsibility

OD17. Increased amounts of ultra-violet light entering through the thinner parts of the ozone layer adversely affect human health. (0.368)

GW33. Burning fossil fuels has increased the amount of CO_2 in the atmosphere. (0.407)

GW43. If global warming gets worse there will be changes in the world's weather patterns. (0.432)

GW47. The greenhouse effect is made worse by too much CO_2 in the air. (0. 435)

GW53. Global Warming can be less affected if unleaded petrol is used. (0. 504)

GW54. Global Warming can be less affected if more trees are planted. (0.440)

GW55. Global Warming can be less affected if recycled paper is used. (0.693)

GW56. Global Warming can be less affected if electricity is not wasted. (0.580)

Factor 3: Ground Level Ozone

OD7. There is now more ozone at ground level than before. (0.661)

OD9. Ozone at ground level is toxic to living things. (0. 451)

OD15. The Sun acting on air pollution makes ozone at ground level. (0.416)

OD21. Ozone produced at ground level will help replace ozone high up in the atmosphere. (0.586)

GW48. The greenhouse effect is made worse by too much ozone near the ground. (0. 520)

Factor 4: Pollution

OD6. Pollution from burning fossil fuels is destroying the ozone layer. (0.349)

OD12. Car engines emit lots of ozone into the air. (0.430)

OD14. Industrial processes in factories emit lots of ozone directly into the air. (0.619)

OD16. Ozone is a pollutant which thins the atmosphere to let more ultra-violet light through. (0.425)

GW38. It is certain that present global warming is caused by human activities. (0.374)

Factor 5: Skepticism

OD3. Over the past years the amount of ozone in the atmosphere at high altitude has remained the same. (0.472)

GW22. Overall, the Earth has not become warmer during the past 100 years. (0.356)

GW23. Any warming of the earth that occurs in future won't have much effect on the climate. (0. 474)

GW26. CO_2 level in the atmosphere is an important factor in global warming over which humans have control. (0.384)

GW37. Natural global warming may be increased by the CO_2 produced by humans. (0.475)

GW40. Since global warming may be a natural effect there is no need to take precautions against it. (0.536)

Factor 6: The Greenhouse Effect

GW28. The Earth is warm enough to support life because of a natural greenhouse effect. (0.440)

GW29. All the energy the Earth gets from the Sun is retained by the planet and its atmosphere. (0. 497)

GW39. Global warming may be due to a natural cycle of warming and cooling of the Earth. (0.448)

GW52. The greenhouse effect is less affected if renewable energy sources are used instead of power stations running on fossil fuels. (0.445)

Factor 7: Excluding Human Intervention

OD11. Before human intervention, the amount of upper atmosphere ozone naturally fluctuated a lot all over the world. (0.535)

GW34. Cutting down forests has no effect on the amount of CO_2 present in the Earth's atmosphere. (0.509)