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PERCEIVED FRAMEWORKS OF YOUNG PEOPLE ON GLOBAL WARMING AND OZONE DEPLETION

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Abstract. *The learner selects and transforms information, constructs hypotheses and makes decisions, relying on a cognitive structure that provides meaning and organization to experiences and allows the individual to go beyond. Quantitative data regarding concepts formed about global warming and ozone depletion was obtained through a questionnaire administered to 280 Maltese post-secondary students, who had already attended Environmental Science lessons. In depth group interviews were performed with four focus groups to elucidate underlying reasoning. Besides the presence of lacunae in their knowledge, the study revealed that students formulated their own logical, but sometimes incorrect, frameworks through which they could explain the issues. Concept maps elicited from the data show how students erroneously linked global warming to ozone depletion and stratospheric ozone to tropospheric ozone. Recommendations are made on how learners can think how an expert of that particular knowledge domain would think in that particular circumstance.*

Key words: *cognitive frameworks, climate change, learning processes, misconceptions in learning, ozone depletion.*

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Introduction

Two major problems that are significantly challenging sustainability are Global Warming and Ozone Depletion. But,

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

Leighton & Bisanz (2003) focused on how environmental concepts are developed by exploring the formation of perceptions based on theories. These were often referred to as informal or naïve theories and concepts that incorporate theoretical beliefs individuals hold about the world and the link between the perceived components of the world (e.g. Siegler 1998, Wellman & Gelman, 1998). How learners organise knowledge has been a recurrent issue of debate among researchers. The main explanations given include:

- cohesive mental models (Vosnidou and Brewer, 1992);
- fragmented knowledge: when individuals possess disorganised and disjointed information (DiSessa, 1988). When enough information is gathered, mental models that support the construction of cohesive and meaningful knowledge emerge; and
- a hybrid of the previous two models: individuals develop concepts according to the way these concepts are presented to them **(**Lawson, 1988).

Lawson (1988) and Vosniadou & Brewer (1992) imply that conceptual understanding and reasoning follows a path of increasingly evolving models. Naïve beliefs about physical phenomena,

form the basis for cohesive models (Lawson 1988). These can develop into more sophisticated models, and form hybrid / synthetic models (Vosniadou & Brewer, 1992). With a greater supply of information these models may further transform into scientific models that integrate new knowledge with perceived beliefs.

Though children are frequently exposed to issues related to global warming, their conceptions regarding the scope and nature of this phenomenon often have lacunae or are inconsistent with predominant scientific understandings (Meadows & Wiesenmayer, 1999). This lack of complex conceptual knowledge might result in the development of incomplete or inaccurate ideas related to the issue.

In their work with scientific concepts, Lawson *et al*., (2000) found a significant relationship ($p < 0.001$) between conceptual knowledge and developmental level showing that procedural knowledge skills associated with levels of intellectual development play an important role in declarative knowledge acquisition and in concept construction. Learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge (Bruner 1973). The learner, who is at the centre of control, selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure (i.e., schema, mental models) to do so. This provides meaning and organization to experiences and allows the individual to "go beyond the information given".

The educator should understand the current state of understanding of the student, engage in an active dialogue and consequently translate information to be learned. Discovering principles develops a predisposition towards learning. The learner constructs an understanding or perception and though the knowledge domain is specified, the content cannot be prespecified. Information on the issue is gathered from many sources and learners must be encouraged to seek new perspectives. 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 (Bednar *et al*., 1995).

Methodology of Research

General Description of the Research

This study investigated the perceptions and misconceptions of Maltese students following a post-secondary course in Environmental Science with the aim of identifying their conceptual framework and its implications. This study also aimed to identify the main sources of information through which students were learning about the environment. Knowing where the problem lies would provide educators with an opportunity to develop methodologies to address misconceptions (Christidou and Koulaidis 1996, Koulaidis and Christidou 1999).

Sample Selection

The test sample included 280 second year students coming from Malta's four post-secondary schools. The students in test sample had already attended lessons on global warming and ozone depletion as part of their regular Environmental Science programme.

Instrument

The research involved a questionnaire (Appendix 1) that provided quantitative data as regards the concepts formed by Environmental Science students, and an in depth group interview aimed at elucidating any underlying reasoning. The questionnaire was based on previous research (Boyes and Stanisstreet, 1993; Summers *et al*., 2001; Leighton & Bisanz, 2003) and used to explore students' ideas about the greenhouse effect and actions that could reduce it, as well as about the ozone layer and its depletion. The questionnaire was adapted to the Maltese situation and statements that were thought to be ineffective in eliciting any useful information were eliminated. Statements, used in the other studies, targeting a younger age group were also eliminated. The final version of the questionnaire contained

21 statements regarding ozone depletion and 35 statements on global warming. Students were asked to respond True, False or Don't Know to each statement by ticking the appropriate box.

Reliability within the questionnaire was accounted for by testing the questionnaire for internal consistency using Cronbach's alpha coefficient. This refers to the degree to which the items that make up the scale fit together and whether all the statements are measuring the same underlying construct. Ideally, the Cronbach alpha coefficient of a scale should be 0**.**7. This reliability test was run with the data of the questionnaire and the alpha value obtained was 0**.**7933, so the scale can be considered reliable within the sample. The questionnaire was piloted with post-secondary students (aged 17-18 years) who were also asked to comment on the format of the questionnaire and on individual statements.

The analyses of the questionnaire lead to the construction of the interview that was conducted with four groups of ten post-secondary students randomly chosen from different schools. The questions asked were:

1. What can be done to reduce Global Warming and Ozone Depletion?
2. Are Global Warming and Ozone Depletion 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. Is there anything you would like to add to all this?

The interviews were recorded, transcribed and examined for clues that could produce insight into the students' reasoning.

Statistical Analyses

Results from the questionnaire were later encoded and the data was analysed using SPSS (Statistical Package for Social Sciences). Frequencies were used to analyse categorical data obtained from the answers given by the students to the 56 statements in the questionnaire. This is an exploratory procedure that reviewed how different categories of values were distributed in the sample. Pearson correlation was run to find relationships between the different variables. It determines the extent to which the values of the two variables are linearly related to each other. The significance level calculated for each correlation was a source of information about the reliability of the correlation.

The 56 statements of the questionnaire on ozone depletion and global warming were also subjected to Principal Components Analysis (PCA) using SPSS. This technique was applied (1) to reduce the number of variables and (2) to detect structure in the relationships between variables and therefore classify variables. 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-Olkin 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, 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, 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 5 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 32.958% of the variance with Component 1 contributing 6.82% and Component 2 contributing 5.504%.

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).

Results of Research

Students' Perceptions about Ozone Depletion

Out of 21 statements about the issue, only 10 were answered correctly by the majority showing that Environmental Science students still lack scientific knowledge regarding ozone depletion (for the full results see Appendix 1). 57.9% of the students were conscious that ozone is not only found in the atmosphere at high altitude (OD 1) and that it is beneficial to living things (67.1%, OD 4), but 50.7% were unaware that the present levels of ground level ozone are already harming the environment (OD 2) and 62.5% that it is toxic (OD 9). Whereas 85.4% recognized that the amount of ozone has changed over the years (OD10), only 43.6% of the students realized that the level of ground level ozone has increased (OD 7).

While the majority of the students were conscious that the thinning out of the ozone layer can slowly be repaired by natural processes (59.3%, OD 13 and 51.8%, OD18), 51.4% of the students were unaware that ozone produced at ground level will not help replace stratospheric ozone (OD 21). The vast majority (92.1%, OD 17) understood that the amounts of ultra-violet light entering through the thinner parts of the ozone layer, [the latter being destroyed by the burning of fossil fuels (90.7%, OD 6)], adversely affect human health and that the depletion of this gas is a major cause of skin cancer (83.2%, OD 20). During the interviews some students 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.

While students were confused about whether the sun has to act on air pollution to produce ozone at ground level (OD 15), only 45% knew about the role of the sun in the formation of atmospheric ozone (OD 10). There seems to be great misunderstandings about atmospheric ozone and ground level ozone. 52.5% of students considered ozone as a pollutant which thins the atmosphere letting more ultraviolet light through (OD 16). Although students knew that ozone is present at ground level and also high in the atmosphere, they had difficulties in understanding how both are formed and whether they are related.

Students also thought that pollution does not decrease the amount of ozone at ground level (58.6%, OD 8), that car engines do not emit ozone directly into the air (60%, OD 12), but only 41.8% knew that emissions from industries do not include ozone (OD 14). This latter response was confirmed in the interviews: where students tend to believe that the most dangerous and harmful actions are the ones carried out on a large scale by industries, as commented by one of the students:

> *"… it is factories and industries that emit the most harmful gases."* Martin[1]

Furthermore, students considered their actions, as individuals, as having a minimum effect on the environment when compared with what can be done by industries.

The respondents were well aware of the practices that cause environmental problems and they were similarly conscious of what could be done to reduce the crisis. However, it is interesting to note that 83.9% of the students believed that the thinning out of the ozone layer is contributing to global warming (OD 19). In fact during the interviews almost all the students, considered global warming and ozone depletion as being linked giving two "*obvious*" reasons for this conclusion, i.e.:

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." Lisa*
> *"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." Maria*

1 Fictitious names used

One student did not think there is a link between the two issues and tried to explain why, however many confusing ideas emerged thus exposing her true framework:

> *"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 UV light and infra red being absorbed in our atmosphere. We will get the harmful UV from the ozone depletion and the greenhouse effect is from increased 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 a 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."* Maria

The majority of students retained that any practice that reduces global warming is able to reduce ozone depletion. However, one could feel a certain feeling of uncertainty while they were expressing themselves on this issue.

Students' Perceptions about Global Warming

The majority of the students (full results can be viewed in Appendix 2) appreciated that during the past 100 years the Earth has become warmer (87.1%, GW 1). Similarly, the majority understood that global warming will be the cause of climate change (93.9%, GW 2); changes in the world's weather patterns (92.1%, GW 22); melting of the ice caps (91.8%, GW 24) and more flooding (78.9%, GW 20). Nevertheless, there was uncertainty among students as regards an increase in desertification as only 49.6% believed this is possible (GW 23).

The majority of the students were also aware that certain gases in the atmosphere act on the planet like the glass in a greenhouse (82.9%, GW 4). Students knew that carbon dioxide is one of the gases that cause global warming and that humans have control over the emitted gas (66.1%, GW 5; 70.0%, GW 16; 71.8%, GW 17; 80.7%, GW 26) as it results from the burning of fossil fuels (90.7%, GW 12). They also knew that deforestation affects the amount of carbon dioxide in the Earth's atmosphere (87.9%, GW 13 and 80.0%, GW 14). Nevertheless, only 26.4% knew that the carbon dioxide is not found at high altitudes (GW 15) and 35.4% understood that ground level ozone does not cause the greenhouse effect (GW 27).

The questionnaire revealed that students knew about ways of reducing global warming and ozone depletion. So the interviews were utilized to understand what the prevailing approaches were 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 gong the same way."* Carl
> *"We should have better waste management, organizing waste and a more light economy. You will get lower electricity bills in this way too."* Carl
> *"Yes the park and ride system is very helpful to reduce the amount of cars and maybe congestion."* Rachel
> *"Separation of waste and disposal of appliances containing toxic waste in the correct way."* Julian

Students were conscious that precautions have to be taken against global warming (84.3%, GW 19). In addition only 37.9% knew that global warming is a natural cycle through which the Earth passes (GW 18). 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. Although students considered humans as the culprits who produce gases that cause the sun's

energy to be trapped in the atmosphere (71.4%, GW 9), they maintained that these gases are unnecessary to keep the Earth warm enough so as to support life (60.7%, GW 6). Students understood that life on Earth is supported by a natural greenhouse effect (73.6%, GW 7) and only 51.4% of the students understood that not all the energy the Earth gets from the sun is actually retained (GW 8).

The students' belief that global warming is caused by too many sun's rays reaching the Earth (70%, GW 25) is slightly related to OD 5 i.e. that the "*holes*" in the ozone layer let too much heat from the Sun get through to Earth [r=0.142, p<0.05].

The reasoning behind this concept might be that pollution traps heat entering through "*holes*" in the ozone layer to cause global warming (60%, GW 3). This reasoning was also confirmed by 79.3% of the students who implied that global warming is made worse by "*holes*" in the ozone layer (GW 30). There is a slight correlation between the two statements [r=0.217, p=0.000]. Only 34.3% were certain that global warming is not caused by the ozone layer trapping extra heat entering through its "*holes*" (GW 10).

Students felt that skin cancer will increase if global warming gets worse since it is attributed to many sun's rays reaching the Earth. Students were aware that ozone depletion contributes to increases in skin cancer (OD 20) and since most confused ozone depletion with global warming, they seemed to have developed a general belief that ozone depletion, global warming and skin cancer are related (GW 21). There was a small correlation between the two variables [r=0.120, p=0.046].

Confusion about the causes of global warming was also evident by a high percentage of incorrect responses to statements regarding the gas produced by rotten waste (GW 28, 46.3%), acid rain (GW 29, 57.5%) and "*holes*" in the ozone layer (GW 30, 86.1%). Results showed that students considered anything that is environmentally wrong as the cause of any environmental problem.

82.5% of Environmental Science students knew that the use of renewable sources of energy instead of fossil fuels (GW 31), planting more trees (GW 33, the use of recycled paper (GW 34, 70.7%) and not wasting electricity (GW 35, 81.4%) would lead to a decrease in global warming. However, this could be another example of "whatever is good for the environment is good against global warming".

Students also revealed a significant misunderstanding that the use of unleaded petrol would decrease global warming (GW 32, 81.1%). 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).

The results of this research seem to imply that students were formulating a number of alternative conceptions.

Students' Sources of Information

Table 1 demonstrates the main sources of information about environmental issues. The students' primary sources were the Environmental Science lessons (94.6%). Television (62.9%) was a secondary source followed by the internet (41.1%) and newspapers (33.2%). Only 9.3% of the students felt that they were learning about environmental issues from their home.

Table 1. Sources of information by percentage number of students.

Source of information	% Number of students using particular source
Environmental Science lessons	94.6
Television	62.9
Internet	41.1
Newspapers	33.2
Magazines	12.1
Home	9.3
Others	7.9

The practices mentioned by the students during the interviews are vastly highlighted during Environmental Science lessons when the sections about Air Pollution and Sustainability are tackled, for example:

> *"… industries emit a lot of Carbon Dioxide during the production of the things on which their economy is based."* Jean-Claude

In addition (as in Gomez-Granell and Cervera-March, 1993) most of the harmful actions mentioned in the interviews were those frequently mentioned by the media, such as,

> *"Deforestation, burning of fossil fuels by industries, car emissions, use of sprays are all a cause of global warming."* Nicola

Discussion

Student Perceptions about Ozone Depletion

Although the investigation showed an awareness of fairly basic science and factual information, students gave contrasting answers to statements that exposed similar principles (OD 13 and OD18) (OD3 and OD11) (DiSessa 1988) showing that their knowledge was disjoint. Students perceived stratospheric ozone as being beneficial to living things and ground level ozone being toxic when the issues were dealt with separately in the questionnaire. However, when statements linked stratospheric and tropospheric ozone, students are confused and show the presence of lacunae in their knowledge. Therefore they formulated their own logical frameworks through which they could explain the issues.

The incorrect or uncertain answers to the statements demonstrated that students seem to be blocked from assimilating new knowledge because they lack the understanding of complex scientific concepts that would explain how ozone as the pollutant is formed, whether the thinning out of ozone is affecting global warming and how and what is destroying the ozone layer (Meadows and Wiesenmayer, 1999).Therefore, concepts stop evolving.

Conceptual understanding and reasoning follows a path of increasingly evolving models (Lawson, 1988 and Vosniadou & Brewer, 1992). However, this seems not to be happening probably because different aspects pertaining to the same issue are taught in isolation, inhibiting students from visualizing the whole picture thus failing 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 correct 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 at times still incorrect framework.

Conceptual Framework Based on Students' Perceptions

Overall the conceptual framework in Figure 1 gives a 2-dimensional representation of a number of critical concepts related to ozone. The purpose of this concept map was to organise the major concepts considered essential to understanding the students' reasoning regarding ozone. It also clearly indicates the supposed link between ozone the pollutant and stratospheric ozone and the students' perception that associates ozone depletion with global warming.

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.

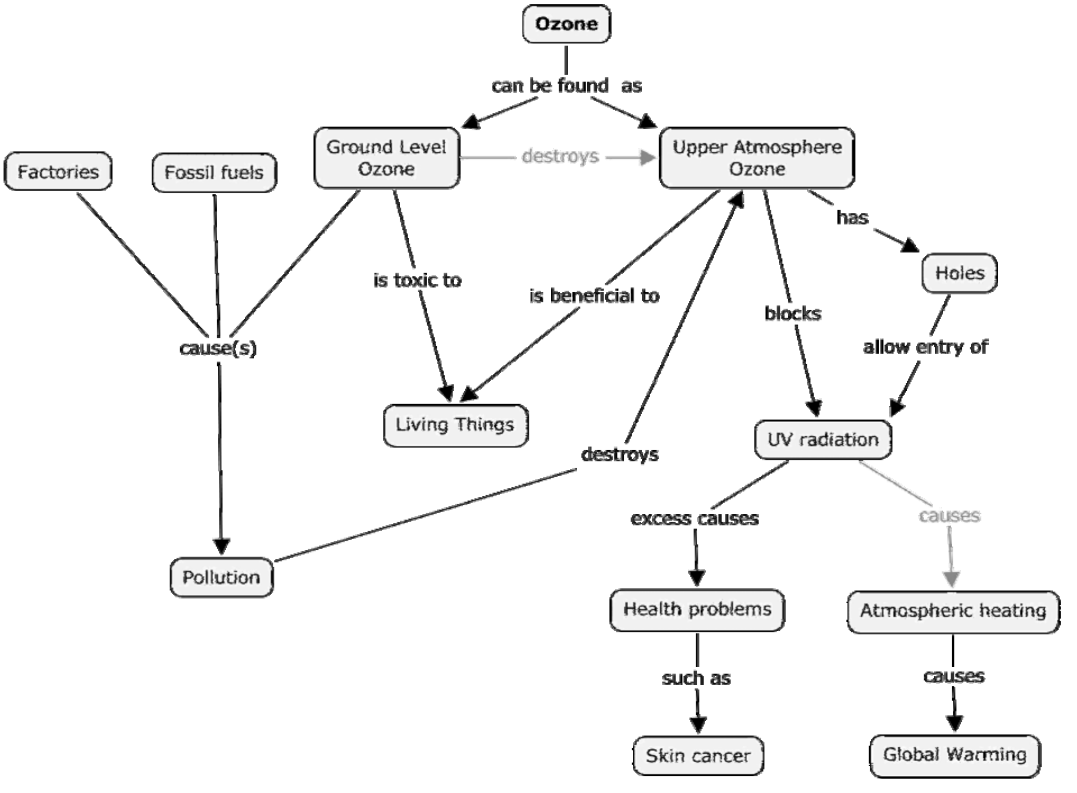

Figure 1: Conceptual framework related to ozone.

Students' Perceptions about 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 (as confirmed in this study), some misconceptions found in very young students seem to remain embedded and are in fact found in older students. For example, the idea that the use of lead-free petrol will reduce global warming featured quite frequently among the Environmental Science students investigated (GW 32, 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 a valid strategy in reducing 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 (also 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. Boyes and Stanisstreet (1993) further explain that another general logical fault seems to 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 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 students have, including their encounters with media and fragmentary information they gather from

various sources, 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. 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.

The Link between Global Warming and Ozone Depletion

About three-quarters of the students thought that more people will die of skin cancer if global warming gets worse (GW 21). This persistent misconception (also reported in Boyes and Stanisstreet 1993) shows a hidden link students created in their minds between global warming and an effect of ozone depletion. A subconscious mental link seems to be created between the perils of extensive sunbathing (i.e. exposure to UV radiation) and warm sunny days (as a result of global warming).

To the majority of students, this link would seem sensible and logical (Boyes and Stanisstreet, 1993, Boyes and Stanisstreet, 1994, Groves and Pugh, 1996 & 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.

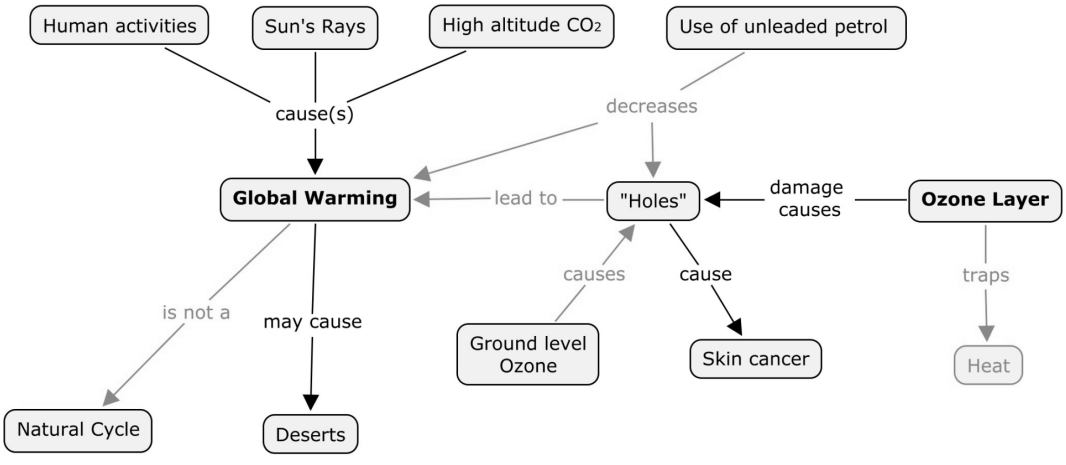

Figure 2: Conceptual framework that links Global Warming to Ozone.

The perceptions that resulted from the analysis (Figure 2) showed that Environmental Science students believed that the depletion of ozone created "*holes*" 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 the blending of ideas about global warming and ozone depletion.

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.

Implications for Education for Sustainable Development

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. Consequently, education for sustainable development programmes need to span all levels of formal education as well as be a regular feature in the non-formal and informal sector (Briguglio and Pace, 1994).

Learning needs to be placed in a rich context that reflects the real world giving rise to authentic learning situations permitting the transfer of knowledge beyond the classroom (Bednar *et al.*, 1995). 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). 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. The main characteristics of this learning strategy include:

(a) ***A focus on the learner***: focusing on the process of knowledge construction and the development of reflexive awareness of that process (Bednar et al., 1995).

(b) ***Specification of objectives***: seeking authentic tasks and letting the more specific objectives emanate and be realised as the learner in solving the real task.

(c) ***A conducive environment***: encouraging understanding from multiple perspectives. Learning always takes place in a context and the context forms an inexorable link with the knowledge embedded within it. Spiro et al., (1988) argue that environments do not have to be simplified (as 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.

(d) ***The strategy of multiple perspectives***: learning to construct multiple perspectives on an issue and that learners can make the best case possible from each one (Bednar et al, 1995).

(e) ***Evaluating constructively***: examining the thinking process to improve the ability to use the content domain in authentic tasks (Brown, Collin and Duguid, 1989).

Therefore, all teachers must gain a sound background about issues concerning sustainable development. It is extremely important that the educator does not propagate any wrong concepts especially at the lower levels of formal education where concepts start to be constructed ready to support 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 and ensure that they present correct environmental issues during their lessons. Cordero (2001) maintains that if teachers do not feel comfortable in their own understanding of these topics, their students may never have the opportunity to thoroughly explore these issues.

As part of their pre/in-service training teachers of any level and subject area need to experience and experiment with the constructivist approach in organised workshops while dealing with authentic environmental issues. This would provide them with first hand experience, familiarity and confidence to do the same in their respective classes.

Adult learning is a central tool in the process of raising environmental awareness and promoting environmentally supportive action. 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 leading to a situation where the environ-

mental dimension has become increasingly important and can hardly be ignored in education efforts committed to social and political goals.

Adult environmental education goes beyond creating understanding and awareness and aims at developing skills, creating a sense of commitment and stimulating individual and collective action. Community relevant 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.

Conclusion

The concepts related to current ecological crises should engage students with real life issues that are analysed within social and cultural contexts in order to make valid judgments. An effective Environmental Science curriculum should include a set of organized experiences aimed at helping students develop correct environmental concepts. The results reported in this study can be used to help the teacher in the selection of concepts and how they can be sequenced in meaningful ways. 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.

It is 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. This implies a paradigm shift in science education based on constructivism. The educator can help students:

a) identify authentic issues;
b) conceptually analyse scientific knowledge related to these issues;
c) determine their existing knowledge regarding these issues; and
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 facilitated. 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.

Students need opportunities which involve the generation of situated knowledge 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 learning opportunities should start from early childhood when environmental frameworks will start to develop.

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Appendix 1: Distribution of responses of Maltese post-secondary Environmental Science students to statements concerning Ozone Depletion (*Bold figures show the highest frequency. Shaded box denotes the correct answer to the statement***).**

Ozone Depletion [OD] Statement	% True	% False	% Don't Know
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

Appendix 2: Distribution of responses of Maltese post-secondary Environmental Science students to statements concerning Global Warming (*Bold figures show the highest frequency. Shaded box denotes the correct answer to the statement***).**

	Global Warming [GW] Statement	% True	% False	% Don't Know
1.	Overall, the Earth has not become warmer during the past 100 years.	6.8	**87.1**	5.7
2.	Any warming of the earth that occurs in future won't have much effect on the climate.	2.5	**93.9**	3.6
3.	Pollution traps heat entering through holes in the ozone layer to cause global warming.	**60**	23.6	16.4
4.	Certain gases in the atmosphere act on the planet like the glass in the greenhouse.	**82.9**	5.7	11.4
5.	CO_2 level in the atmosphere is an important factor in global warming over which humans have control.	**66.1**	19.3	14.6
6.	Gases produced by humans make the Earth warm enough to support life.	13.2	**60.7**	26.1
7.	The Earth is warm enough to support life because of a natural greenhouse effect.	**73.6**	13.2	13.2
8.	All the energy the Earth gets from the Sun is retained by the planet and its atmosphere.	31.1	**51.4**	17.5
9.	Gases produced by humans cause more of the Sun's energy to be trapped in this atmosphere.	**71.4**	11.4	17.1
10.	Global warming is caused by the ozone layer trapping the extra heat entering through its 'holes'.	52.9	34.3	12.9
11.	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
12.	Burning fossil fuels has increased the amount of CO_2 in the atmosphere.	**90.7**	5.4	3.9
13.	Cutting down forests has no effect on the amount of CO_2 present in the Earth's atmosphere.	8.2	**87.9**	3.9
14.	By planting new forests, the amount of CO_2 in the atmosphere will be reduced.	**80.0**	13.6	6.4
15.	Global warming is caused by a layer of high altitude CO_2.	**41.4**	26.4	32.1
16.	Natural global warming may be increased by the CO_2 produced by humans.	**70.0**	15.0	15.0
17.	It is certain that present global warming is caused by human activities.	**71.8**	18.6	9.6
18.	Global warming may be due to a natural cycle of warming and cooling of the Earth.	**37.9**	36.8	25.4
19.	Since global warming may be a natural effect there is no need to take precautions against it.	7.5	**84.3**	8.2
20.	If global warming gets worse there will be more flooding.	**78.9**	10.4	10.7
21.	If global warming gets worse more people will die of skin cancer.	**74.6**	16.1	9.3
22.	If global warming gets worse there will be changes in the world's weather patterns.	**92.1**	5.0	2.9
23.	If global warming gets worse there will be more deserts in the world.	**49.6**	25.0	25.4
24.	If global warming gets worse some of the ice at the North and South Poles will melt.	**91.8**	4.3	3.9
25.	Global warming is made worse because too many of the sun's rays get to the Earth.	**70.0**	21.1	8.9
26.	The greenhouse effect is made worse by too much CO_2 in the air.	**80.7**	7.5	11.8
27.	The greenhouse effect is made worse by too much ozone near the ground.	26.4	35.4	**38.2**
28.	The greenhouse effect is made worse by gas from rotten waste.	**55.7**	16.4	27.9

Global Warming [GW] Statement	% True	% False	% Don't Know
29. Global Warming is made worse by acid in the rain.	35.0	**42.5**	22.5
30. Global Warming is made worse by holes in the ozone.	**79.3**	13.9	6.8
31. 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
32. Global Warming can be decreased if unleaded petrol is used.	**81.1**	9.3	9.0
33. Global Warming can be decreased if more trees are planted.	**82.5**	8.2	9.3
34. Global Warming can be decreased if recycled paper is used.	**70.7**	15.4	13.9
35. Global Warming can be decreased if electricity is not wasted.	**81.4**	8.6	10.0

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