DESIGNING, IMPLEMENTING AND EVALUATING
A
SCIENCE-TECHNOLOGY-SOCIETY (STS)
TEACHING RESOURCE PACKAGE
ON
AIR POLLUTION

VOLUME 1

Margaret Dawn White

A thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

October, 1998.

DECLARATION

I declare that this thesis is my own work completed under the guidance of my supervisors, Professor J. D. Bradley and Mrs M. Brand. It is submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

(Signature)

26 th Day of October 1998

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to:

- My supervisors Professor John Bradley and Mrs Marie Brand for the many hours they spent reading, discussing and guiding me on aspects of the resource package and thesis.

- Professor Gus Gerrans for his advice in the development of the resource package and the early drafts of the thesis.

- SASOL for the generous sponsorship of the development of the resource package.

- Mr Andrew Samson, Mr Peter Fridjhon and Mr Mike Stanton for their assistance and advice in the statistical analysis of some of the data.

- The teachers and students for allowing me and the resource materials to intrude into their classrooms and busy schedules. Without the serious and committed participation of the teachers striving to implement and evaluate parts of the resource package, this thesis would not have been possible.

- To my friends and colleagues Mrs Mina Staskun, Dr Marissa Rollnick and Mrs Gail Green for their ongoing interest in the progress of the thesis and their encouragement to complete it.

- Finally to my family Dave, Neil, Lindsay and Patch for their patient and steady support over the years while the development of the resource package and thesis was in progress. Special thanks to Dave for explaining some of the complexities of statistical analysis to me, for the hours spent proof-reading the final manuscript and for learning to cook such delicious meals while I was "otherwise occupied"!

ABSTRACT

Curriculum change is accompanied by the need for new teaching materials. The proposed introduction of an optional topic: Air Pollution, in standard 9 physical science in South African schools in 1993, prompted the research into the design, implementation and evaluation of a teaching resource package for this topic. The controversy, uncertain consequences and interrelationship of science, technology and society that characterise many of the issues in an environmental topic like air pollution, presented an ideal opportunity for an STS (Science-Technology-Society) approach to be used in the resource materials.

A trial implementation of the resource package was conducted in a sample of urban and rural schools. Valuable insights were gained with regard to the factors which impacted on the implementation of the resource package. At several schools the teaching materials were very successfully implemented. At other schools where the implementation did not proceed as planned, the outcomes provided rich feedback as to some of the complexities and realities of science classes in South African schools.

The resource package was evaluated by

- some experts from a range of disciplines
- the teachers in the sample of schools selected
- a comparison of the students' responses to the administration of a Survey on Air Pollution as a pre- and post-test

Favourable ratings of the resource package were provided by all the experts and most of the teachers. The administration of the Survey as a pre-test revealed that, in general, teachers and students were ill-informed about the topic. After using the resource materials, there was statistically significant improvement in students' knowledge about air pollution. Students also became more aware of and concerned about air pollution; their outlook about some issues became more balanced and there was an improvement in students' scientific literacy with regard to air pollution.

The outcomes of this research into small-scale curriculum change are relevant as they

- suggest ways of improving the poor scientific literacy of South African school students and citizens (as identified by the Human Sciences Research Council and the Foundation for Research Development).
- warn that the vast curriculum changes in South African education, as proposed in *Curriculum 2005*, should be embarked upon with caution.

SUMMARY OF CONTENTS

TABLE OF CONTENTS

INDEX TO FIGURES

INDEX TO TABLES

CHAPTER 1

INTRODUCTION AND MOTIVATION FOR THIS RESEARCH

1.1. INTRODUCTION

Science-Technology-Society (STS) education consists of many different strands. Each strand is shaped by the needs of the society in which it grows (Pedretti and Hodson, 1995). This thesis focusses on the development of such a strand. It describes the processes of materials design, trial implementation and evaluation that were prompted by the planned introduction of an STS topic on Air Pollution into some South African schools. Broad outcomes of all three processes are described and analysed. Both quantitative and qualitative methods of research were used in the analysis of the outcomes. Care has been taken to report all findings in the complex mix of planned and unplanned events in this study and not simply to report those results that were desired or that were statistically significant. Some of the outcomes have been related to the different school contexts in which they occurred in an effort to gain a deeper understanding of their origins.

The field work for this research was conducted in 1991 in anticipation of important national curriculum changes (Department of Internal Affairs, 1985). These never materialised because they were overtaken by political changes. However the development of the teaching resource and some of the outcomes of its implementation and evaluation in a sample of schools, have renewed relevance to the new national curriculum changes for South Africa which have just begun, and to the recent findings of the Human Sciences Research Council (HSRC, 1998) and the Foundation for Research Development (FRD, 1996) that South African school students and citizens are ill-informed about science, technology and environmental issues.

1.2. MOTIVATION FOR THIS RESEARCH

1.2.1. The Need for Change in Current School Science Curricula

In South Africa, physical science is an unpopular subject especially at secondary school level. Relatively few pupils choose it as a matriculation subject (Kahn, 1995). In addition there has been a shift away from science at a tertiary level (HSRC, 1981; Kahn, 1995; SAATPS, 1978). This trend is in keeping with that perceived in many other countries (Holbrook, 1992; Huang, 1992; Solomon, 1992; Yager, 1992a; Yager and Penick, 1987). Apart from the poor quality of science teaching, outdated and irrelevant school science curricula have been identified as a major cause of this trend (Ajeyalemi, 1992; Holbrook, 1992; HSRC, 1981; Huang, 1992). In such curricula, science is portrayed as a *"detached, intellectual activity principally concerned with learning facts and carrying out certain procedures in the laboratory"* (SAATPS, 1978). The emphasis is on content which must be learned without question. Highly abstract ideas abound. Instruction is teacher- and textbook-centred (Yager, 1992a). There is little opportunity for students to offer their own opinions or contribute creatively (Gerrans, 1986; Yager, 1992a). Science has gained a reputation of being a difficult subject with only the more intellectually-able students coping with it successfully (Han, 1992; Holbrook, 1992). Many students report that science makes them unhappy (Huang, 1992). Knowledge gained under these conditions does not appear to be easily related to further studies or issues after students have left school (Yager, 1992b). A negative image of science is further enhanced by the media (Holbrook, 1992). Science and technology are labelled as the principal consumers of dwindling resources and the chief degraders of the environment (Hill, 1991). A balanced picture of the complex role played by science and technology in society is not presented - the significant improvement in the quality of our lives due to science and technology is not given the same coverage.

The focus of science education has been upon producing engineers and scientists for research. Education for citizenship in an industrial and technological society has been ignored (Trowbridge and Bybee, 1990). Science and technology play major roles in the lives of citizens in industrial nations. In developing countries, like South Africa, science and technology will play rapidly increasing roles because of the transition of many people from rural to urban environments. This transition will be accompanied by an increase in the demand for scientists, engineers and technologists. In the light of this increased demand, the decline in the popularity of science and science-related careers is alarming. Scientists, and science educators, have a responsibility to improve the prestige of science and to educate in a clear, accurate and relevant manner (Pimentel and Coonrod, 1987). Science, with its emphasis on evidence and its demand for impartial interpretation should play a key role in future decision-making (Hill, 1991). At present, school science curricula do not reflect the problems and challenges facing humanity. The science learned in the classroom **must** be relevant to the home, society, technology, industry, and the environment. In years to come, the public will become more involved in critical decision-making (Trowbridge and Bybee, 1990). Therefore, in addition to producing scientists and technologists, science curricula should be aimed at producing members of society who are able to evaluate the risks and benefits of technology and make well-informed, balanced decisions. The more people know and understand, the less likely they are to fear, reject and condemn possibilities when making decisions (Kornberg, 1991).

Changes in school science curricula are thus essential (Ajeyalemi, 1992; Hill, 1991; HSRC, 1981; SAATPS, 1978). Indeed, in many parts of the world, curricula have been or are being revised (American Chemical Society, 1988).

1.2.2. The Need for Teaching Materials Relevant to the South African Context

In South Africa, the proposed inclusion in 1993 of an optional topic: Air Pollution, in the standard 9[1] Transvaal[2] Education Department Physical Science syllabus, represented one of the first tentative but concrete steps in the direction of curriculum change in South Africa. This created the urgent need for teaching materials for the new topic, since most science teachers in South Africa have little or no background to teach such a topic. Furthermore, it is difficult to gain the background knowledge and find teaching activities as information is spread over a wide range of sources. Although there are some resource materials that have been developed internationally, these lack relevance to the South African context. This is what initially motivated the researcher to undertake the present study.

---

1 In South African schools, standard 9 is the eleventh year of schooling.

2 The former Transvaal Province is now no longer in existence. The schools in the urban sample used here are in the present Gauteng Province.

1.2.3. The Importance of Learning About Global Change and the Environment

Apart from the wish to meet this urgent specific need, the topic: Air Pollution seemed highly suitable for more general reasons. Improving the quality of the environment is one of the most important tasks that faces humanity in the future (Kornberg, 1991). Thus environmental topics are at the forefront of scientific investigation and public concern (Hill, 1991). In a survey, Project *Ecos (1991), many South Africans rank* pollution and especially air pollution, as one of the greatest threats in the future. In the same survey, many people note that they feel that the education system has failed when it comes to environmental awareness. There is a need for more information. This lack of understanding of environmental issues and their relationship to science and technology is further revealed in a study conducted by the Foundation for Research Development (FRD, 1996).

The FRD reports that in a natural and environmental sciences literacy survey, South African citizens appeared ill-informed. South Africa was ranked 18th out of 20 nations participating in the study on items which tested people's knowledge of basic scientific and environmental facts. In a further 5 items which determined people's attitudes to science and technology, South Africans were generally negative towards science and technology. A study of the responses of the various demographic groups in South Africa revealed that Africans (the majority group) are the most negative about science and technology.

Similarly, the HSRC (1998) reveals that in the Third International Mathematics and Science Survey (TIMSS) conducted on final-year school students in 1995, the performance of South African students on items which assessed scientific literacy was significantly lower than that of students from the 21 other countries taking part in the survey.

1.2.4. The Suitability of an Environmental Topic for STS Education

Environmental topics are ideal for presenting science as a real and relevant subject. In a study of the topic: *Air Pollution, the atmosphere* becomes the "reaction vessel" instead of a test tube in a laboratory. Students do not approach this subject as "blank slates" (Driver et al, 1985). Students come to the classroom with prior knowledge gained largely via the media. Attitudes and beliefs concerning the problem are well-entrenched. This can lead to lively debate where students offer opinions and arguments. The negotiation for balanced solutions depends heavily on an understanding of terminology, scientific principles and concepts. Science and technology play complex roles in air pollution: on the one hand, technology contributes to the problems of air pollution but on the other hand technology vastly improves the quality of life and provides the tools to detect, assess and reduce air pollution. The uncertainties and controversies regarding issues such as the increased concentration of greenhouse gases in the atmosphere, or damage to forests by acid rain indicate that science does not have all the answers - there is still much room for conjecture, experimentation and theorising. The search for solutions is crucial for survival. This search involves the interrelating of knowledge from disciplines such as geography, physics, geology and biology. The compartmentalisation of knowledge has to be broken down.

A study of air pollution can help to reveal that science is a human activity. Errors are sometimes made eg. programming the Nimbus satellite to disregard certain readings. Ideas change or are modified eg. chlorofluorocarbons (CFCs) are no longer thought of as harmless and unreactive. Scientists do not work in isolation. Ideas are shared and communicated eg. the study of the depletion of stratospheric ozone involved the laboratory investigations of Rowland and Molina, the groundwork of Farman and the cooperation of National Aeronautical and Space Administration (NASA) scientists. These insights help to "demystify" science. They remove it from the abstract realms of the "scientific method" and place science within the reach of us all.

1.2.5. The Need for Research into the Implementation and Evaluation of New Curricula and Teaching Materials in South Africa

Great difficulties have been experienced in the implementation of some new curricula and teaching materials. This is largely because the developers of such curricula and materials have had over-optimistic expectations about the capacity of teachers and students to cope with the change. Problems associated with implementation are particularly great in developing countries with scarce resources and a shortage of qualified teachers (Lewin, 1992; van den Hoek, 1997; Walberg, 1991).

South Africa is a developing country. Approximately 50% of teachers in South Africa are underqualified (Kahn, 1995). Many schools have poor facilities and classrooms are over-crowded. English is not the mother-tongue of the majority of the teachers and students. There is a shortage of resources for providing teaching materials and equipment and for preparing and supporting teachers to cope with the demands of curriculum change. Many teachers lack the confidence and flexibility required for the successful implementation of STS curricula - they are set in their ways. Such teachers are insecure about moving away from familiar textbooks to a variety of new teaching materials (Ajeyalemi, 1992).

Although research into science curriculum change in South Africa is starting to emerge (van den Hoek, 1997), South Africa does not yet have a substantial body of research which provides insights into the interactions of teachers and students with new curricula and teaching materials (CEPD, 1995). Most of the research literature reports on implementation and evaluation studies in schools in developed countries (Lewin, 1992).

In this situation, great value lies in developing small teaching modules on topics in curricula which can be piloted and evaluated in a sample of representative schools before being introduced more widely (CEPD, 1995; Walberg, 1991). Such research would inform the promoters and designers of new curricula and teaching materials. The findings of such research could assist in the development of training and support programmes for teachers which would facilitate curriculum change. In this way, the introduction of new curricula and teaching materials in the future could be based on an in-depth understanding rather than on idealistic hopes (CEPD, 1995). This belief underpinned the present research.

1.3. THE RELEVANCE OF THE OUTCOMES OF THIS RESEARCH FOR:

- **CURRICULUM CHANGE AND**
- **IMPROVING SCIENTIFIC LITERACY IN SOUTH AFRICA**

South Africa has undergone considerable political transformation since the field work for this research was conducted in 1991. This political change has been accompanied by a strong drive for curriculum changes in the schools. Thus the curriculum changes proposed for 1993 were not implemented. During 1997, the new government announced fundamental and far-reaching changes in the national school curriculum from grades 1 to grade 9. A broad new curriculum framework, *Curriculum 2005,* emerged (Department of Education, 1997a) which is being phased in from the start of 1998. In addition, a framework for the transformation of further education and training from senior secondary school (grades 10-12) through vocational education and training to adult education, has been developed in the *Report of the National Committee on Further Education* (Department of Education, 1997b).

Scientific literacy is a crucial intended outcome of the new curriculum. This correlates closely with the recommendation of the FRD (1996) that nationwide scientific literacy campaigns be developed to improve the South African public's understanding of environmental issues and to improve the negative image the majority of South Africans have of the role played by science and technology in these issues. The HSRC (1998) likewise advises that if South Africa is to participate successfully in a world in which science, engineering and technology are becoming increasingly important then ways must be found of improving scientific and technological education.

The sweeping curriculum changes, as proposed in *Curriculum 2005,* and the need for the development of scientific literacy campaigns, as advised by the FRD and HSRC, will be viewed in the light of the outcomes of this research.

CHAPTER 2

A LITERATURE REVIEW OF SCIENCE-TECHNOLOGY-SOCIETY (STS) EDUCATION

This review focusses on:

- **What is STS Education?**

  A brief history tracks the relationship between science, technology and society over the past 500 years and the emergence of STS education. The rationale and strategy for STS education are considered and various criticisms of STS education offered.

- **The Design of STS Curricula and Materials**

  STS education initiatives in some developed countries, Africa in general and South Africa in particular, are reviewed. Some features of designing STS teaching materials are considered.

- **The Implementation of STS Curricula and Materials**

  Reasons for the unsuccessful implementation of STS materials and curricula are suggested and possible solutions sought.

- **The Evaluation of STS Curricula and Materials**

  Evaluating STS curricula and materials is complex. Some approaches and their shortcomings are considered. The importance of evaluation to developers of STS curricula and materials is highlighted.

2.1. WHAT IS STS EDUCATION?

2.1.1. A Brief History of the Relationship between Science, Technology and Society

The International Perspective

Over the past 500 years, links between science and society have been forged and broken a number of times (Aikenhead, 1994a; Solomon, 1994a). Science had its origins in natural philosophy. At the time of the Renaissance, natural philosophers freed their observations and ideas of nature from the restrictions of religious domination that had been previously imposed on them (Aikenhead, 1994a). During the 15th and early 17th centuries, their knowledge was sought after and discussed by a wide range of citizens (Jenkins, 1990). However, in the latter part of the 17th century the unstable aftermath of the Reformation brought about a new social order. Curbs were once again placed on natural philosophers by the new social and religious leaders. These restrictions ensured that the focus of natural philosophy was on abstract, objective knowledge. Contentious issues such as politics, religion and morals were excluded from the realm of these philosophers. During the 17th and 18th centuries natural philosophy gave way to "science" and scientists proceeded to separate themselves even more from the general public. Strict controls were placed on access to the science profession (Aikenhead, 1994a). By the 19th century, even prominent engineers were excluded from the scientific circle. Technology was perceived as "applied science" and became divorced from "pure science". As Solomon (1994a) writes,

"It (the system of science) *had divided the making of instruments and machinery from the thinking about them, just as it had divided those who might advance scientific thought and those who would "only" make technical devices. Most of all science ignored those members of society who simply used the prevalent technology. "* (page 5)

This separation of science from the lay public coincided with the formalisation of schooling and more specifically that of science education. Science became taught as a body of disconnected knowledge which was rote-learnt (Jenkins, 1990). The purpose of school science education became to prepare students for university science education (Aikenhead, 1994a).

During the 20th century, the two World Wars and Hiroshima in particular, reformed the links between science and technology and focussed public attention on the scientific enterprise once again (Solomon, 1994a). The alarm at the launching of Sputnik in 1957 brought about drastic science curriculum reform in the USA and later in the UK (Walberg, 1991). The goal of these reforms was technological supremacy (Volk, 1984). In the drive to produce more scientists and engineers, the role model for science education was the **research scientist** (Fensham, 1988). The theme *"Science as Inquiry"* was central to the curricula with the emphasis being to emulate the processes and techniques practised by the scientific community (McIntosh and Zeidler, 1988). The school science curriculum was discipline-based, laboratory-centred and textbook-orientated (Ramsey, 1993). The focus was on academic science. The needs of ordinary citizens were not met (Trowbridge and Bybee, 1990).

Significant scientific and technological advances were made during the 1960s and 1970s. At first this was welcomed by the public as it offered visions of health and prosperity (Kornberg, 1991; Volk, 1984). The degradation of the environment that accompanied some of these advances turned the optimism into dismay, fear and hostility (Carson, 1962; Fleming, 1989; Kornberg, 1991). The public felt that science and technology were controlled by the "experts" alone (Fleming, 1989). There was a gap between school science and the realities of a scientific and technologically oriented society (Hart and Robottom, 1990). During the mid 1970s the public perception and support for science reached an all-time low (Kyle et al, 1988; Yager and Penick, 1988). Dissatisfaction came from within the scientific community and society as a whole. There was an urgent need for reassessment and the search for new goals in science education (Hart and Robottom, 1990; Zoller et al, 1990).

In the USA, Project Synthesis in 1978 was the culmination of many attempts to restructure science education. A nation-wide team of science educators headed by Norris Harms recommended that science education should not only meet the academic needs of students wanting to follow scientific careers but should also meet the personal and societal needs of citizens living in an increasingly scientific and technological world. Four broad goals for the new curriculum framework were identified (Volk, 1984):

I. Personal Needs - to prepare individuals for using science in improving their own lives and coping in a technological world.

II. Societal Needs - to produce informed citizens prepared to deal with science-related societal issues.

III. Academic Needs - to prepare students adequately to follow careers in science and engineering.

IV. Career Awareness - to give an awareness of the nature and scope of scientific and technological careers.

Considerable similarities existed between these goals and five broad objectives decided upon by a number of environmental leaders who met in Tblisi, Georgia, USSR in 1977 to establish goals for environmental education (Hammerman and Voelker, 1987; Volk, 1984). The five broad objectives were:

1. Awareness - to help social groups and individuals acquire an awareness and sensitivity to the environment and its problems.
2. Knowledge - to help social groups and individuals gain a variety of experience in and acquire a basic understanding of the environment and its problems.
3. Attitudes - to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
4. Skills - to help social groups and individuals acquire the skills for identifying and resolving environmental problems.
5. Participation - to provide social groups and individuals with an opportunity to be actively involved at all levels in working towards resolution of environmental problems.

The name Science-Technology-Society (STS) became used for the education reform taking place. This name is probably attributable to the collection of papers published under the name *"Science Technology and Society"* by Spiegel-Rosing and Price in 1977 (Solomon, 1988). However an earlier analysis of the interactions of science, technology and society was also presented by Bertrand Russell in the book *"The Impact of Science on Society"* published in 1952 (Trowbridge and Bybee, 1990).

Progress in the development of an STS approach in science education was accelerated by position papers from the National Science Teachers' Association (NSTA) (*"STS: Science Education for the 1980s"*) and the National Council for the Social Studies (*"Position Statement and Guidelines for the Teaching of Science - Related Social Issues"*) (Waks and Barchi, 1992).

The late 1970s and the 1980s saw the development of new science curricula and materials in Europe, Britain and America with an STS thrust (Aikenhead et al, 1987).

The African Perspective

Western science introduced into Africa has been in great conflict with the socio-cultural background of the people (Jegede, 1997). Jegede states that African cosmology is *"anthropomorphic, monistic-vitalistic and metaphysical"* (page 7). This cosmology is secretive, interpreted as magical and closely related to traditional religion. In contrast Western science is a public activity and divorced from religion. It is exact and is based on mechanistic laws, principles and theories (Jegede, 1994).

The African culture of learning is also very different. The exchange of ideas in the African context has been typically oral. The elders with their greater experience of life are perceived as the authorities. The more youthful learners play a passive role and do not question or challenge the ideas of the elders (Jegede, 1997).

As a natural consequence of Western science being adopted, the science teaching in Africa became (and has remained) based to a large extent on curricula, syllabi, textbooks and examination systems imported from developed countries in the West (Ajeyalemi, 1990; Fensham, 1988; Nganunu, 1988; Walberg, 1991). In addition science education in Africa has been distorted towards "high science" aimed at the identification and development of a very small fraction of academic students who would continue with science at a tertiary level.

There are vast differences in the context in which these science education imports find themselves. Many African countries are amongst the poorest and least industrially and technologically developed countries in the world (Ajeyalemi, 1990). The lifestyle of the majority of the people is still rural. Sociopolitical upheaval is common (Ogunniyi, 1986). Schools are overcrowded, poorly equipped and staffed by underqualified teachers (Ajeyalemi, 1990).

These cultural and contextual differences discussed above have led to *"collateral learning"* (Jegede, 1997). Students in Africa have developed parallel western and traditional understandings of scientific phenomena. Students deliver scientific explanations when called upon to do so in the school context but revert to traditional understanding and explanations in many other situations outside the classroom.

However Africa is part of the global community where science and technology play a vital role in economic growth and development (Jegede, 1994). Thus it is imperative that citizens in Africa become scientifically and technologically literate. Walberg (1991) indicates that "*...mass scientific literacy and technological sophistication may be more important for national welfare than the accomplishments of a scientific elite*". (page 32)

Adaptation of some of the exotic science materials has begun with the inclusion of local examples to illustrate principles. In Botswana (Nganunu, 1988) locally written textbooks and teachers guides support foreign syllabi but this has done little to make the syllabi more relevant. The changes must be more fundamental (Nganunu, 1992).

STS education is yet another import from the developed countries but it holds a great deal of promise for science education in Africa. The goals identified in Project Synthesis are equally applicable to the African context (Ajeyalemi, 1992). STS education being *"the teaching and learning of science within the human experience"* (Yager, 1992a) offers new direction for curriculum and materials development in Africa. In these developments science can be related to the everyday experiences of students living in Africa. This approach will value and respect what the students bring with them to the science class (Nganunu, 1992).

Ajeyalemi (1990) and Ogunniyi (1986) highlight the following issues that are relevant to Africa:

Food	Shelter
Health	Population control
Pollution and shortage of water	Exploitation of natural resources
Peaceful co-existence	

These issues present ideal components for STS curricula and materials.

2.1.2. The STS Rationale in Education

STS education is very complex. This is because there is no *"overarching rationale"* to STS education (Ziman, 1994). Yager (1992a) offers a **broad** definition of STS education by stating that it is *"the teaching and learning of science in the context of human experience"*. However STS education has never been **precisely** defined (Layt‹ '., 1994). Layton suggests that this is why STS education is a strong and appealing movement. It allows for variation and flexibility in the design of curricula and of teaching materials.

Ziman (1994) admits to being confused about the complexity of STS education but feels that the rationale of STS e‿ucation lies in the **approach**. Some of the approaches he lists are:

- Approach Through Relevance - Science is justified in terms of its usefulness.
- Vocational Approach - Prepares students for careers in scientific and science-related fields.
- Transdisciplinary Approach- Emphasises the unity of the natural sciences and their interrelationship with one another.
- Historical Approach- Reveals the historical process of creating ways of thinking and living.
- Philosophical Approach- Presents an account of the nature of science.
- Sociological Approach- Shows how science is linked to and embedded in society.
- Problematic Approach- Offers enlightenment of problems such as environmental destruction, overpopulation, poverty, war etc.

Thus STS education has not developed holistically but consists of many different themes and approaches which are not contradictory but rather complementary. The different themes and approaches have developed because of differences in the contexts and needs of societies (Pedretti and Hodson, 1995; Ziman, 1994).

The broad goals of STS education are to present a relevant, balanced science that produces both students who are able to study further in science and science-related fields at a tertiary level **and** scientifically and technologically literate citizens.

There are many definitions and descriptions of scientific and technological literacy. In a broad sense, literate citizens are able to apply their understanding of science and technology to current problems and issues, make balanced decisions and take personal action as a result of these decisions (Bodmer, 1989; Chen and Novik, 1984; Eijkelhof and Kortland, 1988; Fleming, 1989; Hodson and Reid, 1988; Holbrook, 1992; Kornberg, 1991; Trowbridge and Bybee, 1990; Ramsey, 1993; Yager, 1992a; Zoller et al, 1991). More specific descriptions of scientific literacy are presented by Miller (1983; 1989) and Shamos (1995). Miller's analysis of scientific literacy states that, in becoming scientifically literate, students acquire an understanding of scientific processes and concepts and a vocabulary of scientific terms. This enables students to give opinions about scientific issues particularly those with social overtones. Shamos' views on scientific literacy are more controversial (Shamos, 1995). He argues that scientific literacy (as it is described by most at present) is unattainable in the population at large. He suggests that scientific literacy be redefined more pragmatically as:

- having an awareness of how the science/technology enterprise works
- knowing what **science is about** without knowing much **about science**
- understanding what can be expected from science
- knowing how public opinion with regard to the science/technology enterprise can be heard.

To become scientifically and technologically literate, students should gain an understanding of the relationship between science and technology (Fleming, 1989; Trowbridge and Bybee, 1990). Ramsey (1993) describes science as a means of **explaining** the world and technology as a means of **adapting** to the world. The technological enterprise moulds abstract scientific knowledge to cope with practical realities such as time, cost and personnel (Fleming, 1989). Technology changes society and the environment. Students should understand the relationship between technology and social and environmental change (Fleming, 1989).

Three main aspects or domains are addressed by STS education (Byrne and Johnstone, 1988; Hodson and Reid, 1988; Ramsey, 1993; Trowbridge and Bybee, 1990; Yager, 1992a; Yager and Tamir, 1993). They are the **concept domain**, the **skills domain** and the **affective domain.** Understanding scientific concepts and the acquisition of skills were aims of the curricula of the 1950s and 1970s. However addressing the affective domain is a major difference between STS and earlier science curricula (Byrne and Johnstone, 1988; Zoller et al, 1990). The broad goals to be achieved in these domains are:

1. <u>The Concept Domain</u>

Students should acquire knowledge related to science. They should gain an understanding of the facts, concepts, principles and theories used by scientists (Yager, 1992a).

2. <u>The Skills or Process Domain</u>

Students should be able to develop and use the skills or procedures employed by scientists eg. observing, classifying, measuring, manipulating equipment, communicating, predicting, hypothesising, interpreting data, using scientific models, negotiating, creative thinking, decision making, problem solving etc. (Yager, 1992a).

3. <u>Affective Domain</u>

Students come to science classes with a large variety of values, beliefs, attitudes and opinions with regard to themselves, science classes, science and scientists. (Aikenhead, 1987; Hofstein et al, 1986; Schibeci, 1986; Yager and Penick, 1986). They also have beliefs/attitudes etc. about the interactions of science, technology and society (Fleming, 1987; Fleming, 1989) and about controversial issues and problems with a scientific basis. Some of these beliefs/attitudes etc. are deep-seated and culturally based (Byrne and Johnstone, 1988). Others may have originated via the media, in particular TV (Aikenhead, 1988; Byrne and Johnstone, 1988; Schibeci, 1986; Solomon, 1992).

The terms "values", "beliefs", "attitudes" and "opinions" are used (often interchangeably) throughout much of STS literature. Shrigley, Koballa and Simpson (1988) stress that these terms need to be carefully understood by science educators. They provide the following descriptions of these terms:

i) <u>Beliefs</u> are cognitive in nature. They are based on facts and information. They are more enduring than attitudes.

ii) <u>Attitudes</u> are based on beliefs. However there is an element of evaluation eg. "like or dislike", involved in attitudes. Attitudes are focussed on an object or issue. They are *"a readiness to interpret experiences"*. Attitudes are most susceptible to change (Koballa, 1992).

iii) <u>Values</u> are related to our upbringing and have deep-seated cultural influences. They are manifest in our standards of conduct. They are stable and fairly resistant to change - more so than attitudes.

iv) <u>Opinions</u> are largely verbal expressions of attitudes, beliefs or values. They are statements of what one knows or assumes to be true.

Science-related attitudes and beliefs can change. They should be exposed and addressed in the STS classroom (Koballa, 1992). Students should develop more positive attitudes towards themselves, science and science classes. Beliefs and attitudes of students concerning controversial issues should be worked through to reach more balanced, well-informed outlooks (Yager and Tamir, 1993). However this process is one of learning through open discussion and knowledge acquisition. It is not indoctrination where beliefs and views are imposed as absolute truths (Zoller et al, 1991).

2.1.3. STS Education Strategy

Yager's interpretation (1992a) of STS education being *"in the context of human experience"*, provides an insight into STS strategy. STS education starts with the **relevance** and **application of science to real life** and is **student-centred** (Yager and Tamir, 1993).

1. Relevance of Science

   An STS approach puts science in context by relating it to the everyday life of the students (Bybee, 1987; Hofstein, 1989; Ramsden, 1994; Yager, 1992a). Science, technology and society interact in these applications of science (Bybee, 1987; Fleming, 1989; Ramsey, 1993: Ryan, 1992; Trowbridge and Bybee, 1990).

   Global/environmental issues around which there is controversy are ranked highly by science educators as being very suitable issues to focus on in STS classes (Bybee, 1987; Bybee and Mau, 1986; Hodson, 1993; Volk, 1984). Some of these are:

World Hunger and Food Resources	Population Growth
Air Quality and the Atmosphere	Water Resources
War Technology	Human Health and Disease
Energy Shortages	Land Use
Hazardous Substances	Nuclear Reactors
Extinction of Plants and Animals	Mineral Resources

2. The Student-Centred Approach

STS teaching strategies begin with students' understanding and beliefs about the world in which they live. The constructivist approach (Bodner, 1986) fits very well into the STS strategy. Students' ideas and answers about topics are used to guide the lessons (Yager, 1992a). The student-centred approach is carried over into co-operative group learning experiences (Yager, 1992a). Modern scientists work in groups and students should experience this too (Walker, 1990). Group experiences can be provided in practical activities, group discussions and debates, games and simulations and role-play exercises (Byrne and Johnstone, 1988). During group interactions students may challenge each other's ideas, beliefs and attitudes. Reflection and analysis lead to reformulation of ideas and negotiation of decisions (Solomon, 1992; Yager, 1992b).

Using this strategy, STS education portrays science as a human activity, with successes, disappointments, discoveries and errors - a dynamic science where not all is known and where ideas and theories can be modified as understanding grows (Bodmer, 1989; Hodson, 1993).

The STS teaching strategy is very different from previous teaching strategies. Science teaching was previously content and concept driven. The relevance and application to real life was addressed **after** the concepts and scientific content - if at all! The STS teaching strategy makes the applications of science to everyday life the **starting point**. Students use process skills to work through an issue and finally reach the underlying scientific concepts and principles (Yager, 1992a).

2.1.4. Some Criticisms of STS Education

The STS approach to science education has met with resistance from a number of science educators. Some major criticisms are:

1. Science is a "pure" discipline. The multidisciplinary nature of the STS approach, will *"blur the distinction"* between science and non-science (Bybee, 1987).
2. Science teaching should be "objective" and "neutral". The science classroom is not the place to address emotive political, religious and moral issues (Solomon, 1994a).

3. Valid science is universal and should be taught in the same way everywhere in the world (Ziman, 1994).
4. An STS approach to teaching will result in fewer science concepts being learned. Thus STS science education will not prepare academically strong students for studying science at a tertiary level. The STS approach is for weaker students (Aikenhead, 1994c).

Ziman's (1994) broad response to these criticisms is that STS educators acknowledge the accomplishments of science and simply wish to enhance and extend them. He puts it very neatly: *"The fundamental weakness of 'valid' science as it is usually taught is not what it says about the world, but what it leaves unsaid. The task of STS education is to fill that gap."* (page 22)

Evaluative research (discussed later in this review) is showing that some of the fears that students in STS classes will learn fewer traditional science concepts, are ungrounded. However the Royal Society of Chemistry (1998) reports that on a standardised skills test survey administered to first year chemistry students in the UK, those who had followed the Salters' A-level syllabus (a syllabus with an STS focus discussed later on pages 20 and 21) did not score as well as those who had followed the "standard" A-level syllabus or the Nuffield syllabus.

2.2. THE DESIGN OF STS MATERIALS AND CURRICULA

2.2.1. STS Education Initiatives in Some Developed Countries

Since the 1970s numerous STS curricula and materials have been developed largely in America, Canada, the United Kingdom, Europe and Israel. Developers were able to use the experience and research knowledge gained from previous curricular reform and thus the process has been **evolutionary** in nature (Fensham, 1988; Walberg, 1991). Some examples of STS curricula/materials developed over the last approximately 20 years are:

a. <u>Physics Curriculum Development Project (referred to by the Dutch acronym PLON)</u>

   Begun in the Netherlands in 1972, this project aims to present a balance between scientific (physics), technological and cultural aspects. Forty units have been developed. Some of these are STS units which are taken in addition to or instead of academic science courses (Eijkelhof and Kortland, 1988).

b. Science A Way of Knowing

Developed in 1972 for tenth grade Canadian students, it shows the interaction of science and a rapidly changing society (Aikenhead, 1979).

c. Science and Society

The focus is on the structure of industry and its relationship to society (Lewis, 1981).

d. Science in a Social Context (SISCON)

A historical perspective of problems, their solutions and relationship to present day situations is offered (Solomon, 1983).

e. Chemistry in the Community (ChemCom)

This is a year-long chemistry course for high school students who may or may not wish to continue their studies in chemistry. Using the interrelationship between chemistry, technology and society it aims to present chemistry in a way that is relevant and different from previous "encyclopaedic" type texts and courses (American Chemical Society, 1988; Sutman, 1992).

f. The Chemical Industry in Israel

This textbook of case studies shows how chemical principles are applied to industrial processes. It highlights the importance of industry to society. Technological and environmental aspects of industry are addressed (Nae et al, 1980).

g. Science and Technology in Society (SATIS)

A hundred teaching units which link science to the real world were developed for 14-16 year olds by the Association for Science Education (ASE) in the United Kingdom. Later 75 units were developed for the 16-19 age group. These 75 units could be used as an entire course on science, technology and society for A-level students and to enrich vocational courses. SATIS 16-19 incorporates the use of libraries and computers.

This is a large scale project. For example over 300 000 units of SATIS 14-16 have been purchased in the United Kingdom and overseas (Hunt and Phillips, 1991; Walker,1990).

h. Salters' Science Course

This began as a year-long foundation chemistry course for 14 year-olds in the United Kingdom. The project was led by the University of York Science Education Group (UYSEG). Over the years it has led to the development of four science courses:

Science Focus (11-14 age group)

Science: The Salters' Approach (14-16 age group)

Chemistry: The Salters' Approach (13- 16 age group)

Salters' Advanced Chemistry (16-19 age group)

The Salters' materials start with the application and relevance of science to everyday life. There is a strong emphasis on technology and society. A wide range of teaching and learning strategies is offered. At present more than 500 schools in the United Kingdom are using Salters' materials. Salters' Science projects are influencing STS education developments in countries such as Swaziland, New Zealand, America and Russia (Campbell et al, 1994).

In some of these initiatives, the materials are organised around an existing, traditional science syllabus (Aikenhead, 1994b; Smith 1988) eg. SATIS. In other initiatives, the entire science programme is organised using a sequence suggested by the STS content itself (Aikenhead, 1994b). The scientific concepts are drawn in as needed eg. the Salters' Science courses (Campbell et al, 1994; Smith,1988).

Adopting an STS curriculum and materials throughout a school system takes many years and consists of three stages (Williams, 1994):

Stage 1: During this stage, ideas about the approach to be used are designed, tested, improved or rejected. This cycle can be repeated several times until curricula and materials are developed which are effective in the classroom.

Stage 2: This stage involves the final production of the materials, setting up of support systems for teachers by holding meetings, conferences and workshops.

Stage 3: Finally the STS curriculum and materials are set up in all schools in the country.

Research into radical change of curricula such as the introduction of STS curricula, leads to the following conclusions:

1. <u>The design of STS curricula and materials is complex</u>

   Difficult choices have to be made with regard to **approach** and **content**. The final product has to be relevant to the sociocultural background of the learner (Hodson and Reid, 1988; Sutman, 1992) and has to portray authentic science (Campbell et al, 1994). Some relevant issues or topics may become quickly outdated so themes of long-term importance should be chosen (Eijkelhof and Kortland, 1988).

Many STS topics are broad and there is overlap between disciplines which poses problems when decisions are made about content and feasibility of implementation (Campbell et al, 1994; Eijkelhof and Kortland, 1988). In fact most of the first round of the development of PLON went into the definition of content (Eijkelhof and Kortland, 1988).

Once choices have been made about content, a variety of motivating and interesting activities must be planned which promote meaningful concept learning and skills acquisition (Eijkelhof and Kortland, 1988; Hunt and Lenton, 1992). To promote meaningful learning, developers must find out beforehand what students' (and teachers') attitudes and beliefs are concerning the chosen topic (Aikenhead et al, 1987; Zoller et al, 1991).

In addition language demands of the materials must take the learners into account (Campbell et al, 1994; Hodson, 1993; Walker, 1990).

2. <u>The design of STS materials and curricula is a process</u>

Materials for STS courses are drafted, edited and rewritten and sometimes even scrapped after evaluation (Hunt and Lenton, 1992). Yager found that in centres of teaching excellence, teachers never regard teaching materials as complete and perfect - there is always room for change and improvement (Yager, 1986).

Many STS projects began in a small way and over the years developed into longer courses and complete curricula eg. SATIS (Hunt and Phillips, 1991; Walker, 1990) and Salters' Science (Campbell et al, 1994).

Campbell (Campbell et al, 1994) suggests that a curriculum developer is a technologist. This term could also apply to a materials designer. The development process is a form of technological problem-solving beginning with the identification and analysis of the problem, the formulation of broad design criteria and modification of design based on evaluation. Detailed aims and objectives are only discovered during the design process.

3. <u>Different developmental models can be used</u>

The **centre-periphery** model for development has been used in the development of some STS curricula and materials (Cronin-Jones, 1991; Hart and Robottom, 1990). Examples are *Science in Society* (Lewis, 1981) in the United Kingdom and *ChemCom* in the USA (American Chemical Society, 1988). In this model, the research and design team (the centre) is composed of scientists and science educators (the experts). The materials are disseminated to the teachers (the periphery).

Another approach is the co-operative team model, also termed the **practitioner-based model** (Ramsden, 1994). The research and design team is composed of science educators, volunteer teachers, scientists and members of industry and other institutions. This approach was used in the development of SATIS (Hunt and Lenton, 1992) and Salters' Science (Ramsden, 1994). Ideas are brainstormed by the group. Great use is made of teachers' skills, classroom experience and insights (ie. teachers' *"craft knowledge"*) during the design process (Campbell et al, 1994). In conjunction with other members of the team, teachers draft materials in topics of interest to them (Campbell et al, 1994; Lenton, 1990). This gives rise to a variety of teaching units with a wide range of approaches. Editors refine and finalise the materials (Hunt and Lenton, 1992).

The co-operative team approach extends to teams of developers from different projects meeting to develop materials such as the units on *"Education in Global Change"* (ICSU, 1991).

4. Teachers must be able to interact with the materials

STS teaching materials must be cheap, easy to use, adaptable and copyright free for school production (Hunt and Lenton, 1992). Adequate support must be provided for the teachers. For example, background notes on topics, guidance with regard to use of the materials and teaching strategies, as well as some answers, have been included in SATIS and Salters' Science materials (Hunt and Lenton, 1992; Ramsden, 1994).

5. Limitations are imposed by current examination systems

At present the demands of national examination systems frequently limit the scope of STS materials and curriculum design (Eijkelhof and Kortland, 1988).

6. The design of STS materials and curricula is financially costly

The year-long ChemCom course cost $1.5 million to develop (Sutman, 1992). Each SATIS unit cost approximately $3000, not including the time volunteered by the teachers. For the developers of SATIS, the most costly item was the professional design of the final products (Hunt and Lenton, 1992).

7. The design of STS materials and curricula is costly in terms of time

In common with all teaching materials' design, most STS materials are not right the first time. Units often have to be rewritten and this is time-consuming. It took 13 years to develop 40 units for PLON (Eijkelhof and Kortland, 1988). Eight years were spent developing the year-long ChemCom course (Sutman, 1992). Ten years were spent developing the Salters' Science courses (Ramsden, 1994).

2.2.2. STS Education Initiatives in Africa

With the support of organisations such as UNESCO, the British Council, ICASE and ICSU, some curriculum change with an STS thrust has come about in Africa (Ogunniyi, 1986). Examples of projects with an STS thrust are:

1. The Swaziland Integrated Science Project (SWISP)

   Introduced in 1974, this programme for junior secondary school students has its roots in the West Indies Science Integrated Project and the Scottish Integrated Science Scheme. The broad aims of this project are to

   - teach scientific knowledge
   - develop some skills eg. an ability to think and act creatively, analyse data, perform experiments
   - promote certain attitudes eg. an awareness of the interrelationship between science and other disciplines and an awareness of the contribution of science to the social and economic life of the community (Imenda, 1990).

   In an attempt to make the project more relevant to Swaziland, additional teaching units were developed in 1992 in conjunction with the Salters' Science team from the University of York. These units meet the requirements of SWISP but integrate relevant Swazi technology with interactive teaching strategies (Dlamini et al, 1994; Lubben et al, 1994).

2. Zimbabwe Secondary Science Curriculum

   This is an issue-based curriculum dealing with science in agriculture, in industry, in energy use, in the community, in structures and mechanical systems (Ajeyalemi, 1992).

3. Innovative Ideas and Techniques for Science Educators in Africa

   This collection of materials was developed as a consequence of a gathering of educators in Zimbabwe (termed *"The Harare Generator"*) in 1991. The materials are relevant to the African context in terms of content and school facilities and teaching methodologies (Whittle et al, 1993).

4. Botswana Integrated Science

   A junior secondary science programme was developed in 1984 which relates science to everyday life and local technology in Botswana. Relevant issues such as water conservation, population growth, diseases, housing and solar energy are major themes in the lessons (Nganunu, 1988).

STS educational innovations in Africa will probably become more widespread in the future. Walberg (1991) cautions that large scale curriculum design is risky and costly. He suggests that for developing countries, experimentation with small scale projects may be better than sweeping curriculum change. STS materials and curricula should be designed for implementation under simple classroom conditions and should require the use only of simple, inexpensive equipment (Nganunu, 1992).

2.2.3. STS Education Initiatives in South Africa

The need for a secondary science curriculum which interrelates science, technology and society was identified at a National Science Education Workshop in 1978 (SAATPS, 1978). The HSRC Investigation into Education (1981) supported this view. A curriculum model consisting of a core syllabus and additional optional topics for standards 8 - 10 was developed (Department of Internal Affairs, 1985). These optional topics were intended to provide flexibility so that teachers could make choices with regard to suitability and relevance for their teaching environment. Teaching resource materials for some of these topics have been developed. Examples of projects are:

1. The Wits-Phoenix Project

   Science educators from the University of the Witwatersrand collaborated with the Chamber of Mines in the development of resource packages for standard 8 on metals and minerals relevant to South Africa. Packages on copper, manganese, chromium, coal and gold have been completed. Approximately 400 teachers have attended workshops on some of these packages and they have been implemented in a number of schools (Bradley and McCarogher, 1996).

2 AECI Project (van den Hoek, 1997)

   A teaching resource package for standard 9 on water has been developed and implemented on a trial basis in a number of schools. As a result of this project a number of teaching booklets on water have also been designed. They are pertinent to both the primary and secondary science syllabi.

In addition, during 1990, some syllabi with an STS approach were designed and implemented for Primary and Secondary Teachers' Diploma curricula at colleges of education (Bradley and Brand, 1990; Smith et al, 1998).

The political reform in South Africa has brought education and science education in particular, into the limelight. Developments over the past few years have shown that new policy-makers appear committed to continuing with an STS-type approach in school science education.

For example the National Education Policy Initiative recommends a low cost, *"science for all"* core curriculum for the ten year compulsory phase of education (NEPI, 1992). The Centre for Education Policy Development in *Curriculum Frameworks for Science and Technology and Mathematics* (CEPD, 1995) lists aims which are clearly based in the STS philosophy. Broadly speaking they are:

1. Students should gain an understanding of the interrelationship of science, technology, society and the environment.
2. Students should develop process skills and scientific and technological skills and abilities that equip them for everyday life in South Africa. Responsible decision making and participation in issues should follow.
3. Positive values and attitudes should develop in students. These should encompass self-esteem and attitudes towards science, technology, industry and the environment.
4. Students should develop an interest in science and awareness of career opportunities in science and technology.
5. Physical science should be integrated with other subjects such as the biological and earth sciences.

South Africa is a complex country. It has great diversity of culture and of region. Some regions are industrially and technologically advanced while others are rural and n[illegible] typical of a developing country. In addition the proficiency of teachers is very varied. Curriculum development in South Africa needs to take these factors into account. The curriculum (and teaching materials) must be adaptable to the diversity of classroom contexts (CEPD, 1995).

Fundamental and far-reaching curriculum change is proposed in *Curriculum 2005* (Department of Education, 1997a). The basic tenets of this curriculum are
"to ensure that learners gain the skills, knowledge and values that will allow them to contribute to their own success as well as to the success of their family, community and the nation as a whole". (page 10)

In this curriculum science, technology and society, and the environment are addressed in a number of learning areas eg. the natural sciences, the human and social sciences, technology. The rationale for the learning area of the natural sciences seeks to develop skills, knowledge and attitudes and an understanding of the principles and processes of the natural sciences which

- enable learners to make sense of their natural world
- contribute to the development of responsible, sensitive, and scientifically literate citizens who can critically debate scientific issues and participate in an informed way in democratic decision-making processes
- are essential for conserving, managing, developing and utilising natural resources to ensure the survival of local and global environments
- contribute to people creating and shaping work opportunities.

Thus it appears that the rationale and strategy of the STS education movement will fit very comfortably into the proposed new education curriculum for South Africa.

2.3. IMPLEMENTATION OF STS CURRICULA AND MATERIALS

The success of curricula and teaching materials is determined by the way in which they are implemented in the classroom (Crocker and Banfield, 1986; Cronin-Jones, 1991; Fullan, 1995; Hart and Robottom, 1990; Hord, 1987; Mitchener and Anderson, 1989; Sabar, 1986). It is a matter of great concern that the goals of curricula and materials are often not realised in the classroom - a gap exists between the intentions of the developers who research and design them and the intentions of the teachers who implement the material in the classroom (Ajeyalemi, 1992; Dlamini et al, 1994; Hart and Robottom, 1990; Nganunu, 1992; Zoller, 1991). This explains the disappointments and failures of curricula and materials developed in the 1960s and 1970s. There is evidence that some STS curricular initiatives are encountering the same gap (Crocker and Banfield, 1986; Cronin-Jones, 1991; Fensham, 1988; Hart and Robottom, 1990; Mitchener and Anderson, 1989; Webb, 1993).

2.3.1. Some Suggested Reasons for the Unsuccessful Implementation of STS Curricula and Materials

A great deal of effort has gone into STS curriculum and material **design** but not as much attention has been paid to the **implementation** of curricula and materials in the classroom (Hart and Robottom, 1990; Sabar, 1986; Walberg, 1991). The knowledge, skills and attitudes of the teachers do not match what is required by the new STS initiatives (Zoller, 1991). This leads to teachers adapting and modifying new materials to suit their existing knowledge, skills, beliefs and attitudes (Cronin-Jones, 1991). Thus the new projects do not lead to changes in classroom practice - teachers simply teach the new materials in old ways (Hart and Robottom, 1990; Waks and Barchi, 1992; Yager and Tamir, 1993). In addition teachers become negative and apathetic about initiatives that do not match their perceptions and abilities (Hart and Robottom, 1990). This manifests itself in a reluctance on the part of the teachers to implement STS curricula and materials in their classrooms (Pedersen, 1992).

The implementation process needs to be closely studied and researched (Bybee and Mau, 1986; Cronin-Jones, 1991; Fullan, 1995; Hart and Robottom, 1990; Hord, 1987). The **demands** placed on teachers by STS curricula and the **values, beliefs and attitudes** of teachers with regard to classroom practice and STS curricula, may contribute to problems experienced in implementation.

1. <u>**Demands** Placed on Teachers by STS Curricula and Materials</u>

STS curricula and materials place many demands on the teachers especially with regard to their **knowledge** and their **role in the classroom** (Ogunniyi, 1986; Yager, 1992a; Zoller, 1991).

a. <u>Knowledge Demands</u>

Teachers find it difficult to teach what they do not understand (Lederman and Zeidler, 1987; Rubba and Harkness, 1993). Many STS topics and issues involve knowledge and concepts that are new to the teachers. In addition many of the topics are interdisciplinary and require content knowledge outside the teacher's subject area (Bybee, 1987; Bybee and Mau, 1986; Walker, 1990). Teachers are concerned about their lack of background and this affects their confidence in the classroom (Mitchener and Anderson, 1989). Teachers with weak science backgrounds are particularly reluctant to move away from their subject area and lack the confidence and motivation to acquire new expertise (Walberg, 1991).

A major goal of STS curricula and materials is that students gain an understanding of the nature of science and technology and their interactions with society. Yet many teachers lack this understanding and this places serious limitations on achieving the STS goals of scientific and technological literacy and public understanding (Rubba and Harkness, 1993; Waks and Barchi, 1992; Zoller et al, 1991).

Additional stresses may be placed on teachers by existing examination systems. Teachers have to balance the content and conceptual demands of those systems against the new demands of the STS approach (Mitchener and Anderson, 1989; Zoller, 1991).

b. Demands for a Change in the Teacher's Role in the Classroom

STS curricula and materials may require a significant change in the teacher's role in the classroom. A variety of new teaching and learning strategies are needed (Campbell et al, 1994; Holbrook, 1992; Hunt and Lenton, 1992; Myers, 1992; Ogunniyi, 1986; Ramsden, 1992; Walker, 1990; Yager, 1992a; Zoller, 1991). Teachers find it difficult to change their role in the classroom and feel inadequate and underprepared (Zoller, 1991).

Traditionally the classroom environment has been **teacher-centred** with students being the largely passive recipients of knowledge (Yager, 1992a). The teacher has been the **director** and **controller** of learning, using techniques such as lecturing, praising, criticising in a teaching medium of drill and practice (Cronin-Jones, 1991; Haukoos and Penick, 1987). Students have been required to listen, read, write, repeat answers and rote learn (Ajeyalemi, 1990; Ogunniyi, 1986; Yager, 1992b). These methods have minimised student response (Haukoos and Penick, 1987). In contrast an STS approach requires that learning be **student-centred.** A constructivist approach to learning is vital (Myers, 1992; Yager, 1992b). Teachers must create a classroom atmosphere where creativity is welcomed and students feel that it is safe to contribute ideas (Penick, 1992). Techniques must be employed which invite participation and encourage critical thinking, problem-solving and decision-making (Haukoos and Penick, 1987; Zoller, 1991). The teacher must be a **facilitator** of learning (Cronin-Jones, 1991; Yager, 1992a). The textbook has been the main instructional tool used by the teacher. An STS approach requires that the teacher uses a variety of teaching materials (Yager, 1992a).

Interactive small-group activities eg. group discussions, debates and role-plays, are a feature of an STS classroom (Campbell et al, 1994; Hunt and Lenton, 1992; Ramsden, 1992; Walker, 1990). While using these activities, teachers have to remain neutral and accepting of different points of view. There is often no "right answer" and final decisions have to be negotiated (Pedersen, 1992). These techniques and situations are unfamiliar to most teachers and they feel very uneasy about using them (Walker, 1990). Webb (1993) in his study of teacher perceptions of development needs during the implementation of a science and technology syllabus, found that teachers do not even express a desire to find out more about the new teaching/learning models envisaged by STS course designers.

2. **Values, Beliefs** and **Attitudes** of Teachers with Regard to Classroom Practice and STS Curricula and Materials

Teachers approach STS curricula and materials with a wide range of values, beliefs and attitudes of their own (Cronin-Jones, 1991; Mitchener and Anderson, 1989; Webb, 1993; Zoller et al, 1991). These play a significant role in the implementation process (Cronin-Jones, 1991). Some STS curricula and materials developers erroneously assume that their views about the nature of science, the concept of learning and the importance of topics are the same as those of the teachers who implement them (Cronin-Jones, 1991). This mistake can hamper or even prevent the implementation of STS curricula and materials (Cronin-Jones, 1991; Mitchener and Anderson, 1989).

To compound matters even further, there is sometimes a vast difference between what teachers **say** they believe and what they **do** in the classroom (Hart and Robottom, 1990; Mitchener and Anderson, 1989).

Some examples of the values, beliefs and attitudes held by teachers which affect the implementation of STS curricula and materials are:

a. Many teachers do not believe that affective objectives are as important as cognitive objectives (McIntosh and Zeidler, 1988; Schibeci, 1981; Zoller, 1991). These teachers believe that science is an academic subject and that the emphasis should be on the acquisition of knowledge (Mitchener and Anderson, 1989). Such teachers are often unwilling to relinquish their roles as "lecturer" and "expert".

They structure the learning experience by providing the students with *"neat, unchallenged rules"* for determining the answer (Zoller, 1991). They perceive successful learning as being able to provide the correct answer (Zoller, 1991). Content-free teaching that focusses on processes makes them uneasy (Fensham, 1988). So, too, do situations where there is no right or wrong answer (Mitchener and Anderson, 1989). The development of social skills and the concern for social problems is not perceived as being within the realms of science (Mitchener and Anderson, 1989).

b. Many teachers do not perceive interactive group activities as being important (Cronin-Jones, 1991). Other teachers **say** they strongly support the interactive co-operative learning approach promoted by STS curricula and materials **but do not use** this approach in the classroom (Mitchener and Anderson, 1989). Both these instances may arise because teachers fear losing control of their classes or they are concerned about noise levels (Mitchener and Anderson, 1989). Loosening the reigns of control was a concern amongst some experienced teachers in Swaziland: Dlamini et al (1994) report that some teachers found it difficult to break with the tradition of giving students the answers *"because students get the wrong ideas if they think for themselves"*.

Interactive sessions where students question, argue and provide ideas may be contrary to the values of some cultures where adults (and teachers) are seen as the authorities (Hodson, 1993; Jegede, 1994). In Western cultures, too, some teachers may perceive group exercises and achievements as contrary to the ideals of individual accomplishment and achievement (Hodson, 1993).

c. Some teachers do not perceive **their own role** as crucial to the implementation of STS curricula and materials. They believe rather that **external factors**, such as resources, time, having the equipment, being able to do practical demonstrations and being in possession of special teaching units, are crucial (Webb, 1993).

2.3.2. Ways of Improving the Implementation of STS Curricula and Materials

Teacher involvement in the design process and improved pre- and in-service training for teachers could alleviate some of the problems experienced in the implementation of STS curricula and materials.

1. <u>Teacher Involvement in Curriculum/Materials Design</u>

The centre-periphery model has been used for some STS curricula and materials development. Teachers have been excluded from the processes of research and design (Crocker and Banfield, 1986; Dlamini et al, 1994; Hart and Robottom, 1990). An STS approach to learning promotes co-operative participation, negotiation, problem-solving and decision-making. Yet this experience, too, has to a large extent been denied teachers during the development of many STS initiatives (Hart and Robottom, 1990). There must be much closer collaboration between designers and implementers (Sabar, 1986; Waks and Barchi, 1992). In this way teachers will be able to enrich the design process with their knowledge of classroom environments, their teaching skills and perceptions about curriculum change (Cronin-Jones, 1991; Waks and Barchi, 1992).

STS projects such as Salter's Science (Campbell et al, 1994; Ramsden, 1994) and SATIS (Hunt and Lenton, 1992) have successfully involved teachers in the development process. In Swaziland local teachers were involved in a materials design project led by some members of the Salter's science development team, UYSEG. It was observed that this process led to a growth in the teachers' self-perceptions, an improvement in their conceptual understanding and an acceptance of the demands of the new curriculum initiatives. In addition teachers' confidence in open critical debate on the science curriculum improved (Dlamini et al, 1994).

Teacher involvement can also be brought about by teachers adapting centrally-developed materials to suit their needs. In his research into centres of teaching excellence, Yager (1986) found that hardworking, motivated teachers used the nationally-developed materials as a basis, but modified and adapted them to suit their teaching contexts. Teachers in these centres had a strong sense of ownership and pride with regard to these materials.

2. Improved Training for Teachers

Teachers are often provided with **written** guides to the new curriculum and materials which may or may not explain the rationale behind the initiatives (Cronin-Jones, 1991; Nganunu, 1992). In other instances, short "one-off" training workshops are presented on new materials and approaches but these have been found to not be effective (Kyle et al, 1988).

Teachers need time and support to introduce new STS curricula and materials which are very different from their own learning experiences (Fensham, 1988; Waks and Barchi, 1992). On- and off-site training workshops which are directed at changing classroom behaviour and improving skills need to be developed (Lederman and Zeidler, 1987). Teachers themselves could be involved in the planning and conducting of workshops (Crocker and Banfield, 1986). The training should be long-term with follow-up visits, telephone communication, newsletters etc (Sabar, 1980; Waks and Barchi, 1992).

The focus of the workshops should be on

- the history and philosophy of the new STS approach
- the nature of science and technology and their interrelationship with society
- the beliefs and attitudes of teachers towards the proposed changes (Lederman and Zeidler, 1987; Penick, 1992; Ryan, 1992; Zoller et al, 1991)
- the beliefs and attitudes of teachers about effective teaching strategies (Beasley, 1992).

Use should be made of micro-teaching sessions where teachers teach their peers (or students). Follow-up review and discussion of these sessions will make teachers aware of their teaching strategies and promote change in some of their classroom behaviour (Dlamini et al, 1994).

A system of **networking** can be a very effective means of providing long-term training and support (Fensham, 1988). Teacher leaders are identified and trained. These leaders conduct workshops for other teachers (often in their geographical region). These workshops may involve materials development, trial implementation and evaluation (Yager and Tamir, 1993). A network model of training and support has been used successfully in Iowa (Yager and Tamir, 1993) and in South Africa with the implementation of the Phoenix Project (Bradley and Brand, 1990).

Thus for the successful implementation of STS curricula and materials, the **relevance** of the content to the teacher and classroom context must be apparent. The **affective domain** of teaching has to be addressed as well. The beliefs, values and attitudes of teachers must be taken into account and new **process skills** (or teaching strategies) developed.

2.4. EVALUATION OF STS CURRICULA AND MATERIALS

Aikenhead (1994c) suggests that evaluating STS education is complex. The *"lofty"* goals set by many for STS education (namely to produce wise decision makers, an empowered citizenry, an enlightened democracy and increased numbers of engineers and scientists) defy evaluation (Aikenhead, 1994c). More realistic goals which could be used as criteria for the evaluation of STS education are:

- To increase scientific literacy
- To generate an interest in science and technology
- To encourage interest in the interactions of science, technology and society
- To develop students' skills as critical thinkers, logical reasoners, problem solvers and decision makers.

(Aikenhead, 1994c)

2.4.1. Some Methods of Research Employed in Evaluation

Some methods of research employed in evaluation have serious shortcomings (Robottom, 1989; Robottom and Hart, 1993; Shymansky and Kyle, 1992). These methods of research use the *"technicist"* approach (Robottom, 1989) or *"statistical model"* (Shymansky and Kyle, 1992) which is driven by the need for the research to be rational and objective. Most actions taken in this type of research are to obtain statistically reliable results, either by using very large samples or highly controlled experimental designs. Because of the complexity of the educational settings it is very difficult to construct a truly controlled design (Robottom, 1989). Criticisms of the *"technicist"* approach offered by Robottom are:

- Non-empirical data that is *"anecdotal"* or *"impressionistic"* is often not reported. *"Pre-ordinate research design"* is of paramount importance and thus *"unanticipated events"* are neglected and not reported.
- Heavy emphasis is placed on the assessment of **what** students learn as an indicator of the

efficiency of new programmes. Not enough research is conducted into **how** students learn and **why** they learn some concepts and not others.

- This type of research under-estimates the involvement of teachers and students and gives little attention to the different school settings. Teachers are perceived as *"passive receivers"* of the *"tried and true"* curricula and materials. Little attention is paid to the problems teachers experience during implementation and the pecularities of the different school settings.

Robottom feels that the narrow *"technicist"* approach is inappropriate for environmental education in which many of the issues are not objective but value-laden. With regard to such issues, acquisition of new knowledge is not the only priority. Research should be expanded to include the development of methods to confront and change the misconceptions, beliefs and attitudes held by students concerning environmental problems. Ways must be found of developing students' critical thinking so that knowledge acquisition which brings about changes in attitudes and values, will lead to active participation in environmental problem-solving.

Shymansky and Kyle (1992) echo many of the criticisms presented by Robottom. They further advise that agendas for research into curriculum reform and evaluation should consider some of the following critical issues:

- Changes that are not statistically valid should be onsidered and not simply disregarded.
- The entire process of curriculum reform should be investigated. Information should be gleaned on the successes and constraints regarding the implementation of new curricula. The complexity of classroom practices and the roles played by students and teachers in their interaction with new curricula must be studied to gain an understanding of the factors which facilitate and inhibit the implementation process.
- The knowledge, experience and beliefs of teachers with regard to their role in the classroom and how they manage curriculum reform must be probed. Ways must be found to involve teachers in the processes of planning, observing and reflecting, that accompany curriculum reform.
- Historical, social and political aspects must be taken into account. Scientific knowledge and practices do not equally benefit the developed and undeveloped countries. This is because such knowledge and practices are adapted to suit local contexts. Research into the design and evaluation of curricular reform should find ways of contributing to social upliftment and transformation.

Zoller (1991) reports on a study where he used a mix of quantitative and qualitative approaches which he terms a *"quasiquantitative approach"*. The quantitative measures provided the "hard" data for assessing the effectiveness of the change. The qualitative descriptions provided a richness or depth to the hard data. From these descriptions it was possible to gain further insights that provided valuable directions for research.

Common methods to collect data in evaluation studies include administration of tests or questionnaires, observations of classroom activities and interviews (Schumacher and McMillan, 1993). The administration of tests or questionnaires is a reasonably cheap and effective method if resources are limited and the evaluation team is small (Walberg, 1991). Many researchers feel that the use of such an instrument represents an objective method of obtaining data. However these instruments themselves are social and ideological constructs (Robottom, 1989). A further serious limitation of such instruments is that the items are sometimes ambiguous. The designers of the test and the students responding may not perceive the same meaning in an item (Aikenhead et al, 1987). Aikenhead et al (1987) have constructed an instrument termed Views of Science-Technology-Society (VOSTS) where this ambiguity has been reduced. In each item in VOSTS students respond to a statement (a viewpoint rather provocatively stated) by choosing from a number of options in multiple choice mode. These options reflect various standpoints with regard to the given statement. The options also reveal the reasons behind the students' choice. The options in each item have been based on extensive research which probed students' views about science, technology and their relation to society. Students wrote paragraphs and were interviewed about various statements. Their common responses were then used in the statements and options for each item in the VOSTS instrument.

The administration of questionnaires (not only VOSTS) as pre-tests has provided insights into many of the beliefs and attitudes held by students and teachers about science and technology and their relationship to society. These insights can be of great use to researchers and to developers of curricula and materials (Zoller, 1991). These initial beliefs and attitudes also provide a baseline of data against which the effectiveness of STS curricula and materials can be assessed (Aikenhead, 1994c).

The administration of the VOSTS instrument as a pre-test in some Canadian school (Aikenhead, 1994c) has revealed that students

- hold naive views on the nature of science
- are confused about the nature of technology
- have views about social aspects of science that are formed by culture and the mass media
- do not readily associate science and technology with societal issues.

Boyes and Stanisstreet (1993; 1994) probed students' preconceptions in the UK about global environmental problems and found that students were very confused about these issues. For example many students thought that

- global warming was caused by the depletion of ozone in the stratosphere
- radioactivity damaged the ozone layer
- using lead-free petrol would reduce global warming.

Aikenhead (1994d) reports that students' preconceptions prompted the inclusion of remedial content in STS learning materials that were being written. Research using VOSTS in some Canadian schools showed that many students had misconceptions regarding the meaning of the word *"objective"*. This resulted in a section on *"Subjective versus Objective"* being included in an STS text book being written at the time.

2.4.2. Summative and Formative Evaluation

The evaluation research projects undertaken in STS education have been either **summative** ie. assessing the effects of STS instruction, or **formative** ie. informing the designers on what changes and modifications to make to teaching materials (Aikenhead, 1994c; Schumacher and McMillan, 1993).

A number of **summative evaluation** research projects have been reported in the research literature. Myers (1992), describing some research projects in Iowa, USA, reported that students studying STS curricula learnt as many (or in some cases even more) major science concepts as those learnt by students following traditional science curricula. Varrella (1992) found significant increases in students' abilities to apply scientific knowledge and understanding to issues where aspects of science, technology and society were interrelated. Binadja (1992) found significant growth in science process skills among students following an STS curriculum whilst Penick (1992) found that, in comparison to students following traditional science curricula, students following STS curricula showed significant improvement in creative thinking. Research conducted by Banerjee and Yager (1992) revealed that after STS instruction, students developed more positive attitudes towards science teachers, the nature of science and careers in science.

Solomon (1992) conducted novel research into the effects of an STS teaching strategy - small group discussions on controversial issues. The project was termed DISS (Discussions of Issues in School Science). The analysis and evaluation of group discussions is complex but one of the major findings in this research is that the *"discussion profile"* of a student (compiled by observation of the student's participation in the group discussion) is very different from the student's *"attitude profile"* (determined by the students' response to a questionnaire) ie. the attitudes students have do not correlate with their observed behaviour.

There are fewer reports of **formative evaluation** (Aikenhead, 1994c). This may be because researchers did not publish these evaluations thinking that their findings would not be interesting to others (Eijkelhof and Kortland, 1988). Three formative evaluation research projects by Eijkelhof (1994), Kortland (1992) and Aikenhead (1994d) indicate that writing of STS teaching materials is not simply an intuitive process. For example, outcomes of the first round evaluation of PLON (Eijkelhof, 1994) revealed two important factors. Firstly, careful attention must be paid to what kinds of knowledge are useful and which concepts should be included. Secondly, the lay ideas held by students need to be thoroughly addressed. These lay ideas are very persistent. They are gained largely via the media and students use them in everyday discussions. These findings were used to direct changes in the second draft of the PLON materials.

Similarly, once Kortland (1992) had constructed a broad outline of a unit for teaching an environmental topic, he used students' perceptions gained from interviews, to help him structure the detail of the unit. Finally classroom observations of students' arguments assisted in the design and incorporation of decision-making activities into the teaching unit.

Aikenhead (1994d) also used classroom observations and input from students and teachers to guide him in the development of an STS textbook and teacher's guide *Logical Reasoning in*

Science and Technology (or LoRST). When his expectations of the materials were not met, Aikenhead made these expectations explicit to the students and discussed with them the reasons for the failure of the materials in this regard. Contributions by students were instrumental in the modification of the content and language of the text to meet these expectations.

2.4.3. Some Shortcomings in Current Research

In *Toward a Map of Problems in STS Research* (1994), Solomon highlights a number of shortcomings in current research. She feels that evaluation research should not just focus on the role played by content and the acquisition of skills. **The learning process** must come under the research spotlight too. Solomon advises that the constructivist approach to learning should not be too rigidly adhered to. Instead of looking towards a complete conceptual change in students with regard to STS issues, there should be an acceptance that students will move between a "life-world" or **everyday system of knowing** and a **scientific system of knowing**. In addition Solomon cautions that there are flaws in research into **student attitudes**. The perception, held by some researchers, that attitudes are largely knowledge-based may be too simplistic. Attitudes are also constructed during interactions with others when ideas and questions are exchanged and tested. In other words, **discussion** of issues plays a vital role in attitude formation. There is considerable variation in the views among researchers as to what attitude changes **are** desirable. Some researchers believe that students should change from one extreme to another while other researchers would like students to move from an extreme standpoint to a more moderate position.

Solomon's criticisms have no doubt caused many to reflect on current research practices. However they also offer new and challenging directions for evaluation research in the future.

CHAPTER 3

METHODOLOGY

In this chapter, background will be presented on the processes of

- **Designing**
- **Planning the implementation** of and
- **Devising ways of evaluating** the resource package.

In addition the **methods of researching** these processes to find answers to the **research questions** central to this thesis are described. These research questions are:

- *What factors played a role during the trial implementation of the resource package?*
- *Is the resource package an accurate and balanced representation of the topic: Air Pollution and the problems associated with it?*
- *Can teachers and students in the different school environments effectively use the materials?*
- *Is the package a suitable teaching resource for a standard 9 chemistry class?*
- *Do the materials enable teachers to provide a meaningful learning experience for the students?*

  In this regard

  a. *Do the materials enable teachers to improve the students' understanding of the concepts, principles and terminology associated with air pollution?*

  b. *Do the materials enable teachers to increase the students' awareness and concern about air pollution?*

  c. *Do the materials enable teachers to bring about change in the students' beliefs, attitudes and opinions, that leads to a more balanced outlook concerning the issues related to air pollution?*

  In this way
- *Do the materials enable teachers to improve the students' scientific literacy?*

3.1. THE DESIGN OF THE PACKAGE

The resource package is presented in its entirety in Volume 2.

3.1.1. Background to the Design

The development (and implementation) of the air pollution package was based on the *"centre-periphery"* model (Cronin-Jones, 1991; Hart and Robottom, 1990). The researcher, working under the guidance of her supervisors, represented the *"centre"* and the teachers taking part in the trial implementation represented the *"periphery"*. There were many reasons for opting for the *"centre-periphery"* model in the design and implementation of the air pollution resource package:

- There was an urgent need for the materials for the proposed introduction of the air pollution topic in the schools in 1993. Delays would have been incurred in attempting to involve teachers in the development of the materials.
- The difficulties experienced in finding teachers willing to participate in the trial implementation of parts of the package (discussed later in Chapter 5) are indicative of the problems that would probably have been experienced in finding teachers willing to commit additional time to participating in the design of the materials.
- The outcomes described later in Chapters 5 and 6, highlight the heterogeneous nature of schools in South Africa. It would have been difficult and time consuming to structure and maintain a sample of teachers participating in the development of the materials which was representative of this heterogeneity.
- During 1991, the unsettled political climate in the country in general and in many schools in particular, would have disrupted regular attendance by some teachers at materials design workshops.
- There was a small, limited budget available to the researcher. The expense of gathering and accommodating teachers from outlying regions in a vast country like South Africa, would have exceeded this budget.

Campbell et al (1994) have suggested that one of the disadvantages of not involving teachers directly in the design process is the loss of the *"craft knowledge"* that teachers bring with them to the development of teaching materials. However this *"craft knowledge"* was not entirely absent from the development of the air pollution package. The researcher has several years' teaching experience in schools and one of her supervisors is a methodologist primarily involved in the training of postgraduate science teachers.

The Transvaal Education Department syllabus statement (see Appendix, page A1) was the initial basis for the development of the package. However the design of the materials went beyond the requirements of the syllabus statement as various inadequacies were perceived in its approach to the topic. Firstly the treatment of some topics seemed very superficial. For example:

- A study of the main regions of the atmosphere is not required yet the phrase "ozone layer" is mentioned (see 9.2. syllabus statement).
- Carbon dioxide is not identified as an air pollutant and the enhanced greenhouse effect is not mentioned.
- The oxides of nitrogen are not identified as air pollutants.

Secondly, the sequence of topics in the syllabus statement seemed rather haphazard. For example air pollutants resulting from activities such as the combustion of fossil fuels are not grouped together (see 9.3.1. to 9.3.4. in the syllabus statement). Instead, air pollutants appeared as an unrelated list of substances. Thus the resource package attempts to present a more carefully structured, coherent approach to the topic: Air Pollution than that suggested in the syllabus statement. Finally the approach outlined by the syllabus statement, is a remote, "academic" way of presenting the topic. By contrast, the topic: Air Pollution seemed an ideal opportunity of making science more relevant to the students' everyday experiences and to introduce issues that relate science, technology and society.

The scope of the package was limited by:

- The urgent need for the material for the proposed introduction of this topic in some South African schools during 1993.
- The content and requirements of the standard 9 Transvaal Education Department syllabus. For example, in the package concepts such as equilibrium, kinetics etc., could not be related to the topic: Air Pollution as these concepts are only studied later in standard 10 in this syllabus.

3.1.2. The STS Rationale of the Package

Ziman (1994) and Layton (1994) argue that there is no over-arching rationale to the design of STS curricula and materials. The different themes and approaches have developed because of the variation in the contexts and needs of societies (Pedretti and Hodson, 1995; Ziman, 1994). It was this flexibility that prompted the researcher to design teaching materials that would be relevant to the South African context. The 'STS-ness' of the materials is reflected by some of the following characteristics:

- the relevance and application of science to 'real-life' situations and problems with respect to air pollution in South Africa.
- the interrelationship of the science, technology and society in the topic: Air Pollution.
- the interrelationship of the natural sciences in the study of air pollution and the search for solutions.
- evidence that science is a human activity where, along the path of progress, errors are sometimes made and ideas changed.

Many of these characteristics are highlighted in existing STS approaches of curricula and materials (Ziman, 1994) and classify the package clearly as a means which would facilitate *"the teaching and learning of science in the context of human experience"*. This is the broad definition of STS education offered by Yager, (1992a).

3.1.3. The Aims and Objectives of the Package

The package addresses three main aspects or domains (Yager, 1992a):

1. The Knowledge Domain

   This domain includes the facts, concepts, principles, theories and terminology with regard to air pollution. The prior knowledge students have about this topic has largely been gained via the media or from learning in other disciplines eg. geography and biology. The misconceptions students may have regarding air pollution need to be revealed and corrected.

2. The Process Skills Domain

   Skills or procedures employed by scientists in the area of air pollution are addressed. Some of these skills are observing, classifying, measuring, manipulating equipment, communicating, predicting, hypothesising, interpreting data, using scientific models, negotiating, creative thinking, decision making and problem-solving.

3. <u>The Affective Domain</u>

Students have beliefs, attitudes and opinions about the interaction of science, technology and society in many air pollution issues and problems. These beliefs, attitudes and opinions need to be exposed in the classroom (Koballa, 1992). They can change but the process should be one of open discussion and knowledge acquisition and not indoctrination (Zoller et al, 1991).

The more specific objectives of the package are that students should:

1. gain an accurate and balanced understanding of the issues and complexity of air pollution.
2. understand and effectively use the terminology associated with the topic: Air Pollution.
3. relate the concepts studied to the "real world".
4. perceive science as a human activity, involving team work, where errors are sometimes made and some outcomes remain uncertain.
5. become aware of the roles played by science, technology and society in the problem of air pollution and in the search for solutions.
6. understand and apply principles previously learned in chemistry, to this topic.
7. become aware of the interrelationship of knowledge from different disciplines, in the study of air pollution.
8. realise the importance of a risk/benefit approach in the search for solutions to the problem of air pollution.
9. develop a critical approach to the presentation of information on air pollution eg. by the media.

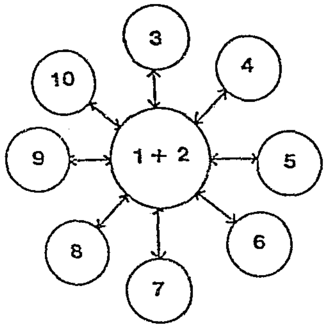
3.1.4. The Structure of the Package

The resource package comprises 10 units as shown in Figure 3.1.

1. The Atmosphere
2. What is Air Pollution?
3. Combustion
4. The Depletion of Ozone in the Stratosphere
5. Smog
6. The Enhanced Greenhouse Effect
7. Acid Rain
8. The Control of Air Pollution
9. The Response by Industry
10. What are Our Alternatives?

Units 1 and 2 form the **core** of the package. Fundamental concepts of the topic: Air Pollution, are presented in these two units. The concepts are dealt with more thoroughly in subsequent units which are related to the core units like petals in a flower.

Figure 3.1. The Structure of the Package and the Relationship between the Units



Each unit consists of:

a. <u>An Introduction</u>

This provides background information for the teacher. It informs and enriches and goes beyond the requirements of the lesson.

b. <u>A List of Learning Objectives</u>

These summarise the essential aspects of each unit and provide a possible framework for the presentation of the lesson.

c. <u>Worksheets</u>

They provide a variety of activities. Many of the worksheets are original in their design. Some, however, have been adapted from exercises in other sources eg. ChemCom (American Chemical Society, 1988) and some prototype units of education on global change (International Council of Scientific Unions, 1991). An attempt has been made to contextualise some of the activities to provide material for the many different types of teaching environments in South Africa. The worksheets could be used as classroom activities, homework exercises, projects or test questions. Cartoons and humour have been used in some worksheets. Titles for most worksheets are in the form of "catchy captions" or humorous statements. This is intended to make the activities more accessible to the students.

d. <u>Solutions</u>

Comprehensive solutions for the worksheets are to be found at the end of each unit. These are intended to assist the teacher and are not intended to be distributed to the students.

e. <u>Glossary of Terms</u>

The terminology associated with the topic: Air Pollution is complex and diversified. It is important that there is a consistency in the use of terms (IUPAC, 1990). The simple glossary seeks to explain some of the terminology used in the package. Explanations of terms have been gleaned from a number of sources (Collins, 1990; IUPAC, 1987; IUPAC, 1990; McGraw-Hill, 1984). A few other terms which have not been used in the package but which may be encountered in other sources have been included. Some vague or misleading terms which are in current use, have also been explained and alternative terminology suggested.

f. A Bank of Questions/Statements

The multiple choice questions/statements used in the survey (which formed part of the evaluation), have been adapted and included in the package. These questions/statements probe conceptual understanding of and attitudes towards air pollution. They could be used by the teacher to introduce the topic of air pollution, to initiate and stimulate debate and to test or examine.

3.1.5. Teaching Strategies Suggested in the Package

The resource package does not aim to be prescriptive. It does not provide consistently explicit guidance with regard to lesson plan or teaching strategies. It is proposed that teachers will make their own choices with regard to suitability of activities for the context in which they teach. Some strategies are implicit in the design of the worksheets eg. in the practical exercises. Many of the activities could be presented in a student-centred manner. Small group discussions could be used frequently. This would develop students' abilities to communicate ideas and teach skills of argument and negotiation to reach agreement by the group.

Most schools in South Africa have poorly equipped science classrooms and laboratories. For this reason, the practical activities suggested in the package do not require sophisticated equipment. Basic laboratory equipment is adequate. Suggestions are made for improvisation if some of the material is not available at the school. Much of the equipment could be purchased at a hardware or grocery store. The practical activities require very basic manipulative skills on the part of the teacher and the students. Attempts are made to relate the practical activities to the "real world".

3.1.6. The Use of Language in the Package

English is not the mother-tongue of many of the teachers and students who would use the package in South Africa. An effort has been made to keep the language demands as simple as possible.

3.1.7. A Closer Look at Each Unit

Each unit has been carefully structured. The activities planned for the students in the worksheets incorporate many of the key concepts of each unit.

Unit 1: The Atmosphere

The atmosphere is vital in supporting life on Earth. The atmosphere provides the gases for respiration and photosynthesis; it provides a benign climate and it protects plants and animals from harmful radiation from the Sun. The atmosphere is naturally reactive and can damage materials eg. the rusting of iron, etc. (American Chemical Society, 1988; Manahan, 1979). Worksheet 1(a) addresses these concepts.

The relevance of science is highlighted in this unit: the atmosphere is the "reaction vessel" and not a test tube in a laboratory. The "sides of the vessel" are the hydrosphere, lithosphere and biosphere. (However, these aspects are not explicitly stated in Unit 1.) A knowledge and understanding of the structure, properties and composition of the atmosphere ("reaction vessel") is essential in the study of air pollution. For purposes of study, the atmosphere is divided into regions based on trends in temperature. These regions are the troposphere, stratosphere, mesosphere and thermosphere (Barrow, 1972; Manahan, 1979; Spedding, 1974). The study of air pollution focusses mainly on the troposphere and stratosphere. Trends in mass, pressure, density and temperature are closely related to the properties of the different regions of the atmosphere (Barrow, 1972; Spedding, 1974). Worksheet 1(b) familiarises students with many of these concepts.

The microscopic nature and composition of the atmosphere (American Chemical Society, 1988; Spedding, 1974; Wayne, 1985) are significant in a study of the chemistry of air pollution. The conditions, under which reactions occur in the atmosphere, are not artificially set or controlled: winds and precipitation (rain, snow etc.) which form part of the weather, affect the conditions (Manahan, 1979; Wayne, 1985). Besides the effects of weather conditions, molecules or atoms move because of diffusion, the turbulence in the troposphere or the jet streams (horizontal currents) in the upper regions of the troposphere and in the stratosphere (Spedding, 1974; Wayne, 1985). A temperature inversion, the tropopause, (Spedding, 1974; Wayne, 1985) affects the movement and the rate of diffusion and mixing of substances between the troposphere and the stratosphere. Students study some of these aspects in Worksheet 1(c) and 1(d). Solar radiation enters the atmosphere and initiates many reactions (Campbell, 1986; Wayne, 1985). An example of such a photochemical reaction is the subject of the practical activity in Worksheet 1(e).

The notion that the composition of the atmosphere has changed naturally over **very** long periods of time (Graedel and Crutzen, 1989; Lovelock, 1989) is introduced in Worksheet 1(d).

Previous principles studied by students, eg. the Gas Laws and Electromagnetic Radiation, are related to the topic: Air Pollution, in Worksheets 1(d) and 1(e).

Unit 2: What is Air Pollution?

The atmosphere only becomes a concern whe problems of air pollution exist (Fuggle and Rabie, 1983). Air pollution is caused by substances in the atmosphere which may be a nuisance or cause damage to life and materials (Chambers, 1971; McGraw-Hill, 1984). Air pollution is apparent because of bad odours, smoke plumes, reduced visibility, damage to vegetation and animals, health problems in humans and damage to buildings and materials (Fuggle and Rabie, 1983; Strauss and Mainwaring, 1984; Wayne, 1985). Air pollutants may be solids, gases or aerosols (Wayne, 1985). These substances may be further classified as primary or secondary air pollutants (Fuggle and Rabie, 1983; Wayne, 1985). The air pollution resulting from such substances may be local, regional or global (Wayne, 1985). Worksheets 2(a), 2(b) and 2(c) address some of these terms and concepts.

Human activities are a major source of air pollution. Broadly speaking, these activities are the combustion of fossil fuels for energy generation, the burning of forests and grasslands, industrial activities, mining, agriculture and construction (Fuggle and Rabie, 1983; Strauss and Mainwaring, 1984; Wayne, 1985). These activities are causing significant changes in the concentrations of the substances that make up 0,05% of the atmosphere (Laburn, 1990). Natural phenomena (in particular volcanoes) can also be a source of air pollution (Wayne, 1985). Worksheet 2(d) familiarises students with sources, and the names of the air pollutants (American Chemical Society, 1988; Wayne, 1985).

Weather conditions play an important role in the dispersion of air pollutants (Preston-White and Tyson, 1988; Strauss and Mainwaring, 1984). The practical exercise in Worksheet 2(f) and parts of Worksheet 2(c), highlight this issue.

Air pollutants do not remain in the atmosphere forever. The atmosphere is able to render some of these air pollutants harmless by chemical reaction with other substances, by dispersion and dilution or by precipitation in rain, snow etc. (Campbell, 1986; Graedel and Crutzen, 1989; Wayne, 1985). Air pollution is a problem when the rate at which air pollutants are released into the atmosphere is greater than the rate at which these air pollutants are removed or rendered harmless (American Chemical Society, 1988; Wayne, 1985). (See parts of Worksheets 2(b) and 2(d).)

Our attitudes towards air pollution have changed since earlier times when smoke billowing from a chimney was a sign of progress and wealth. Now such a sight would be condemned. In South Africa, some cultural and language backgrounds may also influence peoples' attitudes towards and understanding of the concept of air pollution. For example, the inhalation of **smoke** from burning herbs is used by traditional healers for medicinal purposes. In addition, in some cultures there are no words or terms to distinguish "clean air" from "smoky or polluted air". Spray from a waterfall may also be named "smoke" (Matsie, 1988). People living in crowded urban environments where coal fires are still used for heating and cooking, are aware of and experience the consequences of air pollution (Ramontja, 1988). However, in some rural communities far removed from industry, air pollution is not perceived as a problem. There is a lack of awareness of the non-visible forms of air pollution and of the concepts of regional and global air pollution. For many people, economic and political problems appear to be more pressing than the consequences of air pollution (Ngcatshe, 1988; Project Ecos, 1991). Many of the questions in Worksheet 2(c), probe students attitudes to smoke and understanding of the concept of air pollution.

The media play a prominent role in shaping understanding of and attitudes towards environmental issues such as air pollution (Hill, 1991; Solomon, 1992). We need to view presentations by the media critically because errors and exaggerations sometimes occur. Worksheet 2(e) presents such a situation.

Science, technology and industry are often identified by the media as the major contributors to the problem of air pollution. Yet population growth, poverty and wealth in society, our everyday activities and our demand for commodities all impact heavily on the problem of air pollution (American Chemical Society, 1988; Hobbs and Boland, 1991; Lovelock, 1989; Pimentel and Coonrod, 1987). The roles of science and technology in the problem of air pollution are complex: in addition to contributing to the problem of air pollution, science and technology can and will provide solutions to the problem (Hobbs and Boland, 1991). Parts of Worksheets 2(b) and 2(c) address these issues.

Most of the concepts and issues introduced in the core Units 1 and 2 are re-addressed more thoroughly in Units 3 - 10 in the package.

Unit 3: Combustion

The demand for energy by the world's rapidly growing population is a major feature of our existence (Schneider, 1989; Spedding, 1974; Strauss and Mainwaring, 1984; Wayne, 1985). Approximately 90% of the world's energy needs are met by combustion, largely of fossil fuels (Campbell, 1986). Until 20 years ago, the technology used to make this energy available (Worksheets 3(a), 3(d), 3(e)), was hailed as a triumph because it improved our quality of life. Nowadays we are aware of the "hidden costs" of combustion on such a large scale. Combustion is a major source of air pollution (Corcoran, 1991).

This unit attempts to present a balanced perspective on the problems of air pollution. Worksheets 3(a), 3(d) and 3(e) focus on the role played by society. Our everyday activities such as cooking our food, warming and lighting our homes, driving motor vehicles and using other "combustion-driven" machinery, contribute significantly to the problem of air pollution (Strauss and Mainwaring, 1984). Political issues are also significant: the technology and processes used by SASOL to make petrol from coal were implemented to reduce South Africa's dependence on imported oil (Pimentel and Coonrod, 1987). In Worksheet 3(b), students can practise writing skills and creative thinking while they consider warfare as a source of air pollution (Horgan, 1991).

A study of the chemistry of combustion of fossil fuels requires a knowledge of the origins and nature of the non-renewable fossil fuels, coal, oil and natural gas (Elliott and Melchior, 1978; Vorres, 1978). During combustion, reactions of these fuels with oxygen give rise to the substances which are air pollutants (Strauss and Mainwaring, 1984). Worksheets 3(c) and 3(d) present practical exercises in which some of these reactions are studied.

It is important to understand the problems of air pollution in the South African context. Large coal-fired power stations are used in South Africa because coal is abundant (Dutkiewicz, 1990). In many poorer homes, where electricity is not available, coal, paraffin, gas or wood are burnt. Carbon monoxide poisoning (Worksheet 3(a)) is not uncommon (Ngcatshe, 1988). Furthermore, taxis, which are a means of transport for many South Africans, are the subject of Worksheet 3(e). They, too, contribute to the problems of air pollution but represent an efficient use of transport as many people are transported at the same time.

Amongst the possible consequences of releasing air pollutants produced during combustion into the atmosphere are the problem of smog (Unit 5), the enhanced greenhouse effect (Unit 6) and acid rain (Unit 7).

Unit 4: The Depletion of Ozone in the Stratosphere

Most of the harmful radiation from the Sun does not penetrate the troposphere. Some components of the atmosphere in the thermosphere and stratosphere absorb high energy radiation (Campbell, 1986; Manahan, 1979; Wayne, 1985) so that it is mainly lower energy ultraviolet or visible or infrared radiation that reaches the troposphere.

This absorption of radiation by some molecules in the atmosphere results in photochemical reactions Ozone is produced in the stratosphere in photochemical reactions during which oxygen molecules absorb radiation with wavelengths less than 230 nm (Wayne, 1985). Ozone is the only substance in the atmosphere capable of absorbing radiation in the region 290 - 320 nm (Campbell, 1986; Wayne, 1985). If this radiation penetrated the troposphere it would be harmful to life (Wayne, 1985). During the absorption of radiation, ozone is "destroyed" or converted into oxygen. Research indicates that in the past, the concentration of ozone in the stratosphere was more or less constant. The rate at which ozone was produced in the stratosphere was equal to the rate at which it was destroyed (Wayne, 1985). Now the rate at which ozone is being destroyed has increased (Stolarski, 1988). Ozone depletion in the stratosphere is the topic of Worksheet 4(a). In this worksheet, students' understanding of terms such as "ozone layer" and "hole in the ozone" is probed.

Chlorofluorocarbons (CFCs) are substances which are thought to be largely responsible for ozone depletion (Meyer, 1991; Toon and Turco, 1991). They are substances which do not occur naturally. Worksheet 4(b) examines how attitudes to the use of CFCs have changed since their properties have become better understood (Jones, 1988). Although CFCs are unreactive in the troposphere, they become very reactive under the different conditions in the stratosphere (Meyer, 1991; Stolarski, 1988; Toon and Turco, 1991; Wayne, 1985). One CFC molecule can result in many thousand ozone molecules being destroyed (Pimentel and Coonrod, 1987).

Worksheet 4(c) presents [illegible] man activity. Research into the problem of ozone depletion involved the communication of ideas and team work of scientists from different fields (Jacob, 1991). Errors were made although sophisticated modern technology was used (Lean et al, 1990).

Unit 5: Smog

Aerosols (suspensions of very small particles or droplets of liquid in the air) reduce visibility in the atmosphere. Some aerosols form as a result of weather conditions, eg. mist and fog. Other aerosols are a fine suspension of air pollutants or air pollutants in combination with fog/mist. The term "smog" refers to any visible smoky or hazy pollution of the atmosphere (Wayne, 1985). This pollution results mainly from the combustion of fossil fuels (Phillips and Pickering, 1991; Strauss and Mainwaring, 1984; Wayne, 1985). Worksheet 5(a) presents a comparison of the two main categories of smog: the "London-type smog" or classical smog and the "Los Angeles-type smog" or photochemical smog (Phillips and Pickering, 1991). These two categories of smog have different compositions and form under different weather conditions. Temperature inversions and geographic features play a very important role, too (Strauss and Mainwaring, 1984). Strict smoke control measures in many cities have reduced the occurrence of London-type smog (Strauss and Mainwaring, 1984; Wayne, 1985). However photochemical smog is a feature of many of our modern cities crowded with motor vehicles. On sunny days some of the primary air pollutants released from the exhausts of motor vehicles undergo photochemical reactions. The secondary air pollutants formed give rise to smog (Phillips and Pickering, 1991; Stoker and Seager, 1972). Worksheet 5(c) requires students to use their graphical interpretation skills in a study of photochemical smog formation. Using Worksheet 5(d) students can simulate smog formation. Components of the smog are detrimental to health and damage vegetation and many materials (Phillips and Pickering, 1991).

One of the components of photochemical smog is ozone. Ozone is very reactive towards many other substances. In the stratosphere the reactions of ozone which involve the absorption of harmful ultraviolet radiation are beneficial (Unit 4). However in the troposphere the reactions of ozone are detrimental resulting in damage to vegetation and materials and causing health problems (Meyer, 1991; Phillips and Pickering, 1991). Trends in ozone concentrations in the troposphere in South Africa are the focus of Worksheet 5(b). Ozone produced in the troposphere is not able to replace ozone depleted in the stratosphere because ozone is very reactive and its transfer across the tropopause is very slow. Task 2 in Worksheet 5(a) addresses these complex issues.

Unit 6: The Enhanced Greenhouse Effect

The warming of the atmosphere or the "greenhouse effect" is beneficial. Without it Earth would have scorching hot days and freezing nights (American Chemical Society, 1988). The atmosphere is not warmed directly by the Sun's energy; the atmosphere is warmed by energy radiated from a warmed Earth. Approximately 45% of the Sun's energy that enters the atmosphere, warms the Earth. Some of this energy is radiated back into the atmosphere as infrared radiation (Schneider, 1989). The molecules of a number of trace gases (the "greenhouse gases") in the atmosphere absorb some of this infrared radiation (Slanina, 1991). Through collisions, molecules of the "greenhouse gases" transfer energy to other molecules in the atmosphere thus causing warming. Worksheet 6(f) provides an opportunity to investigate the absorption of radiation by some of these "greenhouse gases".

For a long period of time the average temperature of the Earth has stayed more or less the same (Graedel and Crutzen, 1989). The difference between the rate at which energy was absorbed by the gases in the atmosphere and the rate at which energy left the atmosphere and escaped back into space remained more or less constant. This was because the concentration of the "greenhouse gases" in the atmosphere remained more or less constant - a "steady state" (ICSU, 1991). However research is showing that since the Industrial Revolution the concentrations of some of these gases have increased very rapidly. Less of the infrared radiation from the Earth is escaping back into space. Some of our activities, eg. combustion of fossil fuels and agricultural methods used to feed an ever-increasing world population, contribute significantly to this increase (Graedel and Crutzen, 1989). Worksheets 6(d) and 6(e) focus on aspects of these activities. Worksheet 6(c) looks at the correlation between graphs of the growth of the world population and the increase in the concentrations of some of these gases.

Carbon dioxide is one of the major "greenhouse gases" (Slanina, 1991). Worksheet 6(b) provides a study of the carbon cycle (Schneider, 1989; Slanina, 1991) and the effect that the combustion of fossil fuels is having on this cycle.

Worksheet 6(a) addresses the uncertainty surrounding the consequences of the increase in the concentrations of these "greenhouse gases" (Schneider, 1989; Slanina, 1991; Strauss and Mainwaring, 1984). However, the enhanced greenhouse effect remains a matter of extreme concern and the subject of ongoing research.

Unit 7: Acid Rain

Rain is naturally acidic because of the reaction of rain water with carbon dioxide in the air. However, over the last few decades, the acidity of precipitations such as rain, snow and hail, etc., in some regions has increased . The term "acid rain" refers to precipitations that have increased acidity (Campbell, 1986; Pearce, 1982; Wayne, 1985). Worksheet 7(d) presents a long term project to monitor the acidity of rain.

Some primary air pollutants (mainly oxides of nitrogen and sulphur) produced during the combustion of fossil fuels and during some industrial processes contribute to air pollution problems (American Chemical Society, 1988; Campbell, 1986; Strauss and Mainwaring, 1984; Wayne, 1985). In fact more sulphur dioxide is released annually into the atmosphere by our activities than by natural sources (American Chemical Society, 1988). Worksheet 7(b) presents a method for monitoring sulphur dioxide concentrations in the troposphere. The combustion of fossil fuels for transportation and for the generation of electricity contributes more of these oxides than industrial processes (American Chemical Society, 1988). This is the topic of Worksheet 7(c).

Oxides of nitrogen and sulphur may be deposited "dry" or "wet" (Pimentel and Coonrod, 1987). Both wet and dry deposition of these oxides can damage materials, vegetation and aquatic life and cause health problems (Strauss and Mainwaring, 1984). Some of these consequences are studied in Worksheets 7(a) and 7(e). The destruction of vegetation (in particular many forests) cannot be solely attributed to acid rain; other factors such as drought, disease, increased concentrations of tropospheric ozone, soil type and age of the vegetation are also important factors (Meyer, 1991).

Acid rain is also a problem far removed from the areas where these primary air pollutants are produced (Campbell, 1986; Wayne, 1985). Wind patterns play a very important role. Thus the dilution of air pollutants by using tall chimney stacks is not always a solution (Tyson et al, 1988).

Unit 8: The Control of Air Pollution

The control of air pollution by the atmosphere itself is the focus of Worksheet 8(a). Air pollutants are removed from the atmosphere in a number of ways: by dropping out of the atmosphere, by precipitation in rain, snow etc. or by being converted through chemical reactions into other less harmful substances (Wayne, 1985). During the removal of air pollutants there are often reactions between these substances and the lithosphere, the hydrosphere or the biosphere. These reactions form part of cyclical processes (Campbell, 1986; Wayne, 1985) whereby the concentrations of many substances in the atmosphere have remained more or less constant for many thousands of years - a steady state (Wayne, 1985).

Air pollution can also be controlled to some extent by law (Council for Scientific and Industrial Research, 1991; Department of National Health and Population Development; undated). Legislation aims to prevent the concentrations of air pollutants exceeding values that are safe for humans and the environment. Where global air pollution problems exist, international agreements are sometimes reached. The Montreal Protocol on Substances that Deplete the Ozone Layer, is such an agreement (Council for Scientific and Industrial Research, 1991; Department of National Health and Population Development, undated; Jacob, 1991). This agreement seeks to stop the production and use of CFCs, and is the subject of Worksheet 8(b).

Research organisations detect and monitor air pollutants (Brunke et al, 1990; Council for Scientific and Industrial Research, 1991; Graedel and Crutzen, 1989). Findings are pooled and this leads to a deeper understanding of air pollution and the development of possible solutions.

The public is becoming more concerned and involved in problems of air pollution (Council for Scientific and Industrial Research, 1991). Many groups and societies have been formed in an attempt to control air pollution and protect the environment - the "green groups" (Goldsmith and Hildyard, 1990; Lean et al, 1990 ; Leggett, 1990; Walmsley, 1991). Worksheet 8(c) uses a cartoon to stimulate argument/discussion on this issue.

Unit 9: Response by Industry

Industrial companies are increasingly concerned about the environmental consequences of their activities (AECI, 1989; Benkenstein, 1990; Hobbs et al, 1989; SASOL, 1991; Winter, 1990). Air pollution is costly in terms of damage to health, materials and vegetation. Air pollution is also costly in terms of the technology used to control it. A balance must be found between these two cost factors (American Chemical Society, 1988). This balance must take into account the *".....interests of the public who want clean air, industrialists who want to make a profit, the employees who want to keep their jobs and the government who want national prosperity and contented citizens"* (Els, 1990, page 5).

Most of the technology in use at present aims to reduce the emission of air pollutants resulting from the combustion of fossil fuels. Tall chimney stacks are used to disperse and dilute emissions (Strauss and Mainwaring, 1984; Tyson et al, 1988) although this is not always a solution (Unit 7). Electrostatic precipitators, baghouse filters, and cyclones are used in an attempt to reduce the emission of particulates (British Coal Corporation, 1987; Corcoran, 1991; Dutkiewicz, 1990; Strauss and Mainwaring, 1984). The use of "smokeless stoves" (Department of Health and Welfare, 1984) is suggested in South African homes where coal is burned. Catalytic converters can reduce the emission of air pollutants from motor vehicle exhausts when lead-free petrol is burned (Bronze et al, 1990). Dry and wet scrubbing techniques can be used to remove the oxides of sulphur (American Chemical Society, 1988; Corcoran, 1991; Dutkiewicz, 1990). Students are introduced to some of this technology in Worksheets 9(a) and (b). Worksheet 9(c) presents trends in the concentration of some air pollutants over the last few years in South Africa and a study of the impact of technology on these trends. The role-play described in worksheet 9(d) focusses on some South African industries, the commodities they produce and the air pollution problems these industries encounter. The availability of natural resources and social and economic conditions affect the type of solutions adopted at present in South Africa (AECI, 1989; Els, 1990; Ryan, 1991; SASOL, 1991).

Unit 10: What are our Alternatives?

To reduce and control air pollution, our life styles and use of resources must change (Clark, 1989; MacNeill, 1989; Ruckelshaus, 1989).

Alternative sources of energy need to be considered and explored (Gibbons et al, 1989). Although natural gas is a fossil fuel, it is cleaner burning than coal and oil (ICSU, 1991). In a sunny country like South Africa, solar energy is a promising alternative (Bronze et al, 1990; Gandar, 1990). The utilisation of nuclear energy takes place at the power station in Koeberg, South Africa (ESKOM, 1989; Smith, 1987). Some hydro-electric schemes have been developed in South Africa and there is the potential for more use of these as a source of energy (Ryan, 1991). Harnessing energy from the wind is another alternative (Bronze et al, 1990; Gandar, 1990). Worksheet 10 (a) takes a look at some of these alternative sources of energy and the advantages/disadvantages in their use.

Industry is committed to finding alternative compounds to CFCs. The manufacture of methoxymethane (*"Prozone"*) for use as a propellant in aerosol sprays (CHEMSA, 1990) is addressed in Worksheet 10(b). This worksheet also discusses the advantages/disadvantages of the use of hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) as alternative compounds in the refrigeration industry (Sarre et al, 1991).

Changes in society are necessary, too. The rapid growth in the world population is a cause for great concern. The demand for food, energy and commodities by this large population is a major contributor to the problems of environmental pollution. Population growth must be reduced (Keyfitz, 1989). In addition a change in our everyday activities will also contribute to a reduction in air pollution. Worksheet 10 (c) looks at some of the ways we can change our habits in the home and Worksheet 10(d) looks at alternatives in our use of transport.

Although its consequences are serious, air pollution need not present a "doomsday scenario" (Task 3, Worksheet 10(e)). The risks and benefits of our activities need to be weighed up to find balanced solutions (Huntley et al, 1989; Pimentel and Coonrod, 1987). Our ever-increasing knowledge, our technological skills and our ingenuity equip us to live, work and preserve the atmosphere that surrounds our planet.

3.2. IMPLEMENTATION OF THE PACKAGE

3.2.1. Background to the Implementatioı

The urgent need for materials in schools by ·. ., re.ulted in the trial implementation being planned by the researcher whilst some units of the pacl age were still being written.

During the course of the year the package was presented at various meetings and conferences. Efforts were made at these meetings to recruit teachers to participate in the trial implementation and evaluation. Other teachers were invited individually to participate. A number of workshops were run during the course of six months to prepare teachers to implement and evaluate parts of the package.

The trial implementation was carefully structured but as the exercise proceeded, some problems were encountered and plans had to be modified.

A rather detailed description is given of the trial implementation. The details reveal some of the unique problems encountered in South Africa in 1991 when attempting to implement new curriculum material.

The trial implementation of the package that eventually took place can be regarded as a pilot study because of the small scale on which it was conducted.

3.2.2. Planned Implementation

To assess the suitability and adaptability of the package, it was intended to implement and evaluate parts of the package using a varied sample of standard 9 science teachers and schools. For coherency, each teacher would implement the two core units (Unit 1 and Unit 2) and one other unit. The implementation would take place towards the end of the academic year, ie. September - November, 1991. (This coincided with the expected time of the year when the topic would be introduced in standard 9 in 1993.)

Three to five hours teaching time would be required for the trial implementation of three units.

It was planned that the package would be implemented in 16 schools:

8 urban schools:	4 state schools
	4 independent schools
8 rural state schools:	4 schools in district A (Lebowa) (approx 400 km from Johannesburg) 4 schools in district B (Giyani) (approx 500 km from Johannesburg)

The eight urban schools would be selected in and around Johannesburg. Rural schools would be selected in district A and district B because the Chemistry Department (University of the Witwatersrand) had established links with teachers and/or education officers in these regions. It was intended to match the trial implementation of parts of the package by urban and rural schools as shown in **Table 3.1** below. It was hoped to be able to compare the outcomes of the trial implementation and evaluation at the schools from the two different settings.

Table 3.1. Proposed Implementation of Units at Urban and Rural Schools

Urban Schools		Units to be Implemented	Rural Schools	
State Schools	1	1, 2, 4	1	Schools in District A
	2	1, 2, 5	2	
	3	1, 2, 8	3	
	4	1, 2, 10	4	
Independent Schools	1	1, 2, 3	1	Schools in District B
	2	1, 2, 6	2	
	3	1, 2, 7	3	
	4	1, 2, 9	4	

3.2.3. Presentation of the Package and Recruitment of Teachers to Participate in the Trial Implementation and Evaluation

The package was presented at a number of meetings and workshops:

1. South African Association of Teachers of Physical Science (SAATPS) Meeting in Johannesburg (April, 1991)

The development of the package was briefly publicised at this meeting. Four teachers from state schools volunteered to implement and evaluate parts of the package. It was agreed that a workshop be held in Johannesburg in August to familiarise these teachers with the material and the evaluation procedures.

At the same meeting teachers from rural district A were approached. They agreed enthusiastically that a workshop on the package be held in rural district A early in September. Final selection of teachers to participate in the trial implementation would take place at this workshop.

2. Further Recruitment of Teachers

During April, 1991, teachers from four independent schools in the Johannesburg region were approached individually and they agreed to take part in the implementation and evaluation. These teachers agreed to attend a training workshop early in September.

3. Workshop in Rural District B (May,1991)

Approximately 49 standard 8 and 9 teachers from schools all over this region gathered at the Science Centre in this district. An outline of the package was presented to gauge teachers' interest in the project. It was the first contact made by Chemistry Department staff of the University with teachers in this region. During this workshop, feedback was gained via open-ended questions in a questionnaire *Let Us Talk About Air Pollution* (see Appendix, page A2) as to the teachers' understanding of the problems/issues of air pollution. (Some of the findings were used to construct a *Survey on Air Pollution* (see Appendix, page A4). This was used later to probe the beliefs about and understanding of air pollution of teachers and students involved in the trial implementation.) A number of teachers expressed an interest in the project and it was agreed that another workshop be held in September at the Science Centre to familiarise teachers with the material and to select teachers to participate in the trial implementation.

4. Workshop at SAATPS National Convention in Cape Town (July, 1991)

Seventeen teachers attended a 2 hour workshop where material and selected activities from Units 1 and 2 of the package were presented. The teachers came from a variety of schools in South Africa. None of these teachers took part in the implementation as the researcher felt at this stage that her sample of teachers for implementation and evaluation was complete. However the workshop was an opportunity for testing teachers' perceptions of the package and for administering parts of the *Survey on Air Pollution* for the first time.

3.2.4. Preparation of Teachers for Implementation and Evaluation

Teachers were prepared for the trial implementation and evaluation of the package during a number of workshops:

1. Chemistry Department, University of the Witwatersrand, Johannesburg (August, 1991)

Four teachers from different state schools in the Johannesburg region attended. In addition 2 teachers from independent schools who were interested (but not able to implement) attended. The duration of the workshop was approximately 5 hours. To introduce the topic, the first 25 items of the *Survey on Air Pollution* were administered. This was followed by a "mini" lecture on the atmosphere and general aspects of air pollution. Teachers were allowed time to try some selected experiments from Units 1 and 2. An informal discussion of Units 1, 2, 4, 5, 8, and 10 of the package followed. Instructions were also given as to the pre- and post-testing of students and the completion of the evaluation sheets. Teachers left the workshop with an implementation "kit" consisting of:

a. Instructions on how to carry out the implementation and evaluation exercise (see Appendix, page A17).

b. Copies of Units 1 and 2 and the additional unit to be trialled. (Teachers had no choice with regard to this additional unit.)

c. Answers to all worksheets.

d. Sufficient copies of all worksheets for their students. (These had been photocopied beforehand to avoid additional costs to schools and to reduce teachers' preparation time.)

e. Copies of the *Survey on Air Pollution* and answer cards for their students. This survey would be admininstered as a **pre-test** before teaching the three units of the package and then as a **post-test** after teaching.

f. Evaluation sheets (see Appendix, pages A18 and A20) that the teachers would complete after teaching.

g. Contact telephone numbers in case problems were experienced during implementation.

It was agreed by the teachers that the implementation and evaluation would take place during October, 1991 after the standard 9 syllabus had been completed. The researcher would then collect completed evaluation sheets and student answer cards.

2. <u>Chemistry Department, University of the Witwatersrand (September, 1991)</u>

Four teachers from independent schools had agreed to participate but only three of them attended. This workshop was run on identical lines to the August workshop. However the focus of the workshop was on Units 1, 2, 3, 6, 7, and 9 of the package. It was agreed that implementation would take place during October, 1991. Teachers left with similar materials to those described above. The researcher would also collect completed evaluation sheets and student answer cards from these teachers.

3. <u>Science Centre, District B (September, 1991)</u>

Eight teachers attended. Some had travelled almost 100 km to the Science Centre. The workshop was run on very similar lines to those conducted in Johannesburg. The focus of this workshop was on Units 1, 2 , 3 , 6 , 7 and 9. Four teachers indicated that they would be willing to participate in the implementation of the package. They were equipped with similar implementation "kits" to those distributed at the August training workshop at the University of the Witwatersrand. However, as it would not have been possible for the completed evaluation sheets and student cards to be collected by the researcher from these remote schools, stamped addressed envelopes were included.

3.2.5. Problems Encountered with the Planned Implementation

1. Instability at schools in rural district A made it impossible to implement parts of the package in this region. Students were involved in a "stayaway" from school which was followed by a strike by teachers during September (the time intended for the training workshop). Arrangements were made to hold the workshop later but the unrest continued making it impossible to do so.
2. One of the teachers from an independent school in Johannesburg indicated that he was reluctant to participate in the trial implementation of parts of the package. Students at the school had also been involved in protests and a "stayaway". He was concerned that students might be suspicious of the motive for conducting the implementation and that the exercise might spark off trouble among the students again.

3.2.6. Final Selection of Teachers Participating in Implementation and Evaluation

Five more schools in the Johannesburg region were identified to replace the schools that had dropped out of the initial implementation and evaluation. Four of these were independent schools and one a state school. Teachers at these schools were individually briefed as to implementation and evaluation procedures. At one of the independent schools, it was arranged that the researcher would implement parts of the package herself. Therefore sixteen teachers (including the researcher) finally agreed to implement and evaluate parts of the package at **4 state schools** in rural district B, **5 state schools** in Johannesburg and **7 independent schools** in and around Johannesburg.

3.2.7. Research into Implementation

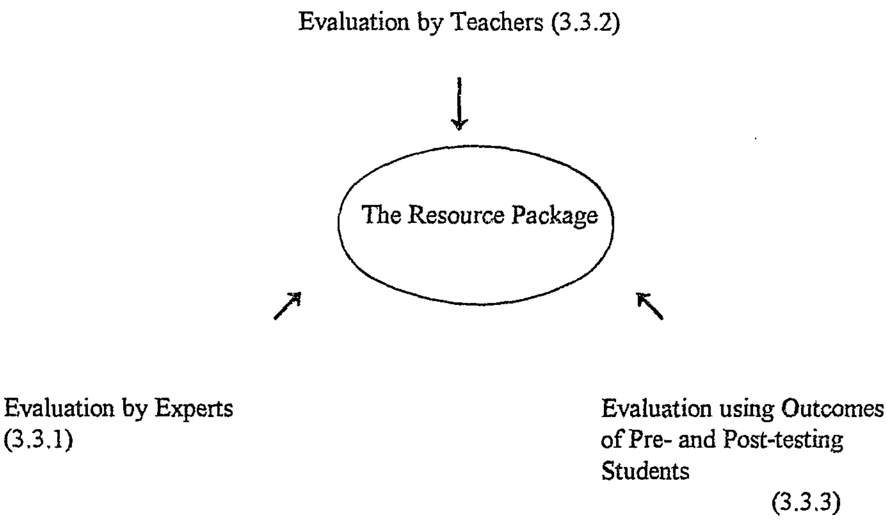
The processes of implementation and evaluation were closely intertwined. Broad aspects of implementation have been discussed above. However the evaluation sheets completed by teachers also provided rich insights into the process of implementation in the different school settings. In addition the responses of a number of teachers to parts of the *Survey on Air Pollution* revealed some of their preconceptions about air pollution. These data, generally qualitative in nature, were used to construct profiles of the schools, teachers and students (see Chapter 4). These profiles and further outcomes of implementation were interrelated, analysed and interpreted (Robottom, 1989; Robottom and Hart, 1993; Shymansky and Kyle, 1992). This was done in a search for answers to the broad research question:

What factors played a role during the trial implementation of the resource package?

3.3. EVALUATION OF THE PACKAGE

A **formative evaluation** of the package was conducted. Data were collected to assess the value of the package as a teaching resource and to inform the researcher about possible changes and modifications to make so that the broad aims and objectives of the resource package could be met (Aikenhead, 1994c; Schumacher and McMillan, 1993). To evaluate the package, a triangulation of methods was used as shown in the diagram below:

Figure 3.2. Methods of Evaluation of the Package



3.3.1. Evaluation by Experts

Feedback from a range of experts was sought to answer the broad research question:

Is the resource package an accurate and balanced representation of the topic: Air Pollution and the problems and issues associated with it?

The first draft of the package and a covering letter asking for their evaluation (see Appendix, page A16) was given to:

i. Three geographers (a professor, a lecturer and a tutor in the Geography Department at the University of the Witwatersrand). All taught environmental topics in their courses. All were involved in developing teaching material for schools.

ii. A lecturer in the Chemistry Department at the University of the Witwatersrand. He lectured the environmental chemistry topic to third year students. He was also a qualified teacher and had taught in secondary schools.

iii. A professor in the nuclear research unit of the University of the Witwatersrand. At the time, he was involved in the monitoring of air pollutants in South Africa.

iv. A local newspaper journalist who reported on environmental issues.

3.3.2. Evaluation by Teachers

The suitability of the package as a teaching resource, was assessed by the teachers who implemented parts of the package. The assessment was made using:

a. <u>Evaluation Sheets for **Each Unit**</u> (see Appendix, page A18)

The general structure of the evaluation sheet for each unit and the evaluation sheet for the package as a whole (see in (b) below) was created by Harris (1993) in her evaluation of a teaching resource package on chemical bonding. Similar evaluation sheets were used by van den Hoek (1997) in her evaluation of teaching resource materials on the topic water. The design of the three teaching resource packages (on "Chemical Bonding", "Water Pollution" and "Air Pollution") occurred concurrently and at the time it was thought that using similar evaluation procedures could provide a valuable comparison of the three resource packages.

Teachers in this research project completed these evaluation sheets after teaching **each of the three units** they were assigned. These sheets probed:

i. the teachers' total teaching experience and experience in teaching standard 9.
ii. the approximate time taken to teach each unit.
iii. the strategies used to teach each unit.
iv. the confidence of the teacher in presenting the unit.
v. the students' enthusiasm for and understanding of the topic presented.
vi. the teachers' need for more information.
vii. the teachers' rating of the unit in terms of its suitability for use in standard 9.

b. Evaluation Sheet for the **Package as a Whole** (see Appendix, page A20)

Teachers completed this sheet after teaching the **entire portion of the package** they had been assigned. On these sheets teachers recorded:

i. difficulties they experienced while teaching their portion of the package.

ii. comments about the language demands of the package both for the teachers and the students.

iii. usefulness of learning objectives, background information, worksheets, experiments, teachers' notes (answers etc.).

iv. suggestions for improving the package.

c. Additional Comments from Teachers

Additional written and verbal comments about the package were provided by some teachers.

The evaluation by the teachers was sought to provide answers to the broad research questions:

1. ***Can teachers and students in the different school environments effectively use the materials?***

2. ***Is the package a suitable teaching resource for a standard 9 chemistry class?***

3.3.3. The Design and Administration of a Survey on Air Pollution

3.3.3.1. The Survey as an Instrument of Evaluation

A multiple choice survey (which contained a number of Likert-type items) was used as an instrument in the evaluation of the resource package because it was considered a cheap and effective method for the **single** researcher to use in a sample of schools spread over a wide area of South Africa (Walberg, 1991). There are shortcomings associated with such instruments (Aikenhead, 1988). However some features of the schools taking part in the evaluation had to be taken into consideration. Several schools in the research sample had not used such instruments before. In addition, English was not the mother tongue of many students and some of the teachers in both the urban and rural schools. Thus it was decided to keep the design and administration of the Survey as simple as possible. It was beyond the scope of this pilot study to develop an empirically based instrument such as VOSTS (Aikenhead, 1988).

It was intended that the use of the Survey as a **pre-test** would provide insights into preconceptions held by students and teachers The researcher had to ensure that these preconceptions were addressed in the resource materials (Zoller, 1991). These preconceptions formed the base line against which the effectiveness of materials in the resource package could be assessed (Aikenhead, 1994c).

The comparison of the outcomes of the pre- and post-tests provided answers to the broad research questions:

1. ***Do the materials enable teachers to provide a meaningful learning experience for the students?***
2. ***Do the materials enable teachers to improve the students' scientific literacy?***

To provide deeper insights, the aspect of **meaningful learning** was further probed by the research questions:

a. ***Do the materials enable teachers to improve the students' understanding of the concepts, principles and terminology associated with air pollution?***
b. ***Do the materials enable teachers to increase the students' awareness of and concern about air pollution?***
c. ***Do the materials enable teachers to bring about change in the students' beliefs, attitudes and opinions, that leads to a more balanced outlook concerning the issues related to air pollution?***

The research questions 1 and 2 are closely linked. **Meaningful learning**, in the context of this research, is a prerequisite for the outcome of **improved scientific literacy**. This method for assessing improved scientific literacy was based to some extent on Miller's analysis (1989) that students acquire an understanding of scientific processes and concepts and a vocabulary of scientific terms which enables them to give opinions about issues in which science and society play a role. Miller's description of scientific literacy is based largely on **cognitive** aspects. However it was considered that meaningful learning of concepts, processes, terms etc. was necessary but not sufficient for achieving scientific literacy. Thus the method used in this research included **affective** aspects as well. Students' awareness/concerns/attitudes/beliefs/opinions had to change and reveal a more **balanced** outlook as a result of them gaining a better understanding of the role played by science, technology and society in the environmental topic: Air Pollution (Fleming, 1989; Holbrook, 1992; Ramsey, 1993; Yager, 1992a; Yager, 1992b).

3.3.3.2. The Design of the Survey on Air Pollution

The ideas for many of the items in the Survey came from feedback from teachers at a workshop in rural district B in May, 1991. At the start of the workshop approximately 50 participants responded to a questionnaire *Let Us Talk about Air Pollution* (see Appendix, page A2). They worked in pairs to answer the items. Twenty four response sheets were handed in. The responses to each item were classified into various categories. Some responses contributed to more than one category. Thus the total percentage responses for each item is often greater that 100%. The responses are quoted as a percentage of the total number of response sheets handed in.

Summary of Responses

Item 1. What is "air pollution"?

Responses	%
Process which makes air "dirty"	46
Presence of substances in atmosphere which damage life and/or property	25
Addition of "impurities" to the atmosphere	17
"Contamination" of the atmosphere by substances not normally found in the atmosphere	12
Process whereby the composition of the atmosphere is changed	12
Process whereby substances "go into the atmosphere"	8
Addition of substances to the atmosphere which are not useful	4
Process which results in the air not being "fresh"	4

Item 2. What are "air pollutants"?

Responses:	%
Substances causing air pollution	58
Impurities	17
Substances which change the composition of the atmosphere	8
Examples of substances eg. SO_2,	8
Substances which make the air unclean	4
Substances which make the air unhealthy	4
No Response	4

Item 3. Make a list of "air pollutants" that you know.

Responses	%		%
Smoke	67	Steam from locomotives	8
Dust	62	Burning diesel	4
Carbon monoxide	38	Mist	4
Chemicals from industry	33	Asbestos	4
Veld fires	12	Tobacco	4
Coal fires	12	Radiation	4
Fumes	12	Oil	4
Car exhausts	8	Sewerage	4
Insecticides	8	Bad smells	4
Sulphur dioxide	8	Use of war weapons	4
Carbon dioxide	8	No Response	4
Soot	8		

Item 4. How are you aware that air pollution is occurring?

Responses:	%
Damage to vegetation or materials	62
Damage to health eg. death, coughing, burning eyes, suffocation	50
Something visible in the atmosphere eg. smoke, mist, fog, steam	42
Presence of smells	21
Changes in the weather	8
Acid rain	8
Dirty house	4
No Response	4

Item 5. What are the causes (sources) of air pollution?

Responses:	%		%
Factories/industries	79	Locomotives	12
Combustion of fuels, coal	46	War	8
Vehicles	29	Homes	8
Veld fires	25	Rotting things	4
Wind blowing dust	21		

Item 6. Is air pollution of concern to you? Explain your answer.

Responses:	%	Responses:	%
YES	71	**NO**	4
Reasons for Answering "Yes":		Reasons for Answering "No"	
Detrimental to health	62	Not much pollution in our environment	4
Damages plants	17		
Damages materials	17		
Oxygen is being destroyed	8		
Weather may change	8		
No Response	25		

Item 7. Explain the meaning of the terms:
a. "Greenhouse effect" **b. "Hole in the ozone layer"** **c. "CFCs"**

Responses to: **"Greenhouse effect"**	%
Planting of trees to balance the O_2 and CO_2 in the atmosphere	8
Ability of particles in the atmosphere to trap light rays	4
Ability of particles in the atmosphere to attract sunlight to warm the Earth	4
No Response	83

Responses to: **"Hole in the ozone layer"**	
Do not know	8
Layer of O_3 high in the atmosphere which is a source of oxygen and protects us from UV radiation	4
CFCs destroying ozone	4
No Response	83

Responses to: **"CFCs"**	
Do not know	8
No Response	92

Item 8. Why do you think air pollution is often discussed nowadays in newspapers, on radio and TV?

Responses:	%		%
To control air pollution	38	To show that air pollution is increasing	4
To make people aware of the problem	38	To show change is occurring	4
To educate people	17	No Response	33
To show that it is a big problem	4		

Item 9. Do you think air pollution can be controlled? Explain your answer.

Responses:	%
YES	50
Reasons for answering "Yes":	
If we use electricity	25
If we avoid veld fires	12
If we plant trees	4
If we change our habits	4
Making people aware so that they can control it	4
No Response	50

Comments on Responses

When assessing teachers' responses, it should be borne in mind that many of the teachers at the workshop came from remote rural areas with no electricity and little access to the media. District B is largely an agricultural region with little or no industry. Droughts occur frequently. Veld (grass) fires are a common feature during winter. Wood, coal and paraffin are burned in many homes for cooking and heating purposes.

An analysis of teachers' responses revealed the following:

1. There may be a general perception that air pollution is always visible. Many teachers responded that air pollution made the air dirty (responses to item 1). Smoke and dust were commonly named as air pollutants (responses to items 2 and 3).
2. Many teachers felt that air pollutants were substances not occurring naturally in the atmosphere. Responses to items 1 and 2 included ideas that air pollution is *"addition of impurities.."*; *"contamination of the atmosphere .."*; *"caused by substances which go into*

the atmosphere..".

3. There is a common perception that industry is the main source of air pollution (response to item 5).

4. The concept of global air pollution and issues or terms such as *"the greenhouse effect"*, *"the hole in the ozone layer"* and *"CFCs"* were unfamiliar to almost all the teachers at the workshop. Many teachers did not respond at all to these items. When they did their answers revealed misconceptions eg. *"the greenhouse effect is the planting of trees to balance carbon dioxide and oxygen"* and *"... ozone layer is a source of oxygen...."* (responses to item 7).

The rural sample of teachers who had responded to this questionnaire were not representative of South African teachers. Nevertheless it was felt that their responses were indicative of some of the preconceptions held by many concerning air pollution. Some of their responses were used in the construction of the *Survey on Air Pollution* as follows:

a. The idea that air pollutants are generally visible (or have a smell) was incorporated in item 14 in the Survey.

b. The notion that air pollutants are substances that do not occur naturally in the atmosphere, formed the basis of item 5 in the Survey.

c. The perception that industry is the main source of air pollution formed the theme for items 7, 18 and 19 in the Survey.

d. The lack of familiarity with the concepts of global air pollution and terminology such as *"greenhouse effect"*, *"the hole in the ozone layer"* and *"CFCs"*, formed the basis of items 8, 9 and 10 in the Survey.

An initial short Survey consisting of 20 items was tested on teachers attending the Cape Town Workshop in July, 1991. Item 1 was modified as a result of this. As the development of the resource package proceeded more items were added.

The final Survey of 45 multiple choice items (see Appendix, page A4) consisted of:

1. **30 Core Items**

   These items were to be answered by **all** students taking part in the trial implementation. In the analysis of outcomes that follows (in Chapters 4 and 6), these items have been **broadly** categorised. (Some items could, however, fit into more than one category.)

   a. **9 Knowledge Items (Items 5, 6, 7, 25 - 30)**

      These items probed students' factual knowledge and understanding of concepts and terminology associated with some of the features of the atmosphere and with air pollution.

   b. ***21 Attitudinal Items* (Items 1 - 4 and 8 - 24)**

      These items probed the students' attitudes/beliefs/awareness/concerns about aspects and issues related to air pollution.

2. **15 Unit Specific Items (Items 31 - 45)**

   These items were specific to the additional unit (ie. Unit 3, 4, 5, 6, 7, 8, 9 or 10) implemented at the various schools. Thus **eight different versions** of this part of the Survey were designed.

3.3.3.3. Administration of the Survey

Before the trial implementation of the package, many of the teachers participating in this pilot study responded to the first 25 items of the Survey at the workshops they attended. (Their responses are discussed in Chapter 4.) Teachers were not post-tested.

The Survey was administered as a **pre-test** to students by teachers before teaching any part of the package. (Some of these pre-test responses are presented in Chapter 4.) The same Survey was administered as a **post-test** to students after teachers had completed teaching their portion of the package. Teachers were **not provided** with any answers to the Survey. Students recorded their responses on computer cards. Students were able to answer the pre- and post-tests using a fictitious name but were required to use the same name on the pre- and post-tests so that their answer cards could be identified. A **chi-square test of significance** (Schumacher and McMillan,

1993) was used in the comparison of students' responses to the **30 core items** of the Survey in the pre- and post tests. Smaller numbers of students responded to the **unit specific items**. Thus a statistical comparison of these outcomes was not made. Instead the **knowledge gain** (as a percentage) for each item was calculated.

In this pilot study, no control or comparison group was used. It was difficult to find sufficient schools to take part in the evaluation of the package. Under these circumstances it was felt that if one or two classes were used as a control group, these would not be representative of the experimental group where there was a great deal of variation in school, teacher, students, mother tongue of teachers and students etc. (Robottom, 1989). It was out of the question to expect teachers who were implementing the units to attempt to form their own control groups. There are flaws in this form of experimental design because of uncontrolled threats to the internal validity of the instrument (Schumacher and McMillan, 1993). However there are instances where this type of design might be used - especially if some of the threats to internal validity are controlled (Schumacher and McMillan, 1993). In this **pilot** research, some of the threats to internal validity were controlled by using pre-and post-test responses from the **same** students and by administering the post-test **relatively soon after** the pre-test (Schumacher and McMillan, 1993). Some of the tentative outcomes generated in this way could then serve as indicators for **more systematic testing** in future research.

The reliability of the Survey as an instrument would not be considered in this research largely because there were no single constructs being probed (Gardner, 1996). Other factors (Schumacher and McMillan, 1993) which played a role in this consideration were:

a. Air pollution was a new topic to the students.

b. English was not the mother-tongue for many students in the sample.

c. The motivation of the students for answering the Survey may have been poor as their answers to the items had no implications for their school performance in terms of marks etc.

d. The Survey was administered by a number of different teachers.

CHAPTER 4

PROFILES OF THE SCHOOLS, TEACHERS[1] AND STUDENTS TAKING PART IN THE TRIAL IMPLEMENTATION AND EVALUATION OF THE PACKAGE

To develop a more interpretative approach to the research in this pilot study, some profiles of the different school settings were constructed (Robottom, 1989; Shymansky and Kyle, 1992). It was against the backdrop of these profiles that the resource package was implemented and evaluated. The profiles were constructed using anecdotal information gained at some of the workshops, using information from the evaluation sheets completed by the teachers and using teachers' and students' responses to parts of the *Survey on Air Pollution*. These profiles include information regarding:

- the science teaching facilities at the schools
- the qualifications of the teachers
- the language status of teachers and students
- some of the conceptual understanding and beliefs of the teachers and students with regard to air pollution.

1 The Survey responses of some teachers who did not take part in the trial implementation, have also been included.

4.1. PROFILE OF THE SCIENCE TEACHING FACILITIES AT THE SCHOOLS

The science facilities at the schools used in the implementation of the package were as follows:

1. Urban State Schools

   Science facilities at these schools were good with adequately equipped laboratories. Laboratory assistants were employed at these schools to assist with maintenance of laboratories and preparation of practical activities.

2. Urban Independent Schools

   Five of these schools had adequate to good laboratory facilities. One of the schools had a new laboratory with very little equipment, the other had no laboratory.

3. Rural State Schools

   One of the rural state schools had a laboratory with basic equipment. At the other three schools there were no laboratories and no science equipment. Experiments were conducted *"on a table, under a tree with a bucket of water standing by"*. (Quoted from a conversation with an education officer in rural district B.)

4.2. PROFILE OF THE QUALIFICATIONS AND LANGUAGE STATUS OF THE TEACHERS

The qualifications and language status of the teachers finally agreeing to participate in the trial implementation and evaluation are shown in **Table 4.1.** below.

Table 4.1. The Qualifications and Language Status of the Teachers

	Urban State Teachers	**Urban Independent Teachers**	**Rural StateTeachers**
Qualifications	1 SSTD[2] 2 BSc HDE[3] 1 BScHons HDE 1 BSc BEd HDE	1 completing BSc 1 BScEng 3 BScHons HDE 2 MSc HDE	1 completing BA 3 STD[4]
Language	5 EL1[5]	4 EL1 3 EL2[6]	4 EL2

Thus with the exception of one teacher, teachers at the urban state schools were well qualified. English was the mother tongue of all these teachers. Teachers at the urban independent schools were also well qualified with the exception of one teacher who was completing his degree. Three of these teachers did not have English as their mother tongue. In contrast all the rural teachers were underqualified and for all of them English was not their mother tongue.

---

2 Senior Secondary Teachers' Diploma

3 Higher Diploma of Education (post graduate)

4 Secondary Teachers' Diploma (junior secondary)

5 English mother tongue

6 Mother tongue not English

4.3. PROFILE OF THE LANGUAGE STATUS OF THE STUDENTS

The language status of the students participating in the implementation and evaluation is summarised in **Table 4.2.** below.

Table 4.2. The Language Status of the Students

Urban State Schools	Urban Independent Schools	Rural State Schools
Students at all schools largely EL1	5 schools with students mixed EL1 and EL2 2 schools with all students EL2	All students EL2

For the vast majority of students at the urban state schools English was their mother tongue. At five of the urban independent schools the language status of the students was mixed while at two of the urban independent schools no students had English as their mother tongue. No students at the rural schools had English as their mother tongue.

4.4. PROFILE OF SOME CONCEPTUAL UNDERSTANDING AND BELIEFS OF THE TEACHERS AND STUDENTS WITH REGARD TO AIR POLLUTION

Both teachers and students responded to the *Survey on Air Pollution*. It was within the framework of these conceptions and beliefs that some of these teachers engaged with their students in the trial implementation of parts of the package.

4.4.1. Responses of Teachers to the Survey on Air Pollution

The responses of teachers to some of the items in the *Survey on Air Pollution* are presented in **Tables 4.3. - 4.17.** that follow. These responses were made by the teachers at workshops in Johannesburg, Cape Town and District B, before any discussion of the package occurred. Teachers responded anonymously to the Survey.

The teachers' responses are classified as:

M (N=17). A varied sample of teachers from different parts of South Africa who attended the Cape Town Workshop, July 1991. None of these teachers took part in the trial implementation. However the responses of these teachers are quoted to present a general view of concepts and beliefs held by teachers from a broad spectrum of South African schools.

US (N=5). These teachers were from urban state schools and four of them participated in the trial implementation of the package.

UI (N=4). These teachers were from urban independent schools and all of them participated in the trial implementation of the package.

RS (N=8). All of these teachers were from rural state schools in district B. Four of them participated in the trial implementation of the package.

The numbers of teachers in the various categories are small. However it was considered that in this small scale pilot study it would be of value to analyse their responses and to relate the findings to the students' preconceptions.

In the tables that follow, where there was a correct response to an item, the option is marked with an asterisk (*).

The responses to items are presented as:

A. Analysis of Teachers' Responses to Some Knowledge Items in the Survey

B. Analysis of Teachers' Responses to Attitudinal Items in the Survey

A. **Analysis of Teachers' Responses to Some Knowledge Items in the Survey**

Table 4.3. Teachers' Responses to Item 5

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
5. Air pollution				
a. only happens when the concentration of a substance occurring **naturally** in the atmosphere, is **increased**.	4	1	2	0
*b. can happen when the concentration of a substance occurring **naturally** in the atmosphere, is **increased** or **decreased**.	3	3	0	2
c. only happens when substances that **do not occur naturally** in the atmosphere, enter the atmosphere.	7	1	1	1
d. is only caused by substances **(in a gaseous state)** that **do not occur naturally** in the atmosphere, entering the atmosphere.	3	0	0	3
e. is only caused by substances **(in a gaseous state)** that **occur naturally** in the atmosphere, entering the atmosphere.	0	0	1	2

Comments on Teachers' Responses to Item 5

The statements in this item probe a deep understanding of the nature of air pollution. Confusion is evident since the majority choice was different for each different group of teachers! Apart from the teachers at state schools, few teachers selected the correct option b. Many rural teachers thought that air pollutants are only gases. A number of teachers were unaware that air pollution can occur when the concentration of a substance occurring naturally in the atmosphere is decreased. (Responses to item 9, discussed later, substantiate this: many teachers in the rural schools had not heard of the phrase "hole in the ozone layer".) The choices of options c and d reflect a popular misconception that air pollutants are only substances **not** found naturally in the atmosphere. It is probable that few science teachers have received formal instruction on air pollution and that many rely on popular sources of information.

Table 4.4. Teachers' Responses to Item 6

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
6. The percentage of the atmosphere that air pollution affects is:				
a. more than 50%	5	1	1	3
b. about 10%	5	1	1	0
c. about 20%	3	2	0	4
d. about 5%	4	0	1	1
*e. less than 0.05%	0	0	0	0
No answer	0	1	1	0

Comments on Teachers' Responses to Item 6

It is remarkable that not a single teacher chose the correct option that air pollution affects the concentrations of the substances that account for less than 0.05% of the atmosphere. It may be argued that the wording "**total** percentage" would have made the issue clearer: teachers may have referred in their decision to a specific region of the atmosphere where heavy, localised air pollution may be occurring.

Table 4.5. Teachers' Responses to Item 7

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
7. Air pollution is the result of the activities of:				
a. industry	3	0	0	1
b. industry, science and technology	5	1	1	5
*c. industry, the rich, the poor, science and technology	8	4	3	2
d. industry, the poor, science and technology	1	0	0	0
e. the rich only	0	0	0	0

Comments on Teachers' Responses to Item 7

Several teachers from the rural sample (RS) and the varied sample (M) identified industry, science and technology as being responsible for air pollution. Rural teachers may be less informed than the others and may be expected to blame industry, science and technology since they have been largely excluded from it.

Table 4.6. Teachers' Responses to Item 25

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
25. The atmosphere extends to an altitude of approximately				
a. 10 km	-[7]	1	0	1
b. 20 km	-	1	0	0
c. 1 km	-	0	1	1
d. 500 km	-	1	3	1
*e. 2 000 km	-	2	0	5

Comments on Teachers' Responses to Item 25

A variety of responses was given by all teachers for the extent of the atmosphere. A relatively large number of rural teachers responded correctly. This may have been due to the fact that some of them attended an earlier workshop (in May, 1991) in which some background to the package was presented.

[7] Item 25 was not tested at tl › Cape Town Workshop.

B. Analysis of Teachers' Responses to the Attitudinal Items in the Survey

Table 4.7. Teachers' Responses to Items 1-4

Item	Responses			
	M (N=17)	**US (N=5)**	**UI (N=4)**	**RS (N=8)**
1. Soil erosion is:				
a. of great concern	-[8]	4	4	8
b. of concern	-	1	0	0
c. of little concern	-	0	0	0
d. of no concern	-	0	0	0
2. Air pollution is:				
a. of great concern	-	5	3	7
b. of concern	-	0	1	1
c. of little concern	-	0	0	0
d. of no concern	-	0	0	0
3. Water pollution is:				
a. of great concern	-	4	2	6
b. of concern	-	1	2	2
c. of little concern	-	0	0	0
d. of no concern	-	0	0	0
4. Exposure to nuclear radiation is:				
a. of great concern	-	0	1	6
b. of concern	-	4	0	1
c. of little concern	-	1	3	1
d. of no concern	-	0	0	0

[8] Teachers at the Cape town workshop responded to a different item which will be shown later in Table 4.8.

Table 4.8. Teachers' Responses to Item 1 at Cape Town Workshop

Of all the environmental issues the one of mo... concern to me is:	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
a. litter	2	-	-	-
b. soil erosion	4	-	-	-
c. air pollution	9	-	-	-
d. water pollution	2	-	-	-
e. exposure to nuclear radiation	0	-	-	-

Comments on Teachers' Responses to Items 1-4 (and the Cape Town Item 1)

All teachers were concerned about air pollution. Concern about water pollution was slightly lower. Concern about soil erosion was greatest among teachers at rural and urban independent schools. Teachers at rural schools were more concerned than teachers from the other categories about exposure to nuclear radiation. Indeed most other teachers had rather little concern about this. Knowledge and/or personal experience seem to influence teachers' concerns.

It is possible that the responses of teachers at the Cape Town workshop were influenced by their attendance at an **air pollution** workshop!

Table 4.9. Teachers' Responses to Items 8 - 10

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
8. With regard to the term "greenhouse effect"				
a. I have not heard of the term	0	0	0	3
b. I have heard of the term but do not understand what it means	2	0	0	3
c. I have heard of it and think I know what it means	10	4	2	1
d. I have heard of it and I am sure I understand what it means	5	1	2	1
9. With regard to the term "CFCs"				
a. I have not heard of the term	5	0	0	8
b. I have heard of the term but do not understand what it means	0	0	1	0
c. I have heard of it and think I know what it means	6	2	0	0
d. I have heard of it and I am sure I understand what it means	6	3	3	0
10. With regard to the term "hole in the ozone layer"				
a. I have not heard of the term	1	0	0	3
b. I have heard of it but do not understand what it means	2	0	0	5
c. I have heard of it and think I know what it means	6	1	1	0
d. I have heard of it and I am sure I understand what it means	8	4	3	0

Comments on Teachers's Responses to Items 8 - 10

The rural teachers were very unfamiliar with the terms (concepts) "greenhouse effect". "CFCs" and the "hole in the ozone layer". Teachers from other categories did not feel highly confident about their knowledge of these terms either.

Table 4.10. Teachers' Responses to Item 11

Item	Responses			
	M (N=17)	**US** (N=5)	**UI** (N=4)	**RS** (N=8)
11. Economic and political issues are more important to me than the issue of air pollution.				
a. Strongly agree	3	0	0	0
b. Agree	3	1	1	0
c. No opinion	1	0	1	2
d. Disagree	6	3	2	5
e. Strongly disagree	4	1	0	1

Comments on Teachers' Responses to Item 11

It is somewhat surprising that economic and political issues were not rated more important than air pollution by many teachers in the situation in South Africa at the time of this research. Their responses may have been prompted to some extent by the focus of the Survey and the workshop they were attending.

Table 4.11. Teachers' Responses to Items 12 and 13

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
12. There is no air pollution where I live.				
a. Strongly agree	0	0	0	0
b. Agree	2	0	0	0
c. No opinion	0	0	0	0
d. Disagree	7	3	3	3
e. Strongly disagree	8	2	1	5
13. Air pollution is not a problem in South Africa.				
a. Strongly agree	0	0	0	0
b. Agree	0	0	0	0
c. No opinion	0	0	0	0
d. Disagree	7	2	1	4
e. Strongly disagree	10	3	3	4

Comments on Teachers' Responses to Items 12 and 13

Most teachers felt that air pollution is a problem in South Africa and in the region where they live.

Table 4.12. Teachers' Responses to Items 14 and 15

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
14. It is only the forms of air pollution that can be seen or smelled that are a problem.				
a. Strongly agree	1	0	0	0
b. Agree	0	0	0	2
C. No opinion	1	0	0	1
d. Disagree	5	1	1	3
e. Strongly disagree	10	4	3	2
15. Once air pollutants enter the atmosphere they remain there forever.				
a. Strongly agree	1	0	1	0
b. Agree	2	2	1	0
c. No opinion	4	0	0	5
d. Disagree	9	3	2	3
e. Strongly disagree	1	0	0	0

Comments on Teachers' Responses to Items 14 and 15

Most of the teachers believed that it was not only the forms of air pollution that can be seen or smelled that are important. A few teachers (mostly from the rural sample) thought otherwise.

A number of teachers from all categories believed that air pollutants remain in the atmosphere forever. Several teachers (particulary those from the rural sample) did not make a decision in this regard.

Table 4.13. *Teachers' Responses to Items 16 and 17*

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
16. The media always report air pollution issues accurately.				
a. Strongly agree	1	0	0	0
b. Agree	1	0	1	1
c. No opinion	3	0	0	3
d. Disagree	8	5	3	2
e. Strongly disagree	4	0	0	2
17. Environmentalists are able to predict with certainty the consequences of air pollution.				
a. Strongly agree	1	0	0	0
b. Agree	1	0	2	1
c. No opinion	2	1	0	4
d. Disagree	8	4	2	2
e. Strongly disagree	5	0	0	1

Comments on Teachers' Responses to 16 and 17

Teachers from the state school sample were very sceptical about the accuracy in the reporting of air pollution issues by the media. Some teachers from the other categories were a little more trusting of the media. Once again some teachers in the rural sample were reluctant to make a decision. Similarly, teachers from the state school sample appeared less trusting of the environmentalists' ability to predict with certainty the consequences of air pollution. Teachers from the independent school sample had greater confidence in the environmentalists' abilities. Again, half the teachers from the rural sample did not commit themselves.

Table 4.14. Teachers' Responses to Items 18 and 19

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
18. Industry is not concerned about air pollution.				
a. Strongly agree	1	0	1	2
b. Agree	2	1	2	1
c. No opinion	2	0	1	1
d. Disagree	10	4	0	2
e. Strongly disagree	2	0	0	2
19. Technological/industrial development should be stopped in order to preserve the environment.				
a. Strongly agree	0	0	0	0
b. Agree	0	0	0	0
c. No opinicn	2	0	0	1
d. Disagree	9	5	3	2
e. Strongly disagree	6	0	1	5

Comments on Teachers' Responses to Items 18 and 19

There was a fairly common belief among teachers from the independent school and rural school samples that industry is not concerned about air pollution. Yet most teachers from all categories felt that industrial and technological development should not be stopped in order to preserve the atmosphere.

Table 4.15. Teachers' Responses to Items 20 and 21

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
20. Air pollution is uncontrollable and will increase steadily until life is destroyed.				
a. Strongly agree	0	0	0	0
b. Agree	1	0	0	0
c. No opinion	1	0	0	1
d. Disagree	9	4	3	6
e. Strongly disagree	6	1	1	1
21. Air pollution can be controlled, using science and technology, but it will need a constant monitoring of the risks and benefits of our activities.				
a. Strongly agree	9	2	2	6
b. Agree	6	3	2	1
c. No opinion	1	0	0	1
d. Disagree	1	0	0	0
e. Strongly disagree	0	0	0	0

Comments on Teachers's Responses to Items 20 and 21

These responses indicate that in general teachers from all categories believe that air pollution is not a hopeless situation: with proper monitoring a balance can be found and air pollution controlled.

These two items are reflections of each other. Item 21 is a positive form of asking item 20. The reasonably consistent responses to these two items indicate that teachers were interpreting the items correctly and that language was not a problem.

Table 4.16. Teachers' Responses to Items 22 and 23

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
22. I contribute very little to air pollution and thus have no role to play in its control.				
a. Strongly agree	2	0	0	0
b. Agree	3	0	0	1
c. No opinion	1	0	0	2
d. Disagree	8	4	2	3
e. Strongly disagree	3	1	2	2
23. To improve air pollution we must be prepared to pay more for things.				
a. Strongly agree	1	2	0	3
b. Agree	7	2	2	1
c. No opinion	0	1	1	3
d. Disagree	7	0	1	0
e. Strongly disagree	2	0	0	1

Comments on Teachers' Responses to Items 22 and 23

All teachers from the state and independent school samples believed that they contribute to the problems of air pollution and have a role to play in its control. A small number of teachers in the rural and mixed school sample responded to the contrary.

With the exception of teachers from the mixed school sample, most other teachers felt prepared to pay more for commodities in an effort to control air pollution.

Table 4.17. Teachers' Responses to Item 24

Item	Responses			
	M (N=17)	US (N=5)	UI (N=4)	RS (N=8)
24. If the topic "Air Pollution" were offered in the Physical Science syllabus in the future, my interest in the study of science would increase greatly.				
a. Strongly agree	-[9]	1	1	6
b. Agree	-	3	3	1
c. No opinion	-	1	0	0
d. Disagree	-	0	0	0
e. Strongly disagree	-	0	0	1

Comments on Teachers' Responses to Item 24

The majority of teachers from all categories thought that the inclusion of the topic: Air Pollution would increase their interest in science. (The teachers at the Cape Town workshop responded to a slightly different form of the questionnaire in which this item was not included.)

[9] Item 24 was not tested at the Cape Town Workshop.

General Comments on Teachers' Responses to Some Items in the Survey

These responses provide insight into the prior knowledge and perceptions of a small sample of teachers in South African schools concerning some aspects of air pollution. In general the claimed knowledge and awareness of air pollution of urban teachers is superior to that of the rural teachers. The principal misconceptions among all the categories of teachers concern:

* what air pollutants are
* the longevity of air pollutants
* the extent/scope of air pollution

4.4.2. Some Pre-test Responses of Urban and Rural Students to the Survey

The implementation and evaluation of the resource package at the rural schools was problematic (see later in Chapters 5 and 6). This resulted in the pre-test responses of only 18 rural students from two rural schools (referred to as RS_1 and RS_2 in Chapters 5 and 6) for 4 knowledge items and 21 attitudinal items in the Survey (the first 25 items) being obtained. However it was decided in this pilot study, to use the results that **were** available from these schools and compare them with those from the urban schools. The reponses of the rural sample and the urban sample (N = 204) to these items have been converted to percentages and plotted on the same barcharts. Because of the difference in the sizes of the samples it is unreliable to reach any **firm** conclusions from these comparisons. Nevertheless the apparent differences in the distribution patterns of the responses from the rural and urban students in this pilot study need to be commented on and could warrant further investigation in the future. These differences are substantiated by a comparison of responses from two more similar sized samples of urban students and rural students presented in the Appendix, page A22.

Broad comparisons are drawn between the trends in students' responses and those of teachers at the rural schools (RS) and urban schools (US and UI) discussed previously in section **4.4.1.**

The responses are presented in the barcharts that follow, as:

A. Analysis of Responses from Urban and Rural Schools to Some Knowledge Items

B. Analysis of Responses from Urban and Rural Schools to the Attitudinal Items

In the barcharts, the asterisk (*) indicates the correct option. The number of students who did not respond to some of the items has not been included on these barcharts because the percentage of the non-responses, when they occurred, was very small (less than 1 or 2%).

A. Analysis of Responses from Urban and Rural Schools to Some Knowledge Items

Item 5

Air pollution

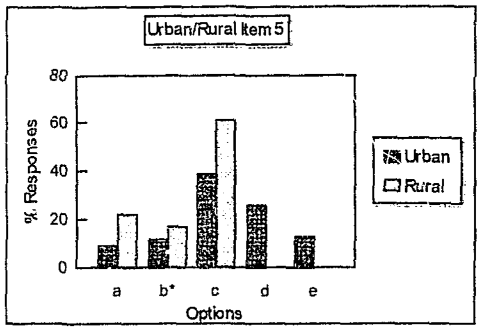
a) only occurs when the concentration of a substance occurring naturally *in the atmosphere is increased.*

b)* can occur when the concentration of a substance occurring naturally in the atmosphere is increased or decreased.

c) only occurs when substances that do not occur naturally in the atmosphere, enter the atmosphere.

d) is only caused by substances (in a gaseous state) that do not occur naturally in the atmosphere entering the atmosphere.

e) is only caused by substances (in a gaseous state) that occur naturally in the atmosphere, entering the atmosphere.



Comments

The most common perception among urban and rural students was that air pollutants are substances that do not occur naturally in the atmosphere. Very few students from both groups selected the correct option.

Their responses were similar to those of the rural and urban teachers who had responded over a wide range of options with relatively few choosing the correct option (b).

Item 6

The percentage of the atmosphere that air pollution affects is:

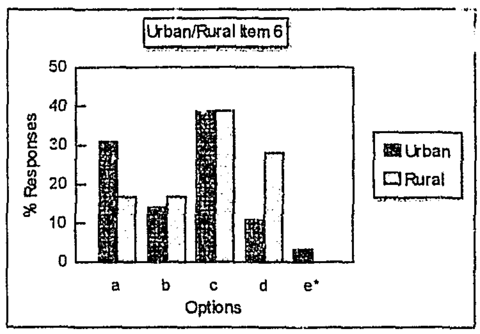
a) more than 50%

b) about 10%

c) about 20%

d) about 5%

e)* less than 0.05%



Comments

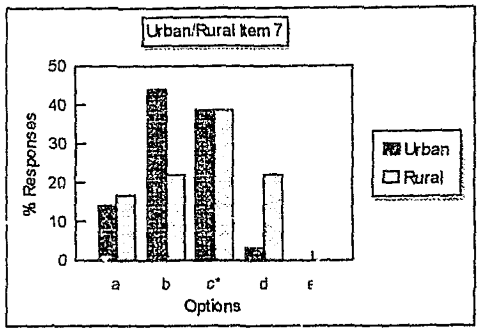
The responses from urban and rural students were fairly similar with the popular choice being option (c). Very few urban students and no rural students selected the correct option.

Their responses were similar to the rural and urban teachers where not a single teacher chose option (e).

Item 7

Air pollution is the result of the activities of:

a) industry only
b) industry, science and technology
c)* industry, the rich, the poor, science and technology
d) industry, the poor, science and technology
e) the rich only



Comments

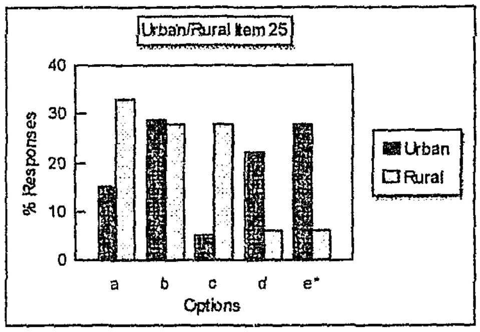
The responses of the urban and rural students to this item were slightly different. The popular choice for urban students was that industry, science and technology were largely to blame for air pollution. The rural students involved more of society in the problem with the rich and poor being included in their responses.

The rural students differed from the rural teachers who thought industry science and technology were largely to blame. Urban students also differed from their teachers who seemed better informed. Most urban teachers had selected option (c).

Item 25

The atmosphere extends to an altitude of approximately

a) 10 km
b) 20 km
c) 1 km
d) 500 km
e)* 2000 km



Comments

The responses for both groups were rather widely spread with fewer rural students choosing the correct option.

The responses of the urban students resembled those of the urban teachers whereas most rural teachers had selected the correct option.

B. Analysis of Responses from Urban and Rural Schools to the Attitudinal Items

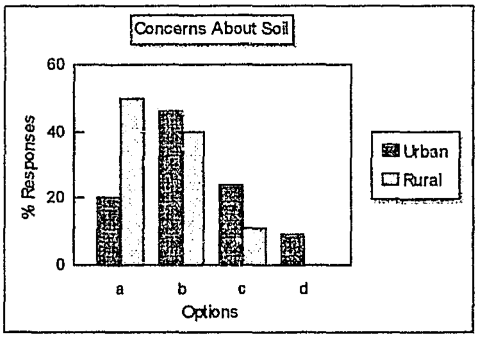
Items 1 - 4

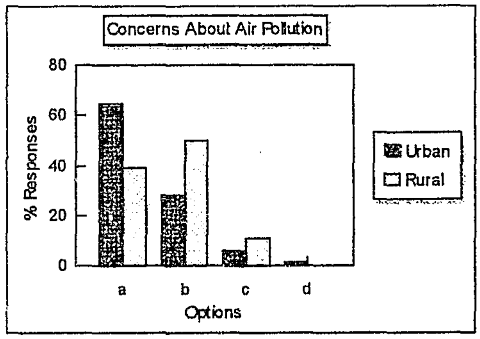
Rate the following environmental issues:

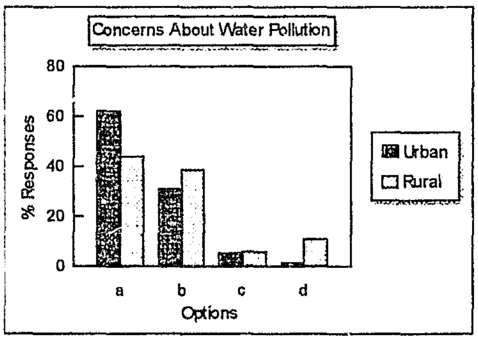
1. Soil erosion
2. Air pollution
3. Water pollution
4. Exposure to nuclear radiation

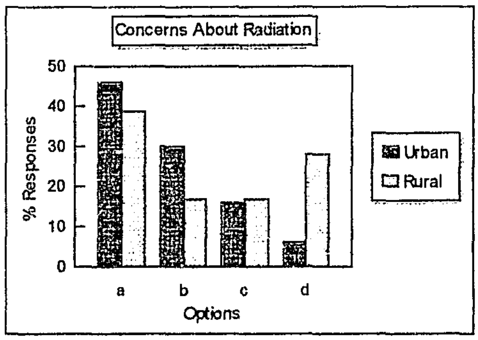
as:

a. of great concern
b. of concern
c. of little concern
d. of no concern









Comments

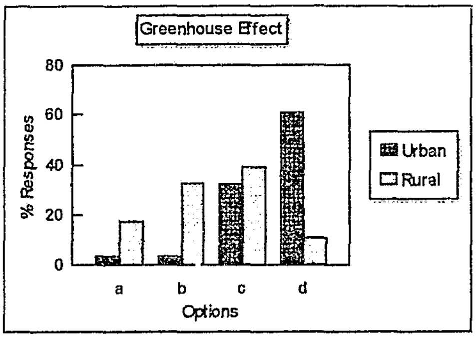
Students at rural schools were more concerned about soil erosion than urban students. Urban students were more concerned about air and water pollution and exposure to nuclear radiation. Concern about exposure to nuclear radiation was not as great in both groups of students.

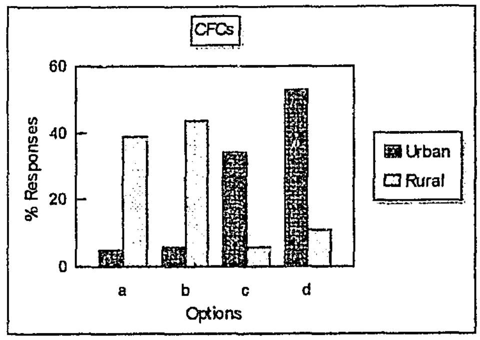
Rural teachers were also slightly more concerned about soil erosion than the other issues. Their concern about exposure to nuclear radiation was greater than that of the rural students. The responses of the urban students resembled those of the urban teachers.

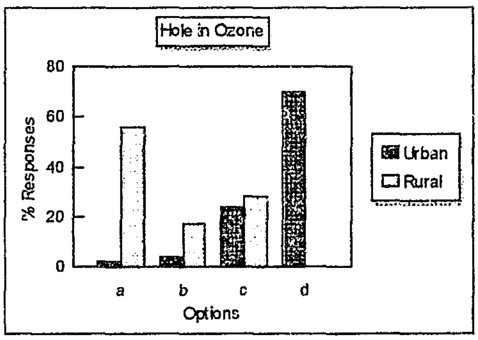
Items 8 - 10

Assess your understanding of the terms/phrases:
8. greenhouse effect
9. CFCs
10. hole in the ozone layer

as:
a. I have not heard of the term/phrase.
b. I have heard of it but do not understand what it means.
c. I have heard of it and think I know what it means.
d. I have heard of it and am sure I know what it means.







Comments

The responses of the urban and rural students to these items differed. The majority of urban students indicated that they were familiar with these terms/concepts and many claimed that they understood their meaning. By contrast, rural students seemed ill-informed about these terms/concepts in particular "CFCs" and the "hole in the ozone layer".

The responses of the rural students resembled those of the rural teachers while the responses of the urban students were similar to those of the urban teachers.

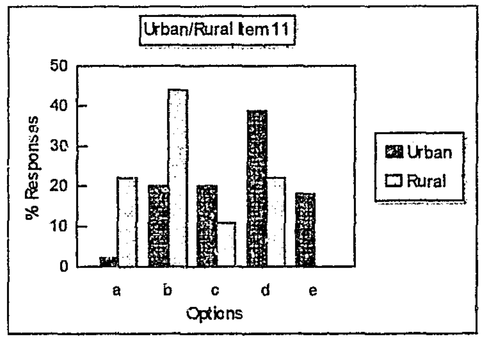
Items 11 - 24

Students respond to items 11 - 24 as:

a. I agree strongly with this statement
b. I agree with this statement
c. I have no opinion about this statement
d. I disagree with this statement
e. I disagree strongly with this statement

Item 11

"Economic and political issues are more important to me than the issue of air pollution."

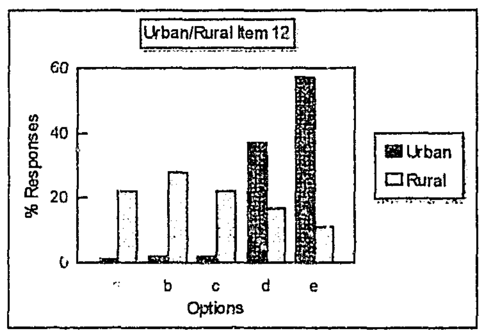


Comments

The rural students (in contrast to the urban students) appeared more concerned about economic and political issues than air pollution. This was unlike the rural teachers who, surprisingly, claimed to be more concerned about air pollution. The responses of the urban students resembled those of the urban teachers.

Item 12

"There is no air pollution where I live."



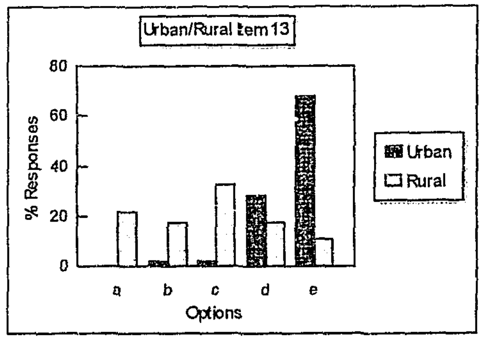
Comments

Urban students felt strongly that there was air pollution where they lived. The response from rural students was more widespread with a number of students feeling there was no air pollution where they lived.

The responses of the rural students differed from those of the rural teachers whilst the responses of the urban students again resembled those of the urban teachers.

Item 13

"Air pollution is not a problem in the Republic of South Africa."



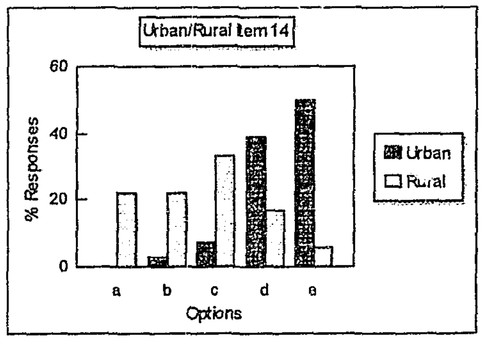
Comments

In a similar trend to that in item 12 above, urban students felt more strongly than rural students that air pollution is a problem in South Africa.

Again the responses of the rural students differed from those of the rural teachers.

Item 14

"It is only the forms of air pollution that can be seen or smelled that are important."



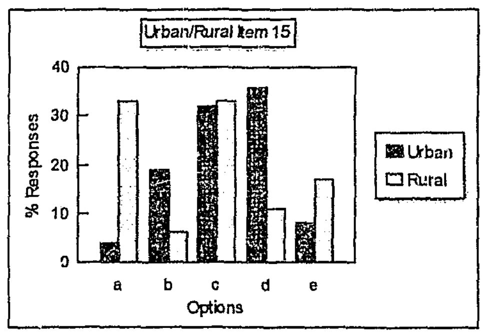
Comments

Most rural students tended to agree with this statement and a fair number were undecided.

The responses of the rural students were fairly similar to those of the rural teachers whilst the responses of the urban students were similar to those of the urban teachers.

Item 15

"Once air pollutants have entered the atmosphere they remain there forever."

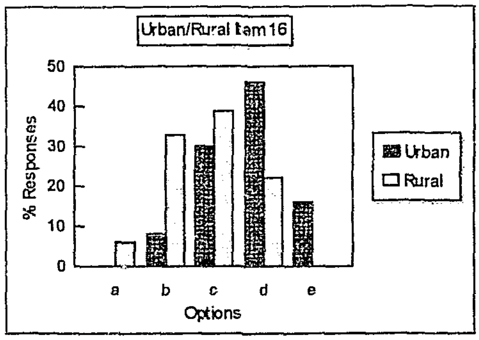


Comments

Both groups of students had mixed feelings about this issue. Almost a third of the students in both groups were undecided.

The responses of the students in both groups were similar to those of both groups of teachers who had also responded over a wide range of options.

Item 16
" The media always report air pollution issues accurately."

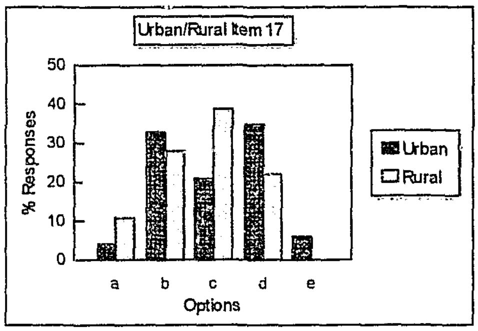


Comments

Urban students were more critical of the media than the rural students. Once again approximately a third of the students from both groups were undecided.

The responses of the rural students were similar to those of the rural teachers. The urban students resembled the urban teachers in being more critical of the media.

Item 17
"Environmentalists are able to predict with certainty the consequences of air pollution."

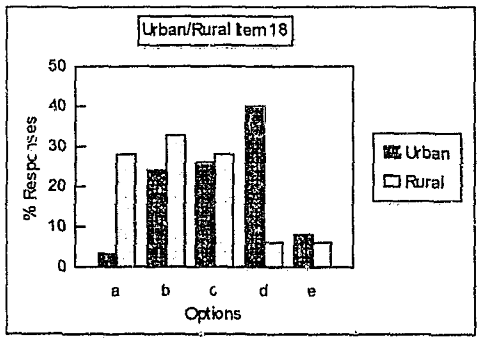


Comments

Both groups of students had mixed feelings about this issue. Many rural students were undecided.

Rural and urban teachers were in general also rather undecided about this issue.

Item 18
"Industry is not concerned about air pollution."



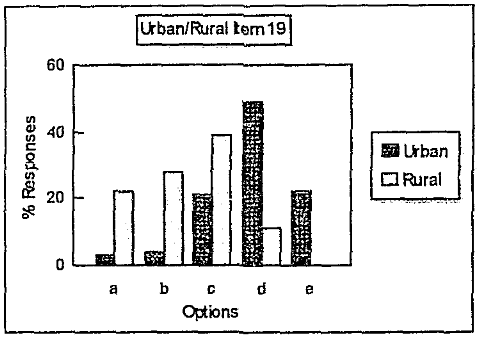
Comments

The responses from both groups were wide-spread with rural students agreeing more with this statement than the urban students.

Rural and urban teachers had also responded over a range of options to this item.

Item 19

"Technological/industrial development should be stopped in order to preserve the environment."



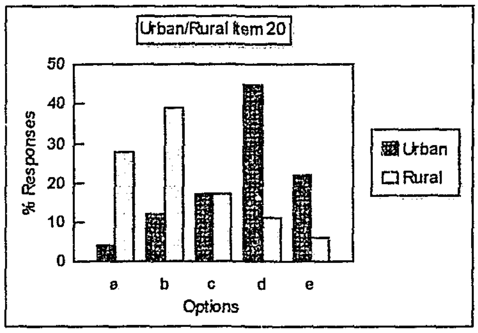
Comments

Urban students tended to disagree with this statement. The majority of rural students agreed with the statement whilst a number of them felt undecided about this issue.

The responses of the rural students differed from those of the rural teachers in this item. The responses of the urban students were fairly similar to those of the urban and rural teachers.

Item 20

"Air pollution is uncontrollable and will increase steadily until life is destroyed."

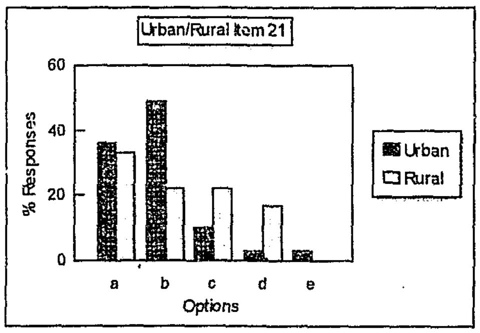


Comments

Rural students tended to agree with this statement. Their responses differed from those of the urban students, urban teachers and rural teachers.

Item 21

"Air pollution can be controlled, using science and technology, but it will need a constant monitoring of the risks and benefits of our activities."



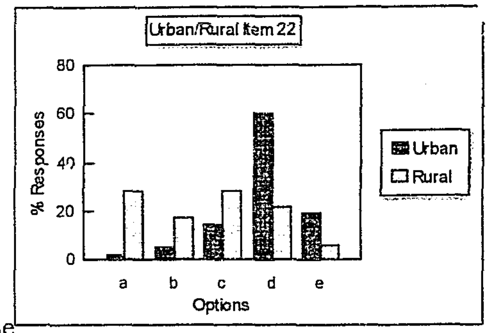
Comments

Both urban and rural students tended to agree with this statement.

Their responses were similar to those of the teachers.

Item 22

"I contribute very little to air pollution and thus have no role to play in its control."

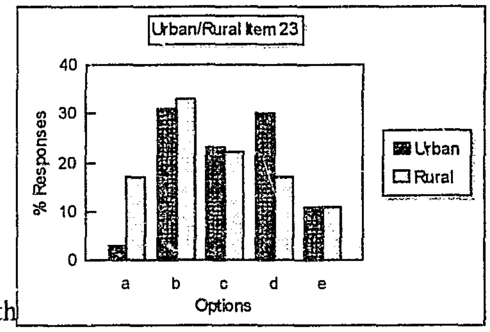


Comments

The majority of urban students felt they had a role to play in the control of air pollution. The responses of rural students were rather wide-spread on this issue and resembled those of the rural teachers. The responses of the urban students were similar to those of the urban teachers.

Item 23

"To improve air pollution control we must be prepared to pay more for things."



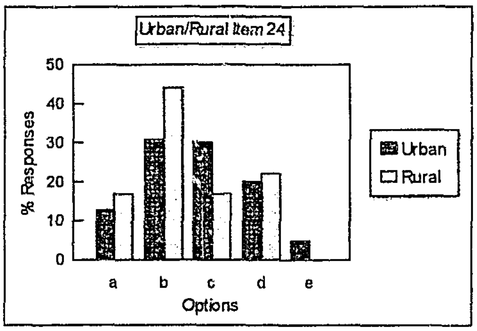
Comments

Urban and rural students responded ambivalently to this item.

Most urban and rural teachers tended to agree with this statement.

Item 24

"If the topic Air Pollution were offered in the Physical Science syllabus in future, my interest in Science would increase greatly."



Comments

Rural students appeared to be a little more positive than the urban students about the inclusion of the topic in the syllabus.

In this regard the responses of the rural students resembled those of the urban and rural teachers.

4.4.3. Some Overall Comments About the Comparison of the Pre-test Results from Urban and Rural Schools

Knowledge Items

Broadly speaking, the responses of the urban and rural students to the knowledge items were similar with very few students choosing the correct options.

Generally speaking, the responses of the students in both groups matched those of their teachers whose background knowledge for the topic was also rather scanty.

Attitudinal Items

For the attitudinal items, the rural students tended to agree with the statements more often than the urban students. In fact in all fourteen attitudinal items more rural students agreed with the statements than disagreed. In rural schools the students are not encouraged to offer their opinions and the teacher plays more of an authoritative role (Jegede, 1994). Thus students may have felt they should comply with the statements. This was probably the first time that the rural students were confronted with such a questionnaire. In addition, English is not the mother tongue of the rural students and the language in some items may have confused them. This is substantiated by the inconsistent responses of the rural students to items 20 and 21.

The responses of the urban students were in general similar to those of the urban teachers. Rural students appeared to differ at times from the rural teachers. Because of the issues discussed above, one is not sure how genuine this disagreement is. However the rural students were in agreement with the rural teachers with regard to their lack of understanding of the terms "greenhouse effect", "CFCs" and "hole in the ozone". Rural students and rural teachers appeared to be more concerned about soil erosion than air pollution.

The major common misconceptions among all groups of students and teachers were:

* what air pollutants are
* the longevity of air pollutants
* the extent/scope of air pollutants

4.5. A BRIEF COMPARISON OF URBAN AND RURAL PROFILES

There were some marked differences between the urban and rural profiles.

1. **The Science Teaching Facilities**

   The science teaching facilities at the urban schools were generally much better than those at the rural schools.

2. **Qualifications of the Teachers**

   With the exception of one teacher, the urban teachers were well-qualified. The rural teachers were poorly qualified.

3. **Language Status of Teachers and Students**

   English was the mother tongue of majority of the teachers and students at the urban schools. In contrast English was not the mother tongue of any of the teachers and students at the rural schools.

4. **Conceptual Understanding and Beliefs of Teachers and Students**

   - The knowledge and awareness of the urban teachers with regard to air pollution seemed superior to that of the rural teachers.
   - In general the responses of the urban teachers and urban students to items in the Survey were similar. However the rural students differed frequently from their teachers.
   - Air and water pollution were the chief concerns among urban teachers and students. Rural teachers and students were more concerned about soil erosion.
   - Urban teachers and students claimed a better understanding of the terms "greenhouse effect", "CFCs" and "hole in the ozone layer" than did their rural counterparts.
   - In the attitudinal items the majority of the rural students agreed with the statements. There was more variation in the responses of the urban students to these items.
   - There is evidence that the English language skills of the rural students impacted more heavily on their responses to the items in the Survey than was the case for the urban students.

CHAPTER 5

IMPLEMENTATION AND EVALUATION OF THE PACKAGE

This chapter presents:

- A description of what happened in the schools as teachers attempted to implement parts of the package.
- The outcomes of evaluation of the package by the experts and teachers.

5.1. IMPLEMENTATION OF THE PACKAGE

Although 16 teachers had agreed to implement and evaluate the package, not all these teachers were able to complete the exercise. When the evaluation sheets and students' response cards were collected by or posted to the researcher, it was found that:

1. Teachers at only **four** of the **five** selected urban state schools completed the implementation. The teacher that did not implement the package had appeared very enthusiastic at the workshop. She had even requested additional units so that she could read more about the topic. These were given to her. She stated that in the end she did not have time to implement her portion of the package.
2. Implementation was completed at **five** of the **seven** urban independent schools selected. A teacher at one of the schools did not implement at all. At another school, the teacher was only able to pre-test the students and implement Unit 1.
3. Implementation was completed at **one** of the rural state schools in district B. However the teacher at this school post-tested the students after **every** unit was taught. Thus students answered the Survey **four** times!

   At a second rural state school in district B, the implementation was incomplete. The teacher only administered the first 25 questions of the Survey as a pre-test. No post-testing was conducted. In addition this teacher did not submit all the evaluation sheets given to him.

   Teachers at **two** other rural state schools in district B did not mail their evaluation materials back to the researcher. When contacted by telephone, one of these teachers said he did not have time to implement the package. There was no response from the other teacher. There was no telephone at the school and he did not respond to letters.

Table 5.1. below summarises the final implementation of the package at the various schools.

Table 5.1. Final Implementation of the Package

Unit of Package Implemented	Schools where Implementation of Units Took Place
1	4 urban state schools (termed US_1, US_2, US_3, US_4) 6 urban independent schools (termed UI_1, UI_{2a}[1], UI_{2b}, UI_3, UI_4, UI_5, UI_6) 2 rural state schools in District B (termed RS_1, RS_2)
2	4 urban state schools (US_1, US_2, US_3, US_4) 5 urban independent schools (UI_1, UI_{2a}, UI_{2b}, UI_3, UI_4, UI_6[2]) 2 rural state schools (RS_1, RS_2)
3	2 urban independent schools (UI_1, UI_{2a})
4	1 urban state school (US_1)
5	1 urban state school (US_2)
6	1 urban state school (US_3) 1 urban independent school (UI_3) 1 rural state school (RS_1)
7	2 urban independent schools (UI_5, UI_6) 1 rural state school (RS_2)
8	1 urban state school (US_4)
9	1 urban independent school (UI_6)
10	Not implemented at all

---

1 The researcher implemented parts of the package using two classes, UI_{2a} and UI_{2b}, at an urban independent school UI_2.

2 School UI_5 did not implement this unit.

5.2. OUTCOMES OF EVALUATION BY EXPERTS

Six experts had been approached to evaluate the package. The outcomes were as follows:

a. **Evaluation by Geographers**

Professor - He was not able to evaluate the package because of other commitments.

Lecturer - She completed a very thorough evaluation. She rated it a very good package which was suitable for standard 9. Some suggestions were made to include a few more detailed geographical concepts particularly in the section dealing with temperature inversions. She requested a copy of the package for her own use as she felt that some activities would be suitable for her first year geography class at university.

Tutor - She also completed a thorough evaluation of the package. Her overall impression of the package was that it was very good. However she took strong exception to Worksheet 8(c) "Greenies" (page 207, Resource Package). She felt the cartoon character portrayed environmentalists in a poor light. She suggested that the cartoon character should rather be a scientist!

b. **Evaluation by Lecturer in Chemistry Department**

He was not able to evaluate the package due to pressures of work.

c. **Evaluation by Professor of Nuclear Physics**

His only criticism was that the diagram of a cyclone (page 216, Resource Package) was too small. He rated the package very good and felt it could play an important role in environmental education.

He subsequently arranged that the researcher present some of the background of the package at a seminar for some environmental officers in the township of Soweto, Witwatersrand. Arrangements were made to use some of the activities at an "Environmental Day". Unfortunately unrest in the township at that time prevented this from happening.

At present he is still keenly interested in having the package published.

d. **Evaluation by Journalist**

He rated the package as excellent. He suggested that it could be used in the classroom and as a resource in some of the environmental education centres in the country.

5.3. *OUTCOMES OF EVALUATION BY TEACHERS*

Rich feedback was provided by teachers during their evaluation of the package. Their responses on the evaluation sheets have been summarised in the tables that follow. The findings of the researcher when she implemented units of the package at the urban independent school UI_2, are referred to separately at the end of this section.

In some of the tables that follow, teachers' qualifications are listed below the school. "HDE" indicates that teachers have Higher Diplomas in Education (postgraduate) qualifying them to teach physical science up to the standard 10 (matric) level. "STD" indicates that teachers have Secondary Teachers' Diplomas qualifying them to teach up to standard 8 level.

In some of the tables, the experience of the teachers has been indicated under their qualifications. For example, "5/4" shows that the teacher has five years' **total** teaching experience and four years' experience teaching standard 9 science.

Other terms used in some of the tables are:

"OHP"	-	a presentation by the teacher using transparencies on the overhead projector.
"V"	-	use of a video relevant to the topic. (Videos were not included in the package.)
"C & T"	-	a "chalk and talk" presentation by the teacher using the blackboard.
"IW"	-	individual work with students working on their own.
"GW"	-	group work with students working in small groups of 2 - 5 students.
"IPW"	-	individual practical work.
"PDT"	-	practical demonstration by the teacher.

5.3.1. *Feedback on Unit 1- The Atmosphere*

Table 5.2. Responses regarding Presentation of Unit 1 in the Classroom

School	Time Spent[3] on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
US$_1$ BSc HDE 14/6	~4.5h	1(a), 1(b), 1(c), 1(d), 1(e)	OHP, C&T, IW, GW, IPW
US$_2$ BScHons HDE 18/18	~2h	1(b)	V, C&T, IW, GW
US$_3$ BSc BEd HDE 9/8	~1.5h	1(d)	OHP, IW
US$_4$ BSc HDE 7/7	~2.5h	1(a), 1(b), 1(c), 1(d), 1(e)	C&T, IW, GW
UI$_1$ BScEng 25/25	~5h	1(a), 1(b), 1(c), 1(d)	C&T, IW, GW, PDT
UI$_3$ MSc HDE 5/4	~1h	1(b), 1(c), 1(d)	OHP, GW
UI$_4$ BScHons HDE 3/3	~1h	No activity selected for students	C&T
UI$_5$ BScHons HDE 8/8	~1.5h	1(a)	C&T, IW
UI$_6$ Completing BSc 4/4	~4h	1(a), 1(b), 1(c), 1(d), 1(e)	OHP, C&T, IW, GW, PDT
RS$_1$ Completing BA 8/3	~1h 10min	1(a), 1(b)	C&T, IW, GW

3 The symbol '~' represents 'approximately'.

Table 5.3. Teachers' Evaluation of Unit 1

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_1 BSc HDE 14/6	Good	Average	Average	Good
US_2 BScHons HDE 18/18	Average	Average	Good	Good
US_3 BSc BEd HDE 9/8	Good	Good	Average	Excellent
US_4 BSc HDE 7/7	Poor but will improve with time	Poor	Average	Excellent
UI_1 BScEng 25/25	Good	Good	Good	Excellent
UI_3 MSc HDE 5/4	Good	Average	Average	Good
UI_4 BScHons HDE 3/3	Good	Poor	Poor	Poor
UI_5 BScHons HDE 8/8	Good	Good	Good	Excellent
UI_6 Completing BSc 4/4	Good	Good	Good	Excellent
RS_1[4] Completing BA 8/3	Good	Average	Average	Good

4 The teacher at RS_2 did not return his evaluation sheet for Unit 1 although he indicated that he did implement this unit.

Some Additional Comments provided by Teachers on Unit 1

Responses from the teachers at the schools:

US_1 - *Units in worksheet 1(d) should be changed to SI units ie. m^3 and Pa.*

US_3 - *Students stated that they had studied much of the content in this unit in Std 8 geography.*
This unit links with other disciplines eg. philosophy, and adds human interest to the study of science.

US_4 - *Some students had difficulty drawing axes for the graph.*
I was shocked to discover that some of my students thought that molecules of a gas get bigger when a gas is warmed! (Worksheet 1(c), Task 2)
Units in Gas Law calculation should be changed to SI units eg. dm^3 and Pa.
This topic really does need to be taught at the end of the Std 9 year as it relies a great deal on concepts studied earlier in the year.

UI_1 - *The students requested more practical work.*

UI_3 - *I had no time to do experimental work.*

UI_4 - *I was very short of time so did not present this unit as I would have liked.*

UI_5 - *This unit overlaps with physics, biology and geography.*

RS_1 - *Could not do practical activities because of lack of equipment.*

5.3.2. Feedback on Unit 2 - What is Air Pollution?

Table 5.4. Responses regarding Presentation of Unit 2 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
US_1 BSc HDE 14/6	~4.5h	2(a), 2(b), 2(c), 2(d), 2(e)	OHP, C&T, IW, GW, PDT
US_2 BScHons HDE 18/18	~1.5h	2(b), 2(c), 2(d), 2(e), 2(f)	C&T, IW, GW, PDT
US_3 BSc BEd HDE 9/8	~1.5h	2(c), 2(e)	C&T, IW, GW
US_4 BSc HDE 7/7	~1h	2(b)	Class discussion
UI_1 BScEng 25/25	~6h	2(a), 2(b), 2(c), 2(d), 2(e) 2(f)	C&T, IW, GW, PDT
UI_3 MSc HDE 5/4	~1h	2(b), 2(c), 2(d), 2(e)	OHP, C&T, IW, GW
IU_4 BScHons HDE 3/3	~1h	2(b), 2(c)	C&T
UI_6[5] Completing BSc 4/4	~6h	2(a), 2(b), 2(c), 2(d), 2(e), 2(f)	V, C&T, IW, GW, PDT
RS_1 Completing BA	~1.5h	2(b)	C&T, IW, GW
RS_2 STD 5/5	~3.5h	(Not indicated in response)	C&T with some student participation

[5] Teacher at UI_5 was only able to implement Unit 1 and did not implement Unit 2.

Table 5.5. Teachers' Evaluation of Unit 2

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_1 BSc HDE 14/6	Average	Average	Average	Good
US_2 BScHons HDE 18/18	Good	Average	Average	Average
US_3 BSc BEd HDE 9/8	Good	Average	Average	Excellent
US_4 BSc HDE 7/7	Average	Poor	Average	Excellent
UI_1 BScEng 25/25	Good	Very Good	Good	Excellent
UI_3 MSc HDE 5/4	Good	Average	Average	Good
UI_4 BScHons HDE 3/3	Good	Average	Poor	Good
UI_6 Completing BSc 4/4	Good	Good	Good	Excellent
RS_1 Completing BA 8/3	Good	Average	Good	Excellent
RS_2 STD 5/5	Good	Good	Good	Excellent

Some Additional Comments provided by Teachers on Unit 2

Responses by teachers at the schools:

US$_1$ - *I found the Unit enlightening - I hadn't thought of Nature causing air pollution. This unit lends itself to a video presentation.*

US$_2$ - *The ideas of steady state and temperature inversions appealed to students. This unit is perhaps a bit longwinded: students became restless.*

US$_3$ - *I need more information on anaerobic decay.*
Not enough time!

US$_4$ - *I wouldn't have managed without the answers! But I found the unit interesting and easy to understand.*

UI$_1$ - *This unit gave us a great deal of pleasure. It led to lively discussions and students could all be involved in practical work.*

UI$_3$ - *Some students' views changed as a result of this unit! Not as much fun as the first unit. Maybe there is too much information. It would have been more fun if we had had more time!*

UI$_4$ - *Short of time.*

RS$_1$ - *The shortage of laboratory equipment was a problem.*

RS$_2$ - *Students were not interested when we discussed the atmosphere. They thought we were learning geography in a physical science lesson! They became interested when they could link air pollution to chemistry.*
This unit is interesting and understandable.

Smaller numbers of teachers implemented the additional Units 3 - 9. Feedback on these units is presented below.

5.3.3. Feedback on Unit 3 - Combustion

Table 5.6. Responses Regarding Presentation of Unit 3 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
UI_1 BScEng 25/25	~3h	3(a), 3(b), 3(c)	C&T, IW, GW

Table 5.7. Teacher's Evaluation of Unit 3

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
UI_1 BScEng 25/25	Good (except for the SASOL process)	Good	Good	Excellent

<u>Some Additional Comments provided by Teacher on Unit 3</u>

Response from the school:

UI_1 - *I would like more information on the SASOL process.*

My students are budding journalists, so the essays for Worksheet 3(b) were a great success.

5.3.4. Feedback on Unit 4 - The Depletion of Ozone in the Stratosphere

Table 5.8. Responses regarding Presentation of Unit 4 in the Classroom

School	Time Spent On Unit	Activity/Work Sheet Chosen	Teaching Strategies Used
US_1 BSc HDE 14/6	~1.5h	4(a), 4(b)	C&T, IW, GW

Table 5.9. Teacher's Evaluation of Unit 4

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_1 BSc HDE 14/6	Average	Good	Average	Good

Some Additional Comments Provided by the Teacher on Unit 4

Response from school:

US_1 - *Students enjoyed this unit. It was new content for them and helped them understand the "ozone hole".*

The students and I found the processes for the generation and destruction of ozone difficult to remember.

This unit is probably handled better by the brighter students.

5.3.5. Feedback on Unit 5 - Smog

Table 5.10. Responses Regarding Presentation of Unit 5 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
US_2 BScHons HDE 18/18	~1h	5(a), 5(b)	C&T, IW, GW

Table 5.11. Teacher's Evaluation of Unit 5

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_2 BScHons HDE 18/18	Good	Poor	Poor	Average

Some Additional Comments provided by the Teacher on Unit 5

Response from school:

US_2 - *Students find graphs difficult to interpret.*

We were very short of time so things were hurried.

One needs to be very well prepared to teach this unit.

This was the real chemistry part.

5.3.6. Feedback on Unit 6 - The Enhanced Greenhouse Effect

Table 5.12. Responses Regarding Presentation of Unit 6 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
US_3 BSc BEd HDE 9/8	~1.5h	6(e)	OHP, GW
RS_1 Completing BA 8/3	~1h	6(b)	C&T, IW, GW

Table 5.13. Teachers' Evaluation of Unit 6

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_3 BSc BEd HDE 9/8	Good	Good	Average	Excellent
RS_1 Completing BA 8/3	Good	Average	Average	Good

Some Additional Comments provided by teachers on Unit 6

US_1 - *The class did not know that other possibilities existed with regard to the outcomes of the greenhouse effect.*

Students were highly motivated by the practical work.

Needed more time.

RS_1 - *At the start my students knew nothing about the greenhouse effect.*

Lack of practical equipment restricted my choice of activity.

5.3.7. Feedback on Unit 7 - Acid Rain

Table 5.14. Responses regarding Presentation of Unit 7 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategies Used
UI_3 MSc HDE 5/4	~1h	7(a), 7(c)	OHP, C&T, IW
UI_4 BScHons HDE 3/3	~1h	7(a)	C&T

Table 5.15. Teachers' Evaluation of Unit 7

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
UI_3 MSc HDE 5/4	Average	Average	. Poor - students were put off by the equations!	Good
UI_4 BScHons HDE 3/3	Good	Average	Poor	Average

Some Additional Comments Provided by the Teachers on Unit 7

UI_3 - *Time was a big constraint. It could have been more fun if I had had more time. Practical work would have been done!*

UI_4 - *Time was a big problem for me and compelled me to lecture.*

5.3.8. Feedback on Unit 8 - The Control of Air Pollution

Table 5.16. Responses regarding Presentation of Unit 8 in the Classroom

School	Time Spent On Unit	Activity/Worksheet Chosen	Teaching Strategies Used
US_4 BSc HDE 7/7	1h	8(a), 8(b), 8(c)	C&T, IW, class discussion

Table 5.17. Teacher's Evaluation of Unit 8

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
US_4 BSc HDE 7/7	Average	Poor	Average	Excellent

<u>Some Additional Comments Provided by the Teacher on Unit 8</u>

Response from school:

US_4 - *I learned a lot from this unit.*

5.3.9. Feedback on Unit 9 - The Response by Industry

Table 5.18. Responses regarding Presentation of Unit 9 in the Classroom

School	Time Spent on Unit	Activity/Worksheet Chosen	Teaching Strategy Used
UI_6 Completing BSc 4/4	~5h	9(a), 9(b), 9(c), 9(d)	OHP, C&T, IW, GW

Table 5.19. Teacher's Evaluation of Unit 9

School	Teacher's Confidence	Students' Enthusiasm	Students' Understanding	Teacher's Rating of Unit
UI_6 Completing BSc 4/4	Good	Good	Good	Excellent

There were no overall comments from the teacher regarding Unit 9.

NB. As mentioned earlier no evaluation of Unit 10 took place.

5.3.10. Responses from Teachers regarding Overall Evaluation of Portion of the Package Taught

The teachers' overall evaluation of the portion of the package they taught is presented in the **Tables 5.20 - 5.22.** and is followed by a summary of comments from teachers.

Table 5.20. Reasons Given for not Completing Assigned Portion of the Package

Reason	Total No of Teachers Choosing Reason (N=10)
Lack of time	8
Material too difficult for students	0
Equipment not available	2[6]

[6]Responses from teachers at rural state schools, RS_1 and RS_2

Table 5.21. Evaluation by Teachers of Language Demands of the Package

School	Language Status of Teacher	Comments on Language Demands of Package on Teacher	Language Status of Students	Comments on Language Demands of Package on Students
US_1	EL1[7]	*Fine*	EL1	*Coped well*
US_2	EL1	*Qualified teachers would cope*	EL1	*Some students asked for meanings of words - even in the questionnaire*
US_3	EL1	*Exactly right for me*	EL1	*Suitable for my students*
US_4	EL1	*Suitable*	EL1	*Suitable*
UI_1	EL1	*Fine*	EL1 & EL2[8]	Fine
UI_3	EL1	*I had to learn some Geography terms, otherwise no problems*	EL1 & EL2	*Some students whose mother tongue was not English, asked for the meanings of a few terms*
UI_4	EL2	*Depends on the background of the teacher - some may find language used difficult*	EL2	*Many students might find the language difficult*
UI_6	EL2	*Fair*	EL2	*There were some terms they did not understand but on the whole the package was not difficult to understand*
RS_1	EL2	Response by teacher indicated that he had misinterpreted the question: *It is of vital importance for the better communication and understanding of the content*	EL2	Response by teacher indicated that he had misinterpreted the question: *It is needed for the better understanding and communication* with *the teacher and even fellow students*
RS_2	EL2	*Less*	EL2	*Not that much*

7 English mother tongue.

8 English not the mother tongue.

Table 5.22. Summary of Responses of the Teachers (N = 10) regarding the Usefulness of Some Features of the Package

Feature of Package	Responses (N = 10)				
	Very Useful	Useful	Not So Useful	Useless	No Response
Learning Objectives	7	3	0	0	0
Background Information	7	3	0	0	0
Worksheets	10	0	0	0	0
Experiments	5	3	0	0	2
Teachers Notes (Answers)	8	1	0	0	1

Summary of Overall Comments on Evaluation Sheets regarding Implementation and Evaluation of the Package

Comments from teachers at schools:

US_1 - *Package would take too long. Teachers would have to decide on a theme and follow that theme through the package.*

US_2 - *Package is too detailed. Preparation was very demanding and the students pick up one's lack of confidence.*

US_3 - *Notes stating what the main aim of each worksheet was, might help in choice of activity.*

Students were restless because they wanted to do revision for end of the year examinations.

US_4 - *I would have liked to do much more but students wanted to do end of year revision.*

I thought the package was very interesting but the students were not very happy about doing package. Some said "I gave up geography so that I didn't have to do this and now we have to do it in science!" or

"We did all of this in biology in Std 8. Now we're doing it all over again."

The answers are invaluable and the package is excellent.

UI_1 - *I would like some references.*

Geography teachers would enjoy involvement in a package like this.

Videos would add more.

I had a small group of students (only 5). We had completed the Std 9 syllabus so had lots of time to spend on the package. The package is really outstanding full of fun, information and stimulation.

UI_3 - *I didn't do any practical work because of lack of time.*

My students were anxious to get back to their revision for the examinations. They kept asking "Is this for marks?" and "Why are we doing this?"

UI_4 - *Some material is a bit difficult particularly Unit 1.*

Package could be reduced a little and the language simplified. Then it would be very helpful.

UI_6 - *My class (only 8 students) had completed the Std 9 syllabus so we were able to do many activities. My students really seemed to enjoy the package.*

RS_1 - *"Our school is in a remote area of which it is difficult to even borrow some equipments from neighbouring schools. I think if we can get enough equipments things will be well.*

Package is good for challenging students' insight and objectivity." (Quoted as comment was written by teacher.)

RS_2 - *"Package is too long. Its introduction is not interesting to the students. I suggest that you shorten the introduction for students seem to participate much more in the body of the lesson."* (Quoted as comment was written by teacher.)

5.3.11. Implementation of Parts of the Package by the Researcher at an Urban Independent School (UI_2)

The researcher implemented two portions of the package at an urban independent school using two standard 9 classes. These classes were not normally taught by the researcher. Their teacher was on leave for 8 days. Approximately 6 hours with each class were available for the implementation of three units of the package and for the pre-and post-testing of the students.

The qualifications of the researcher are BScHons, TTHD[9]. At the time of implementation, the researcher had taught for approximately 21 years. She had spent 5 years teaching at standard 9 level.

The presentation of the units is summarised in **Table 5.23.** below.

Table 5.23. Presentation of the Units by Researcher

School	Unit	Time Spent on Unit	Activity/ Worksheet Chosen	Teaching Strategies Used
UI_{2a}	1	~1.5h	1(b). 1(d), 1(e)	OHP, IW, GW
UI_{2a}	2	~1h	2(c), 2(d)	GW, IW
UI_{2a}	3	~1h	3(a), 3(d)	GW, PDT
UI_{2b}	1	~1.5h	1(b), 1(d), 1(e)	OHP, IW, IPW
UI_{2b}	2	~1h	2(c), 2(d)	GW, IW
UI_{2b}	6	~1h	6(a), 6(b)	GW

Some Additional Comments on this Implementation

1. The shortness of the time available was a problem. It took time for the students to settle in with a "new teacher".
2. The researcher also perceived that students were restless. They asked *"Why are we doing this now?"* and *"Is this for marks?"* They appeared to be concerned about revision for the

9 Transvaal Teachers' Higher Diploma - qualifying her to teach physical science up to standard 10 level.

forthcoming examinations. To the students the work on the package seemed to be an unnecessary and time-consuming diversion.

3. A number of students in both classes said they had studied this content in standard 8 geography and knew all about air pollution. They also queried why this section was being taught in physical science and not in geography. However in some of the activities where there was an interrelationship with geography, students did not appear to have the background knowledge they claimed they possessed from geography.

4. Although both classes were mixed EL1 and EL2, the students appeared to cope well with the language demands of the worksheets and only posed questions about some of the new terms associated with the topic.

5. Although the students were reluctant about spending time on the materials, as described in (2) above, they appeared to be reasonably enthusiastic and co-operative about the activities. They participated in the group discussions and readily volunteered answers. The students appeared to understand the main objectives of the worksheets presented to them.

6. The researcher found it necessary to make choices about activities. The choice was based on presenting a variety of activities to the students. These activities were plotting graphs, problem solving, reading and comprehension, practical tasks, individual work and group tasks and discussions. Some specific outcomes of the activities were:

   i. Students found the graph plotting exercise in Worksheet 1(b), Task 1, difficult. They struggled to find suitable scales for the axes. They also had difficulty in placing the axes and in deciding whether for example the horizontal axis should represent temperature.

   ii. While working on this same worksheet, students argued about the meaning of the term "temperature inversion". They were only familiar with the type of inversion occurring at the tropopause ie. where the temperature trend is a reversal from cooling to warming. They were resistant to labelling the temperature inversion between the stratosphere and mesosphere because this temperature reversal was from warming to cooling. They felt a temperature inversion referred only to the reversal in temperature trend from cooling to warming. They had to be encouraged to broaden their understanding of the term.

iii. Students found the problem solving in Worksheet 1(d), Task 1 (i), difficult. This calculation interrelated concepts learnt earlier in their physical science course, namely, the gas laws, density, unit conversions and the mole. In the end the problem was solved as a group exercise with students offering suggestions as to the steps involved. The weaker students were led by the constructive ideas of the more competent problem solvers in the class.

iv. Students seemed to cope with the practical work presented. The concept of the origin of colour was highlighted in Worksheet 1(e) when the students viewed various different coloured light bulbs through the potassium dichromate solution. The exercise seemed to be thought provoking and led to a lively group discussion.

v. While working through the activities selected in Unit 2, both classes seemed to become more aware that it was not just industry that contributed to air pollution. They appeared to appreciate that our daily activities eg. using electricity and driving cars, are also major contributors to the problem.

vi. The class that was required to draw pie charts in Worksheet 6(a), Task 4, also struggled with this activity.

vii. In the same worksheet students revealed a perception that the greenhouse effect was detrimental. The discussion which distinguished between the "greenhouse effect" and the "enhanced greenhouse effect" appeared to correct this perception.

viii. The ideas of steady state and the carbon cycle seemed novel to the students and they appeared to enjoy these tasks.

CHAPTER 6

ANALYSIS OF PRE- AND POST-TEST SURVEY RESULTS

This chapter will focus on analyses of:

- The pre- and post-test results for the **core items** (ie. items 1 - 30) in the Survey
- The pre- and post-test results for the **unit specific items** (ie. items 31 - 45) in the Survey

6.1. AN ANALYSIS OF THE PRE- AND POST-TEST RESULTS FOR THE CORE ITEMS (ITEMS 1 - 30)

The responses from 10 urban schools were analysed. As mentioned earlier, the responses from the rural schools, RS_1 and RS_2, and the urban independent school, UI_5, could not be included in this comparison because of problems incurred in the administration of the Survey at these schools. Responses to the pre- and post-test that could be identified as coming from the **same** students were included in the sample. The sample size was 204. The teachers were not post-tested. Therefore their responses are not included in the following analyses.

The responses to the pre- and post-tests are presented in the barcharts that follow, as:

- **Analysis of Responses to Knowledge Items in Pre- and Post-tests**
- **Analysis of Responses to Attitudinal Items in Pre- and Post-tests**

6.1.1. Analysis of Responses to Knowledge Items in Pre- and Post-tests

A summary of the responses of all the students to each item in the pre- and post-tests is presented in the form of a bar chart labelled **"Pre/Post"** which appears below each item. The correct option is marked with an asterisk (*). The "no-responses" are once again not included as, when they occurred, they were small percentages (usually less than 1 or 2 %).

The level of significance (p) of the change which occurred between the pre- and post-tests was measured using the chi-square test, with the cut-off level set at $p < 0.05$ (two-tailed). The level of significance is quoted below the "Pre/Post" bar chart for each item.

A comparison of students' responses to items in the pre- and post-tests is also included. These bar charts are labelled **"Comparisons"**. The comparisons are labelled as follows:

R-R Correct response in pre-test and post-test.

W-R Incorrect response in pre-test, correct response in post-test.

R-W Correct response in pre-test, incorrect response in post-test.

W-W Incorrect response in pre-test, **same** incorrect response in post-test.

W-W' Incorrect response in pre-test, **different** incorrect response in post-test.

Comparisons in which students gave **correct** responses in the post-test are shown as **positive** % responses on the "Comparisons" barcharts. Those comparisons in which students gave **incorrect** responses in the post-test are shown as **negative** % responses on the barcharts.

Item 5

Air pollution

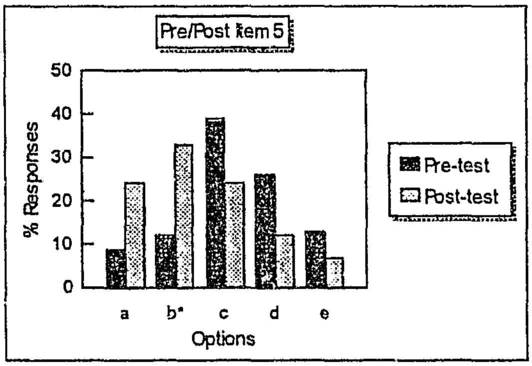
a. only occurs when the concentration of a substance occurring naturally in the atmosphere is increased.

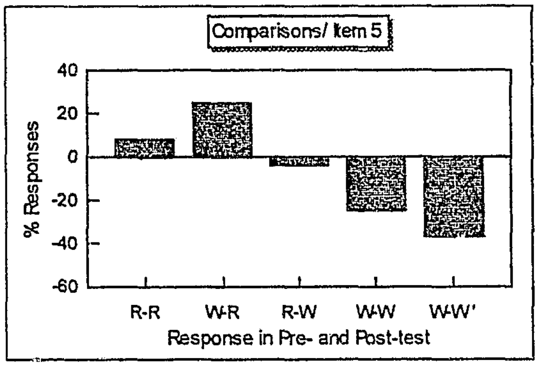
b.* can occur when the concentration of a substance occurring naturally in the atmosphere is increased or decreased.

c. only occurs when substances that do not occur naturally in the atmosphere, enter the atmosphere.

d. is only caused by substances (in a gaseous state) that do not occur naturally in the atmosphere, entering the atmosphere.

e. is only caused by substances (in a gaseous state) that occur naturally in the atmosphere, entering the atmosphere.





($p < 0.001$)

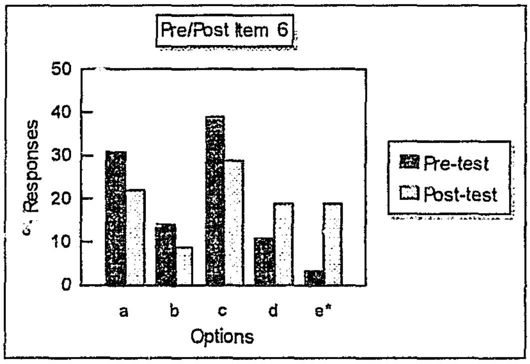
Comments

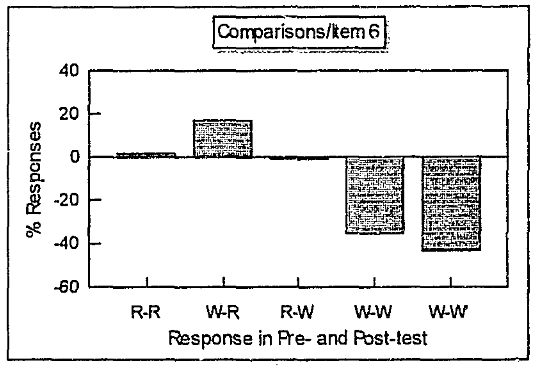
This is a difficult item. In a rather veiled way, it is testing students' broad understanding of air pollution including the depletion of ozone. This is a very new concept for most students. During the implementation only one school studied this concept in more detail in Unit 4 of the package. After teaching had taken place, there was an increase in the number of correct responses. However in the post-test the number of correct responses remained low. Less than 40% of students responded correctly. However the responses do reveal common, persistent misconceptions among the students that air pollutants are substances that do not occur naturally in the atmosphere and that air pollutants are only substances in a gaseous state. The "Comparisons" bar chart indicates that guessing was still prevalent in the post-test. In spite of the low number of students responding correctly in the post-test, the improvement was significant.

Item 6

The percentage of the atmosphere that air pollution affects is:

a.	more than 50%	b.	about 10%
c.	about 20%	d.	about 5%
e.*	less than 0.05%		





($p < 0.005$. However the significance had to be viewed with caution because of low counts in some of cells for the determination of chi-square.)

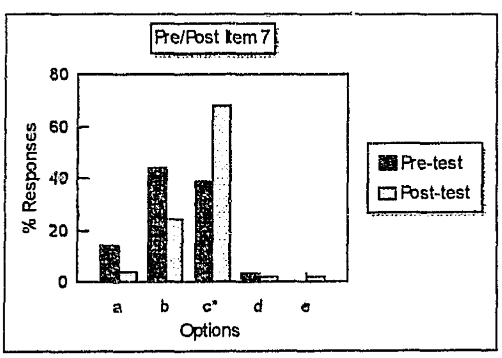
Comments

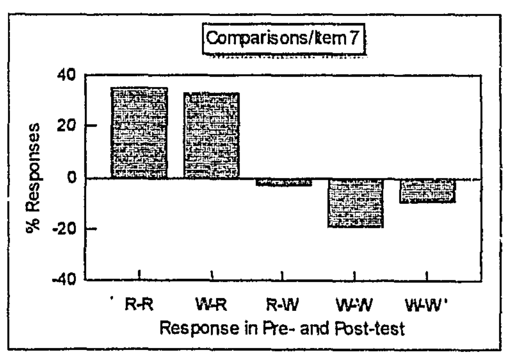
Students had little background knowledge for this item in the pre-test. After teaching the change was significant although viewed with caution. However the number of students responding correctly was still low. The "Comparisons" bar chart indicates that considerable guessing was occurring as students shifted from one wrong answer in the pre-test to another in the post-test.

Item 7

Air pollution is the result of the activities of :

a.	industry only	b.	industry, science and technology
c.*	industry, the rich, the poor, science and technology	d.	industry, the poor, science and technology
e.	the rich only		





($p < 0.001$)

Comments

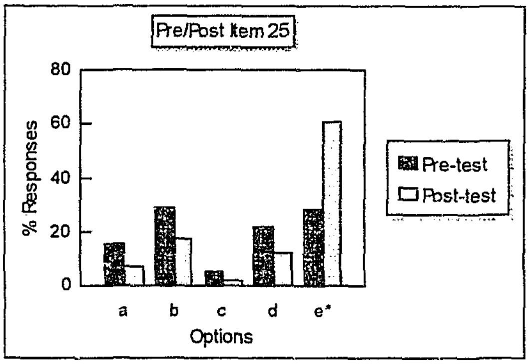
Before teaching, students tended to identify the activities of only industry, science and technology as the sources of air pollution. After exposure to just three units of the package, many students chose the option which portrayed air pollution as being the result of "all of our activities". This change appears to indicate that after gaining some knowledge, students' outlook became more balanced.

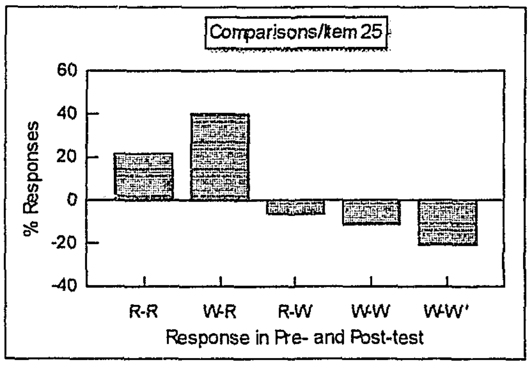
The improvement on this item was highly significant.

Item 25

The atmosphere extends to an altitude of approximately

a.	10 km	b.	20 km
c.	1 km	d.	500 km
e*.	2000 km		





($p < 0.005$)

Comments

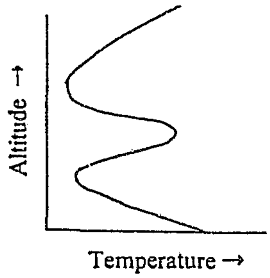
This is a factual item. Students responded over a wide range of options in the pre-test. Many of them responded correctly in the post-test.

The improvement on this item was significant.

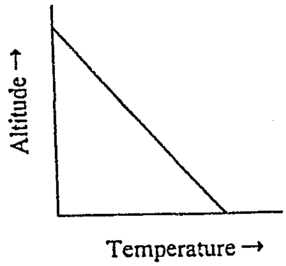
Item 26

The graph which is a correct representation of the variation of the temperature of the atmosphere is:

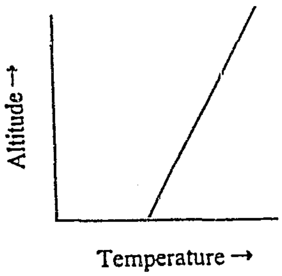
a*.



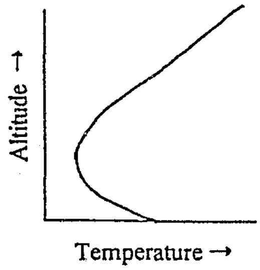
b.



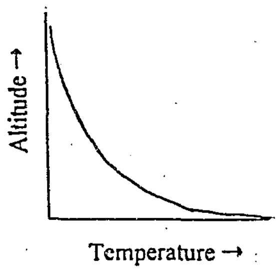
c.

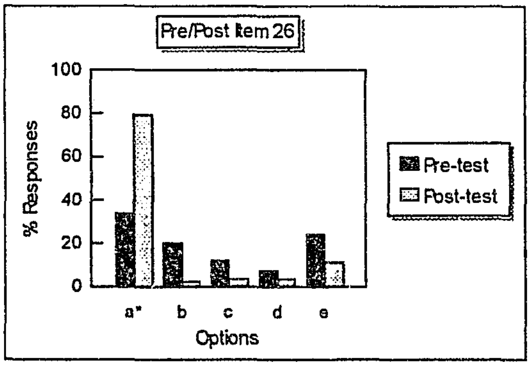


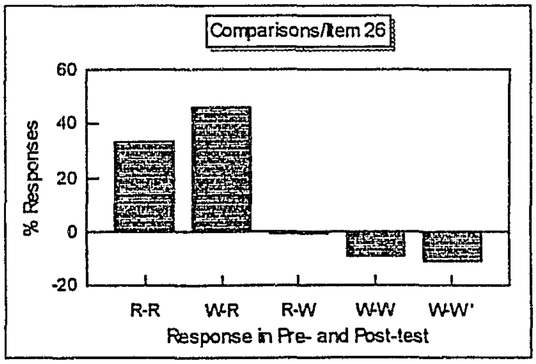
d.



e.







($p < 0.001$)

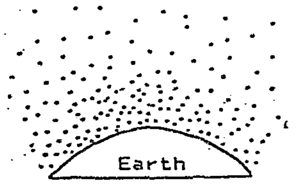
Comments

Once again students responded over a wide range of options. There was a highly significant improvement on this item after teaching, with little guessing occurring in the post-test.

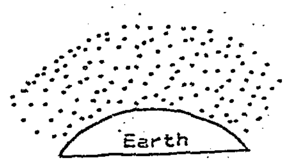
Item 27

Which diagram is a correct representation of the distribution of particles in the atmosphere?

a.*

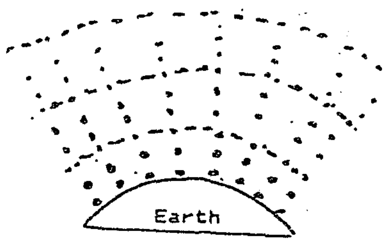


b.

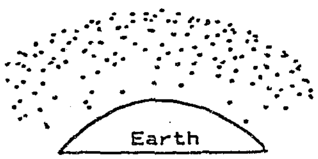


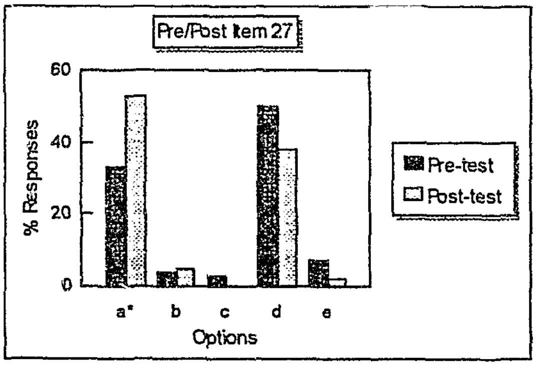
c.

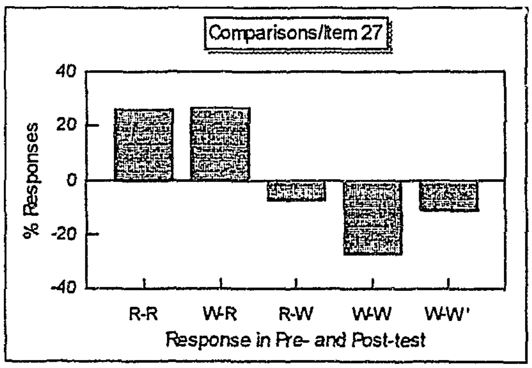
d.



e.







($p < 0.001$)

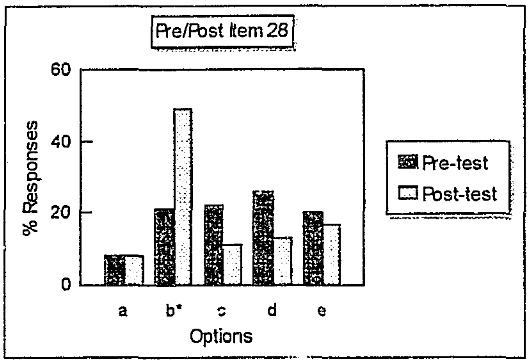
Comments

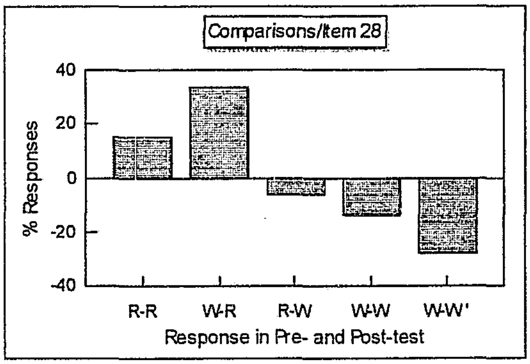
Distractor (d) was a popular option in the pre-test as well as the post-test. This could indicate that students believed that particles of air are arranged in clearly demarcated **regions** of the atmosphere. However students may have decided correctly that the bigger (heavier) particles of air would be closer to the surface of the earth. This item is perhaps ambiguous and needs refining. Nevertheless the improvement on this item was significant.

Item 28

The approximate percentage of carbon dioxide present in the lowest region of the atmosphere (troposphere) is:

a. 50% b.* 0.03% c. 30% d. 25% e. 1%





($p < 0.005$)

Comments

Students responded over a wide range of options in the pre-test. The improvement on this item was significant.

Item 29

Which statement is incorrect?

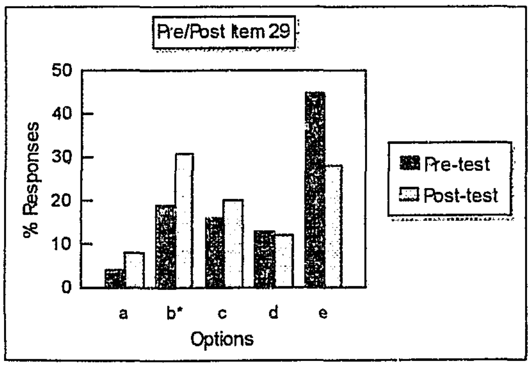
a. The atmosphere protects life from the harmful solar radiation.

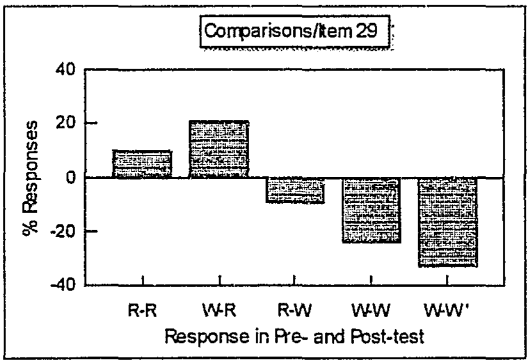
b.* The "greenhouse effect" or energy trapping effect of the atmosphere is harmful to life.

c. The properties and composition of the atmosphere are not the same throughout.

d. Scientists believe that the composition of the atmosphere has changed over the billions of years since the birth of the planet.

e. The atmosphere is naturally reactive.





($p < 0.05$)

Comments

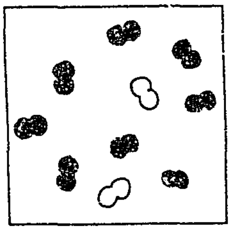
This was a difficult item and very conceptually dense. Distractor (e) remained popular even in the post-test with almost a third of the students perceiving that the atmosphere was not naturally reactive. The number of students responding correctly in the post-test was still low but nevertheless the improvement on this item was significant.

Item 30

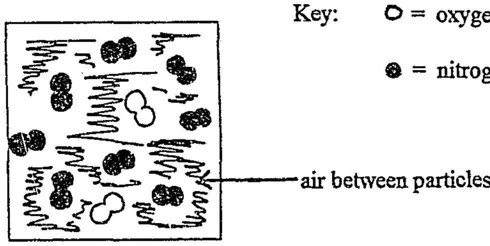
Which diagram is a correct representation of air in the lowest region of the atmosphere?

Key: O = oxygen atom; ● = nitrogen atom

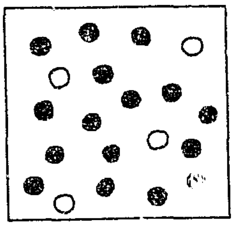
a.*



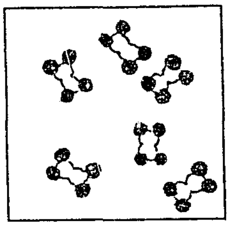
b.



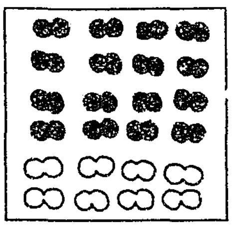
c.

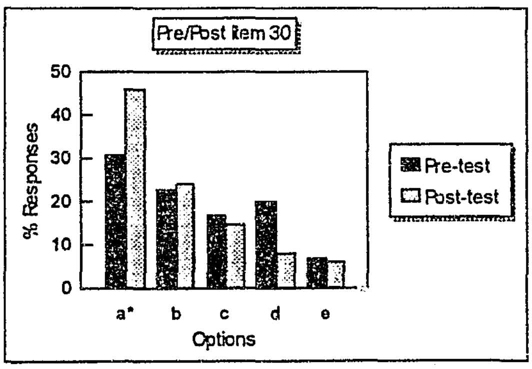


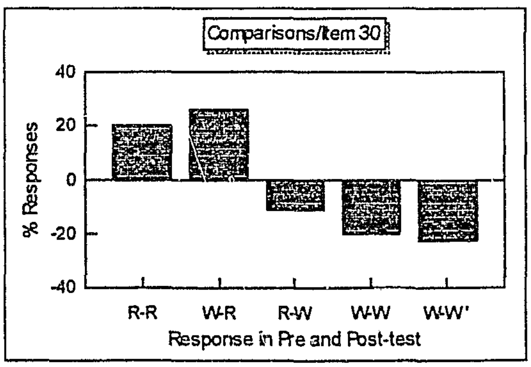
d.



e.







($p < 0.005$)

Comments

Students' responses were wide-spread in the pre-test. In the post-test, option (b) remained fairly popular - maybe the students perceived it as indicating "air pollution" between the microscopic particles. Most of the change in the post-test appears to have occurred from option (d) to (a). The improvement on this item was significant.

Some Overall Comments About the Pre- and Post-test Knowledge Items

Examination of the outcomes for each item in the pre-and post-tests provides some insight into students' prior knowledge and the way in which this knowledge changed after exposure to **just three units** of the resource package. There were significant improvements in all nine knowledge items after teaching, although the level of significance for Item 6 must be viewed with caution. The **"Comparisons"** bar charts show that considerable guessing still occurred in the post-test but it is reassuring that very few students who had the correct response in the pre-test shifted to a wrong response in the post-test.

6.1.2. Analysis of Responses to Attitudinal Items in Pre- and Post-tests

The level of significance (p) of the change in the students' responses in the pre- and post-tests was again measured using the chi-square test, with the cut-off level set at $p < 0.05$ (two-tailed). When applying this test to items 1 - 4 and 8-10, options (a) and (b) were grouped together and so were options (c) and (d). This was done because the number of students responding to some of the options was very low. For some items almost all the students either "agreed" or "disagreed" with the statements. For such items, during the statistical analysis there were so few numbers in some cells for the determination of chi-square that the results for the level of significance had to be viewed with caution. When this is the case, the level of significance is indicated as #p.

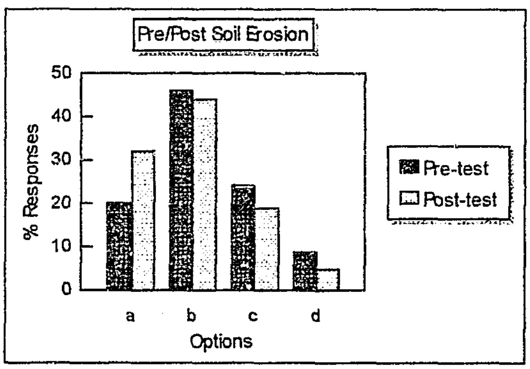
Items 1-4

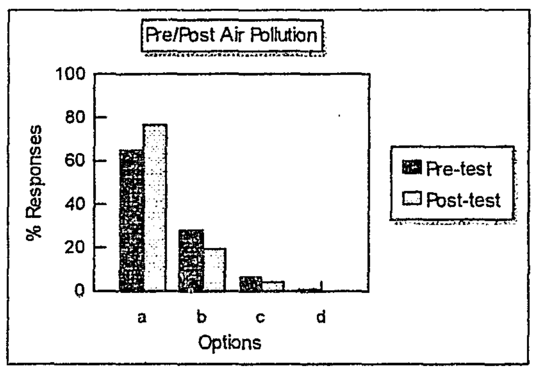
Rate the following environmental issues:

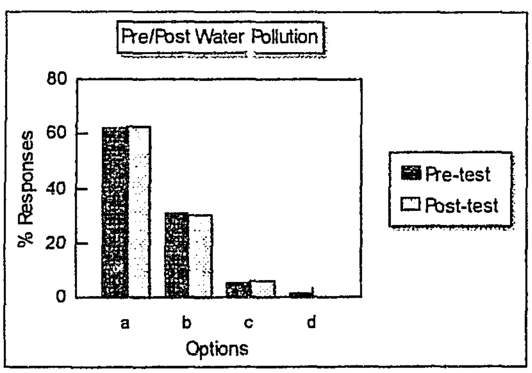
1.	Soil erosion	2.	Air pollution
3.	Water pollutio	4.	Exposure to nuclear radiation

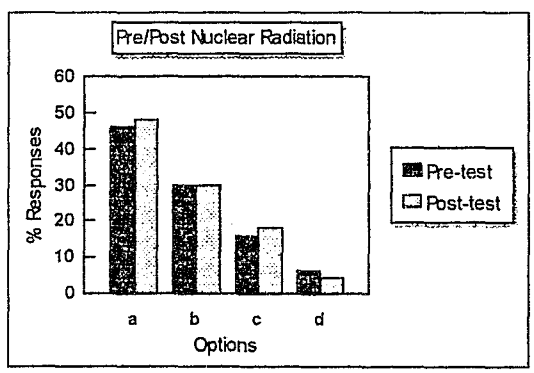
as:

a.	of great concern	b.	of concern
c.	of little concern	d.	of no concern









(Soil, $p < 0.001$) (Air, #$p < 0.001$) (Water, #$p < 0.001$) (Radiation, $p < 0.001$)

Comments

Students were more concerned about water and air pollution than the other issues in the pre-test. After exposure to the package, they became even more concerned about air pollution. Students also became more concerned about soil erosion. The increase in concern about water pollution and exposure to nuclear radiation was less.

The increase in students' concern about soil erosion and nuclear radiation was significant. The significance of the increase in their concerns about air pollution and water pollution needs to be viewed with caution.

Items 8 -10

Assess your understanding of the terms/phrases:

8. "greenhouse effect" 9. "CFCs" 10. "hole in the ozone layer"

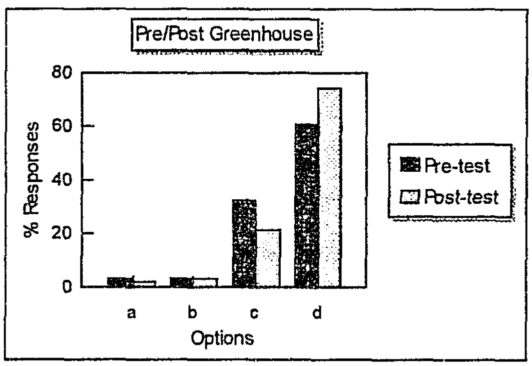
as:

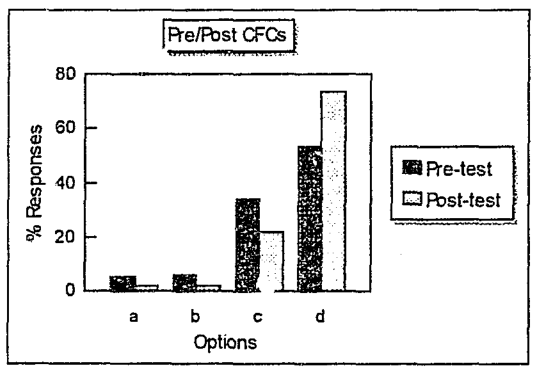
a. I have not heard of the term/phrase.

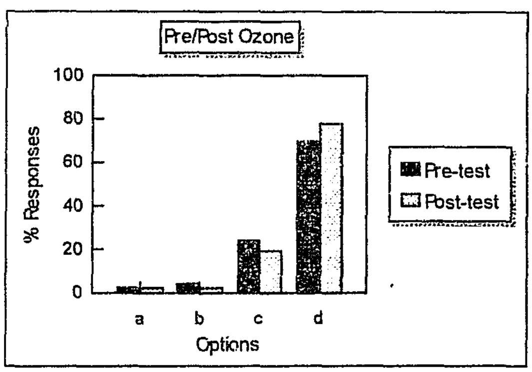
b. I have heard of it but do not understand what it means.

c. I have heard of it and think I know what it means.

d. I have heard of it and I am sure I know what it means.







(Greenhouse, #p < 0.001) (CFCs, #p < 0.001) (Ozone, #p < 0.001)

Comments

Students claimed to understand these terms/concepts in the pre-test. Yet their performance on item 1 and item 29 in the knowledge items did not reveal this understanding.

There was a claim of improved understanding for items 8 - 10 in the post-test. The level of significance of this improvement must be viewed with caution.

Items 11-24

When applying the chi-square test for significance for these items, options (a) and (b) were grouped together and so were (d) and (e). Once again in some cases, the level of significance had to be viewed with caution for the same reasons cited above.

Students responded to items 11-24 as:

a. I agree strongly with this statement

b I agree with this statement

c. I have no opinion about this statement

d. I disagree with this statement

e. I disagree strongly with this statement

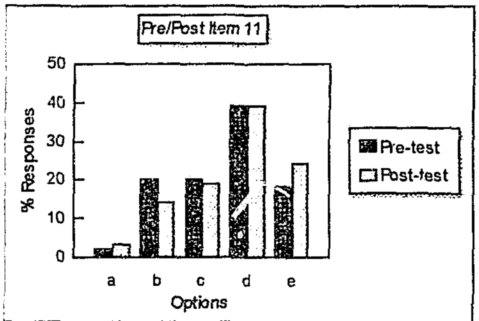
Item 11

"Economic and political issues are more important to me than the issue of air pollution."

($p < 0.001$)

Comments

Students tended to disagree with this statement in the pre-test. In the post-test, students disagreed even more. The change on this item was significant.



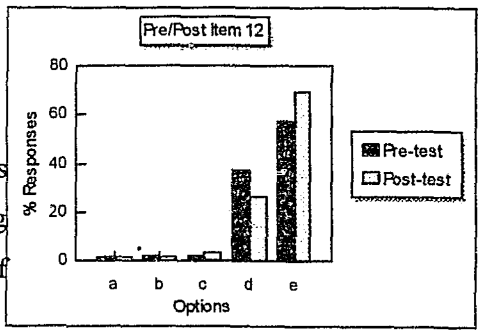
Item 12

"There is no air pollution where I live."

(#$p < 0.05$)

Comments

In the pre-test, students believed that air pollution was present in the region where they lived. After teaching there was an increase in this belief. The significance of this increase must be viewed with caution.

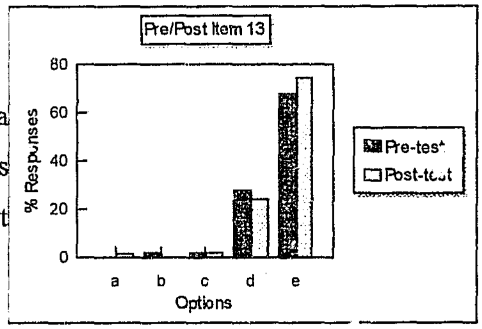


Item 13

"Air pollution is not a problem in the Republic of South Africa."

(#p > 0.1)

Comments



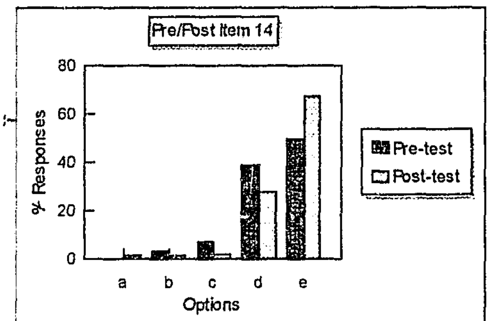
Most students were aware that air pollution was a problem in South Africa. There was an increase in this awareness in the post-test. The change was not significant.

Item 14

"It is only the forms of air pollution that can be seen or smelled that are important."

(#p > 0.05)

Comments



Most students disagreed with this statement in the pre-test. In the post-test, this feeling increased.

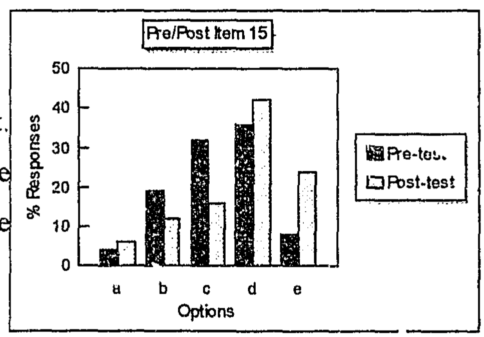
The change was not significant.

Item 15

"Once air pollutants have entered the atmosphere they remain there forever."

(p < 0.001)

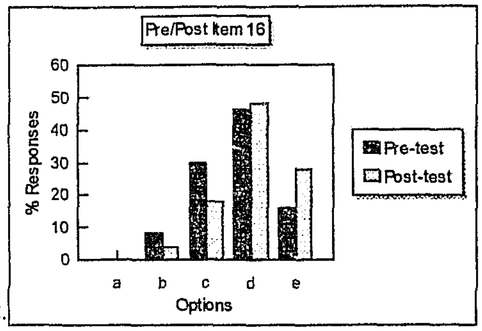
Comments



Students were confused about this issue in the pre-test. After teaching there was a significant increase in the number of students (correctly) disagreeing with the statement.

Item 16

"The media always report air pollution issues accurately."



(#p < 0.001)

Comments

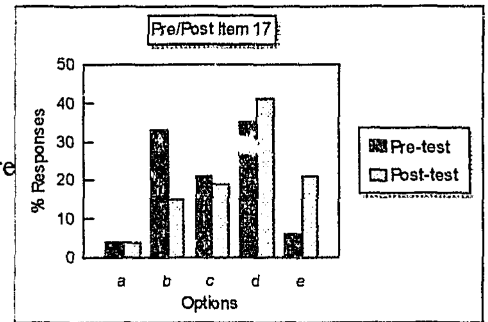
In the pre-test, students were fairly sceptical of the media's ability to report air pollution issues accurately.

Students became even more critical in the post-test.

The change was significant but the outcome should be viewed with caution.

Item 17

"Environmentalists are able to predict with certainty the consequences of air pollution."



(p < 0.001)

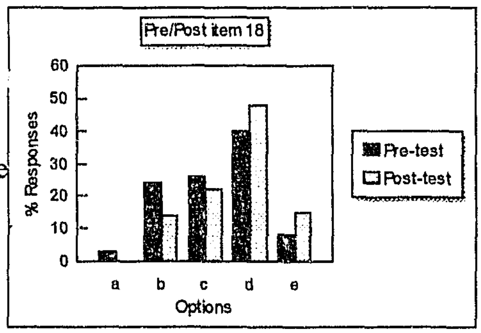
Comments

Students were rather undecided about this issue in the pre-test. In the post-test, they were more critical of the environmentalists.

The change in their attitude was significant.

Item 18

"Industry is not concerned about air pollution."



(p < 0.001)

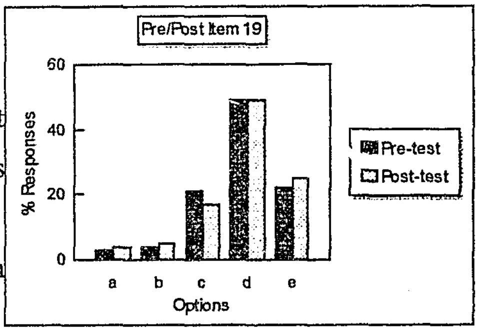
Comments

In the pre-test a number of students believed that industry was concerned about air pollution. There was a significant increase in the number of students who had this belief in the post-test.

Item 19

"Techn' ical/industrial development should be stopped in order to preserve the environment."

(#p < 0.001)



Comments

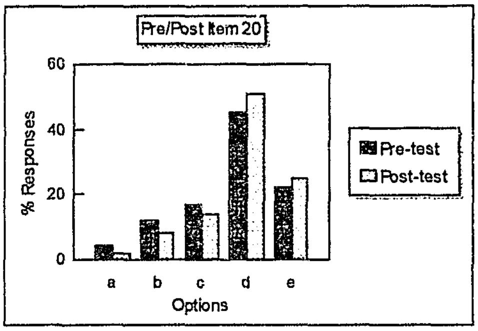
In the pre-test many students felt that development should not be stopped. There was an increase in this perception in the post-test.

The significance of this change must be viewed with caution.

Item 20

"Air pollution is uncontrollable and will increase steadily until life is destroyed."

(#p < 0.001)



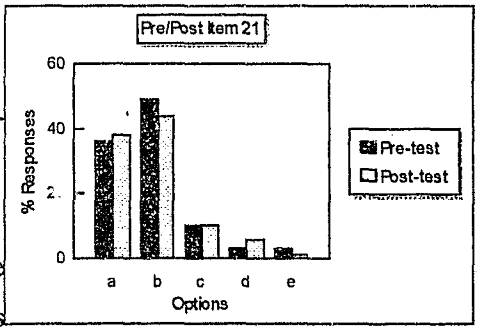
Comments

In the pre-test many students felt that air pollution was controllable. This perception increased among students in the post-test. The significance of this change must be viewed with caution.

Item 21

" Air pollution can be controlled using science and technology but it will need a constant monitoring of the risks and benefits of our activities."

(#p < 0.001)

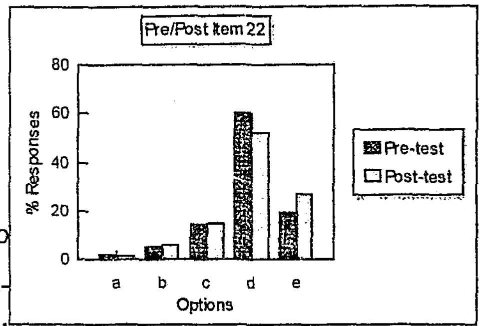


Comments

Most students agreed with this statement in the pre-test. In the post-test there was a small increase in the number of students disagreeing. This lack of consistency in comparison with item 20 above, may be due to some students experiencing language problems with this item. The significance of the change for this item must be viewed with caution.

Item 22

"I contribute very little to air pollution and thus have no role to play in its control."



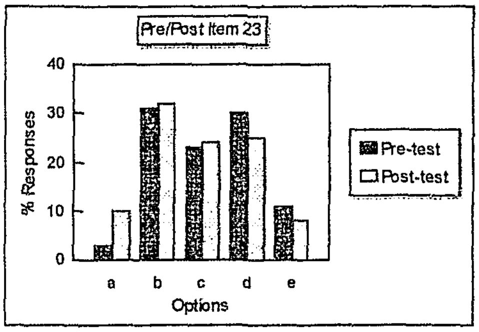
(# $p < 0.001$)

Comments

In the pre-test, most students felt they did contribute to air pollution. This perception was increased in the post-test. The significance of this change must be viewed with caution.

Item 23

"To improve air pollution control we must be prepared to pay more for things."



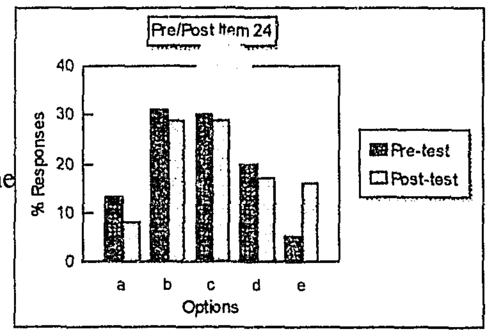
($p < 0.001$)

Comments

In the pre-test students felt ambivalent about this issue. In the post-test, more of them agreed with the statement. The change was significant.

Item 24

" If the topic air pollution were offered in the Physical Science syllabus in the future, my interest in the study of science would increase greatly."



($p <0.001$)

Comments

Students were less positive about the inclusion of the topic after teaching. This change was significant.

Some Overall Comments About the Attitudinal Items

Inspection of the outcomes of students' responses to each item in the pre-test reveals some of the students' opinions/ attitudes/ beliefs prior to teaching. The comparison of outcomes in the pre- and post-tests shows the change which occurred after students were exposed to parts of the package. The interest of the students in the topic appeared to decrease. This is consistent with reports from teachers that many students wanted to get on with revision for the forthcoming examinations etc. It is interesting to note that in spite of their resistance to the implementation of the package, some "worthy" changes occurred! In some items most students had already indicated in the pre-test a strong concern and awareness of air pollution (eg. items 2, 12 and 13). In the post-test, these concerns and perceptions appeared to be enhanced. The students' claimed understanding of terms/issues improved and they appeared to become more critical of the media and environmentalists. In general the students' responses in the post-test seem to indicate that the students were becoming better informed and that they were forming a more balanced outlook about issues regarding air pollution.

6.2. AN ANALYSIS OF THE PRE- AND POST-TEST RESULTS FOR THE UNIT SPECIFIC ITEMS (ITEMS 31-45) IN THE SURVEY

These Survey items were specific to the additional unit that each school implemented. To each item students responded **True (T), False(F)** or **I do not know(DK)**. Students were asked not to guess and to mark the column "I do not know" if they were not sure of the answer. The outcomes are presented in the form of stacked bar charts. The correct response to each item is indicated as True (T) or False (F) at the end of the description of each item. For each item, the percentage of correct responses (either true or false depending on the item) is represented as **C**. The percentage of incorrect responses is represented as **W** and the percentage of "I do not know " responses is shown as **DK.** Once again the non-responses (which were generally a small number) are not shown on the bar charts. Thus in some cases the totals for the percentage responses are not 100%.

The outcomes of the administration of this part of the Survey as a pre-test, provide some insight into the state of prior knowledge of the students concerning some of the more specific issues with regard to air pollution. In this analysis the items have been broadly classified as

- **A.** those in which students had a **good prior knowledge** (60% or more correct responses in the pre-test).
- **B.** those in which the students had a **fair prior knowledge** (50% - 59% correct responses in the pre-test).
- **C.** those in which students had a **poor prior knowledge** (less than 50% correct responses in the pre-test).

The comparisons of the outcomes of the pre- and post-tests show how this knowledge changed after students had interacted with some units of the package. Some of the classes were very small. Thus a statistical comparison of the pre-and post-test outcomes was not made. Instead **knowledge gains** for each item were calculated. The knowledge gain (as a percentage) for each item is presented under the bar charts for each school. The average knowledge gains (as percentages) for categories A, B and C described above are also presented. The percentages of the **total DK** responses in the pre-test and in the post-test are recorded at the end of the items for each unit.

In the discussion that follows the outcomes for the items in each unit, an attempt has been made to relate the average knowledge gains for each category to the activities students engaged in in the classroom. Data on these activities were provided by the teachers when they completed the evaluation sheets for each unit (see Chapter 5).

The responses are presented in the barcharts that follow, as:

- **Analysis of Items for Unit 3 - Combustion**
- **Analysis of Items for Unit 4 - The Depletion of Ozone in the Stratosphere**
- **Analysis of Items for Unit 5 - Smog**
- **Analysis of Items for Unit 6 - The Enhanced Greenhouse Effect**
- **Analysis of Items for Unit 7 - Acid Rain**
- **Analysis of Items for Unit 8 - Control of Air Pollution**
- **Analysis of Items for Unit 9 - Response by Industry**

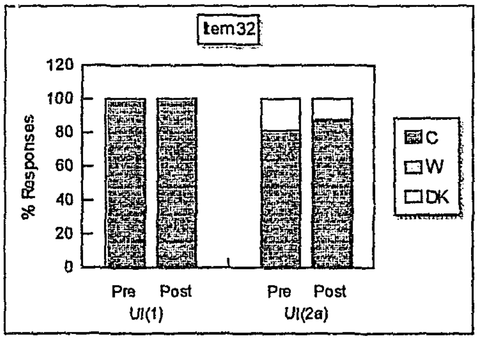
6.2.1. Analysis of Items for Unit 3 - Combustion

This unit was implemented in schools UI_1 (N = 5) and UI_{2a} (N = 16). The items were classified according to the weighted average percentage response in the pre-test for **both** schools. The knowledge gains were calculated from the average responses for **both** schools in the pre- and post-tests.

A. Items in which Students had a Good Prior Knowledge

Item 32

Both coal and oil are classified as fossil fuels. (T)

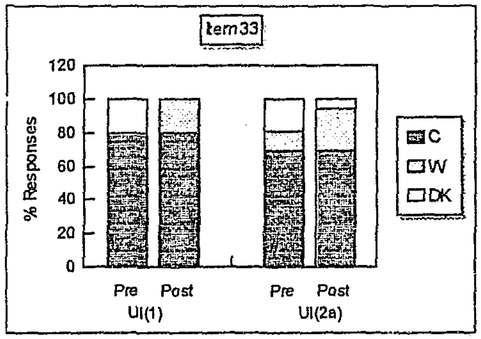


Pre-test Average: 86% Post-test Average: 90%

Knowledge Gain: 4%

Item 33

Coal is composed of only carbon. (F)

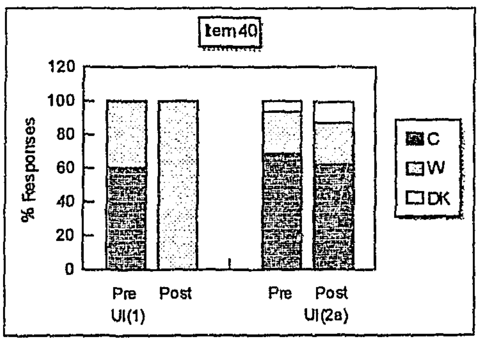


Pre-test Average: 71% Post-test Average: 71%

Knowledge Gain: 0%

Item 40

The total contribution to air pollution by motor vehicles is very small compared to industry. (F)

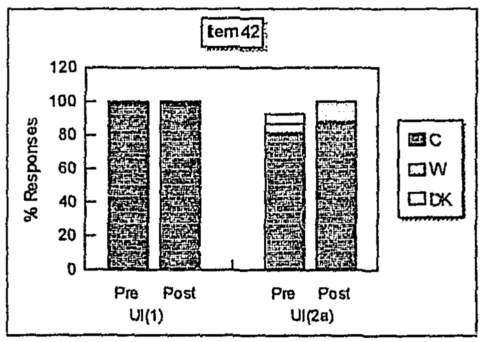


Pre-test Average: 67% Post-Test Average: 48%

Knowledge Gain: -19%

Item 42

Petrol sold in South Africa contains lead compounds. (T)



Pre-test Average: 86% Post-test Average: 90%

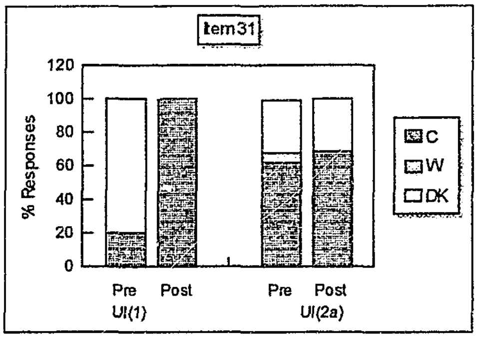
Knowledge Gain: 4%

Average Knowledge Gain for Good Prior Knowledge Items: -3%

B. Items in which Students had a Fair Prior Knowledge

Item 31

Approximately 90% of the world's energy needs comes from the combustion of coal.(T)

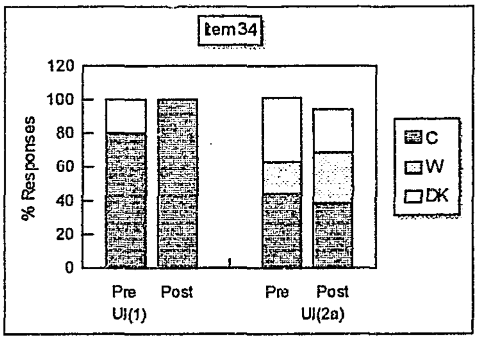


Pre-test Average: 52% Post-test Average: 76%

Knowledge Gain: 24%

Item 34

The only products formed when coal is burned are: ash, soot, carbon dioxide and carbon monoxide.(F)



Pre-test Average: 52% Post-test Average: 62%

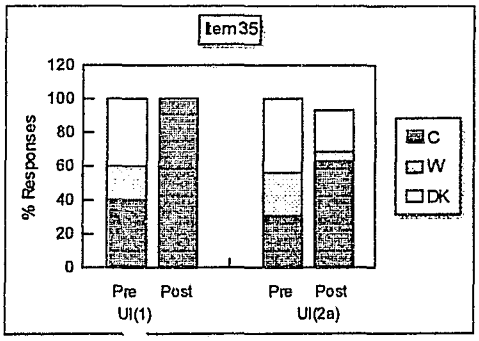
Knowledge Gain: 10%

Average Knowledge Gain for Fair Prior Knowledge Items: 17%

C. Items in which Students had a Poor Prior Knowledge

Item 35

The ash produced by burning coal does not present any air pollution problems because it is solid and can be easily removed. (F)

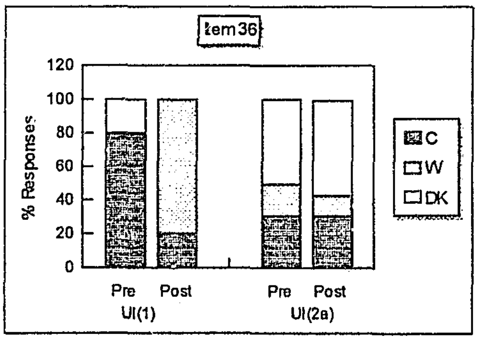


Pre-test Average: 33% Post-test Average: 71%

Knowledge Gain: 38%

Item 36

South African coal has a low sulphur content. Therefore the release of sulphur dioxide from coal combustion is negligible. (F)

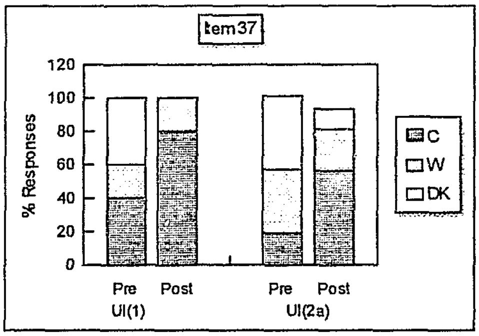


Pre-test Average: 43% Post-test Average: 29%

Knowledge Gain: -14%

Item 37

The burning of coal in households can produce worse air pollution than that produced by power stations. (T)

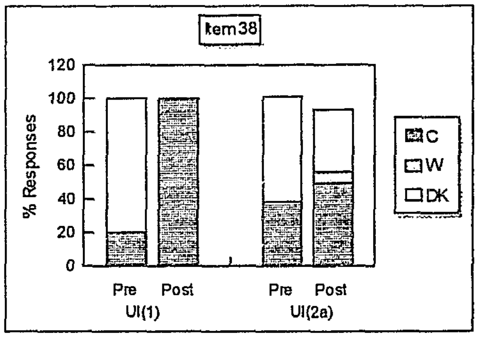


Pre-test Average: 24% Post-test Average: 62%

Knowledge Gain: 38%

Item 38

In South Africa, coal-fired power stations burn more coal than industries such as ISCOR. (T)

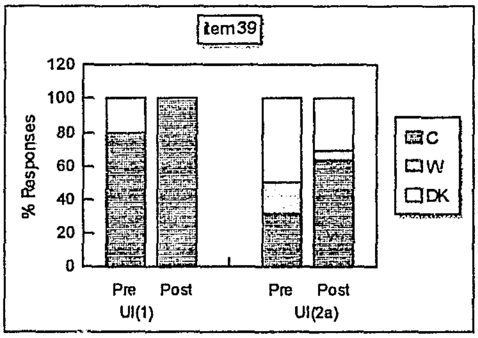


Pre-test Average: 33% Post-test Average: 62%

Knowledge Gain: 29%

Item 39

Nitrogen oxides which contribute to air pollution problems are only produced by industrial processes. (F)

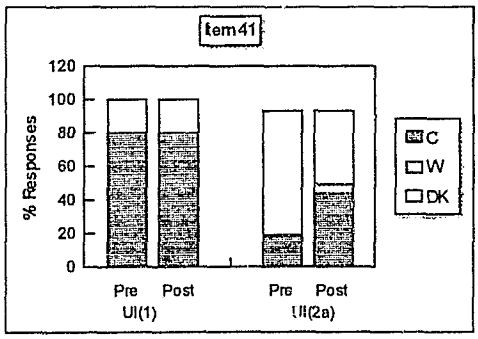


Pre-test Average: 43% Post-test Average: 71%

Knowledge Gain: 28%

Item 41

The temperature in parts of the running motor car engine is sufficient to bring about a reaction between nitrogen and oxygen in the air. (T)

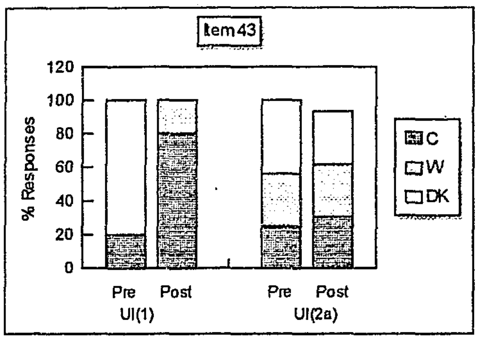


Pre-test Average: 33% Post-test Average: 52%

Knowledge Gain: 19%

Item 43

The only products formed when petrol is burnt in the engines of motor vehicles are: carbon dioxide, carbon monoxide and lead compounds. (F)

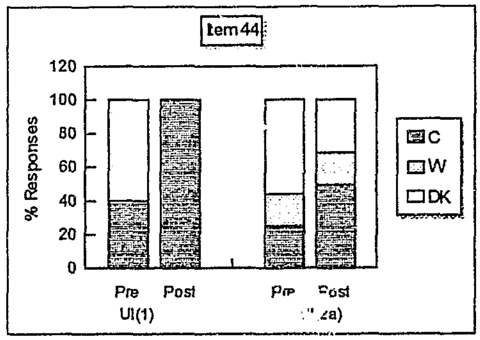


Pre-test Average: 24% Post-test Average: 43%

Knowledge Gain: 19%

Item 44

Natural gas is methane. (T)

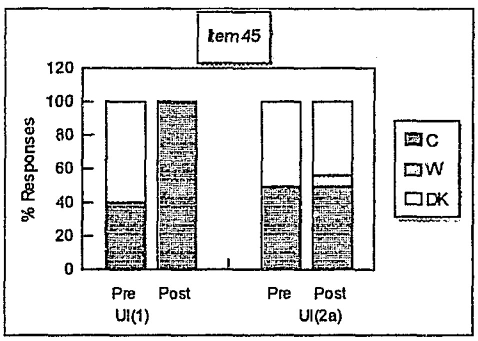


Pre-test Average: 29% Post-test Average: 62%

Knowledge Gain: 33%

Item 45

In South Africa, natural gas deposits have been discovered near Mossel Bay. (T)



Pre-test Average: 48% Post-test Average: 62%

Knowledge Gain: 14%

Average Knowledge Gain for Poor Prior Knowledge Items: 23%

School UI_1	School UI_{2a}
% DK (Pre-test) = 39%	% DK (Pre-test) = 40%
% DK (Post-test) = 21%	% DK(Post-test) = 27%

Comments:

The outcomes for the two schools were slightly different. The numbers of students at both schools were relatively small so no firm conclusions can be drawn from these differences. The discussion below focusses on the **average** outcomes for the two schools.

Pre-test Outcomes

The items in which students appeared to have **good prior knowledge** were generally those which required simple factual knowledge about combustion or in which the answers were possibly more obvious. Few students chose the DK option in these items. The items focussed on the nature of fossil fuels, the composition of coal and of petrol sold in South Africa. This background knowledge could have been acquired in other school subjects such as biology or geography or via the media (television, newspapers and magazines). Background knowledge for item 40 (which required a comparison of air pollution from motor vehicles and industry) could also have been gained this way. The problems facing cities such as Los Angeles and Tokyo have recently been highlighted a great deal in the media.

For items 31 and 34 in which there was a **fair prior knowledge**, students may have drawn on their experiences gained from living in a coal-producing country and first-hand exposure to the problems associated with coal-combustion.

Items in which students had a **poor prior knowledge** required a deeper factual knowledge and the ability to make informed comparisons. This appeared to be the case in items 35, 36, 37, 38, 39, 41, and 43. Natural gas is not widely used in South Africa and the discovery of natural gas at Mossel Bay was a fairly recent event. This may have affected the outcomes for items 44 and 45.

The DK option became steadily more popular among students for the items in which students had a fair to poor prior knowledge.

Comparison of Pre- and Post-test Outcomes

The negative average knowledge gain (-3%) for the **good prior knowledge** items resulted from the poorer outcomes in the post-test for item 40 in both schools but particularly school UI_1. The average knowledge gain for this item was -19%. (The other items in this category showed little or no gain.) On relating this outcome to the classroom activities chosen by the teachers, it was found that both teachers had selected Worksheet 3(a) (see Package, page 49). The last task in this worksheet partly addressed the statement in item 40. It is possible that Unit 3 did not make this issue explicit enough to the students. Guessing probably played a role in all items in the administration of this part of the Survey. Although students were requested not to guess, they may have felt confident about their answer to item 40 in the pre-test (and did not choose the DK option) because they had **heard** about the issue.

Items in which there was **fair** and **poor prior knowledge** showed fairly substantial average knowledge gains (17% and 23% respectively). Item 36 showed a negative knowledge gain (again largely from school UI_1). There is the possibility that something in the lesson at school UI_1 misled the students. However, this item may have been a little too subtle. Students did not seem to take into account the role played by the **scale** of coal combustion in South Africa. This issue was not dealt with explicity in the introduction to the unit nor was it directly addressed in the worksheets for this unit.

In the post-test, there was a marked decrease in the percentage of DK responses for both schools.

After exposure to Unit 3, students in both schools seemed to become better informed about the topic combustion and the air pollution problems associated with it. There was an improvement in 9/15 items at school UI_1. (There was already a 100% correct response for items 32 and 42 in the pre-test.) At school UI_{2a} there was an improvement in 10/15 items.

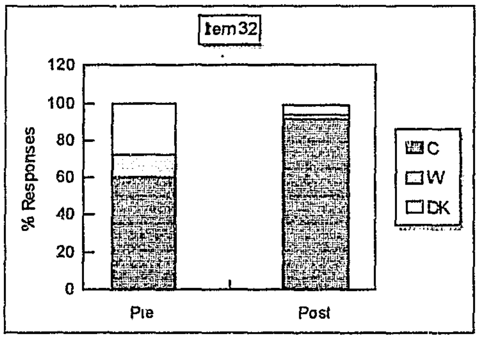
6.2.2. Analysis of Items for Unit 4 - Depletion of Ozone in the Stratosphere

This unit was implemented by school US_1 (N = 57).

A. Items in which Students had a Good Prior Knowledge

Item 32

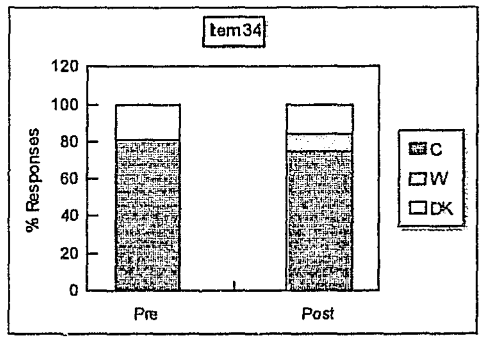
The concentration of ozone is the same throughout the atmosphere. (F)



Knowledge Gain: 31%

Item 34

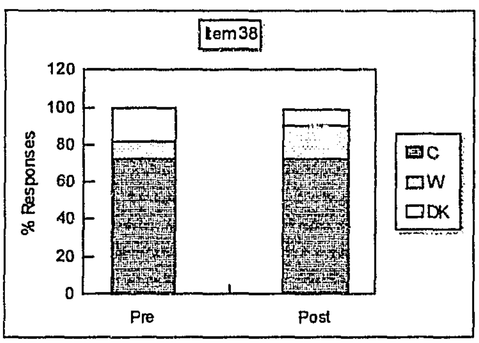
The sky is blue because ozone is a blue gas. (F)



Knowledge Gain: -6%

Item 38

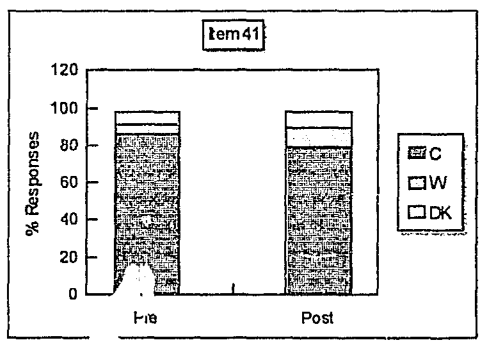
CFCs are only used in industrial processes. (F)



Knowledge Gain: 0%

Item 41

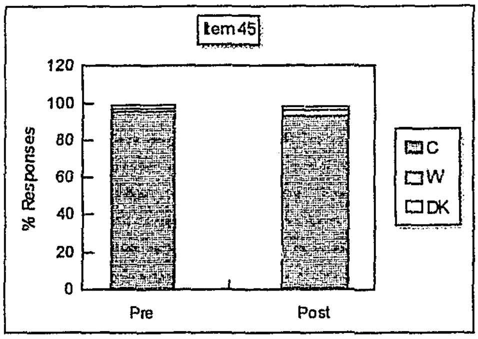
All solar radiation that enters the atmosphere, reaches the surface of the Earth. (F)



Knowledge Gain: -7%

Item 45

With modern day technology, scientists never make mistakes. (F)



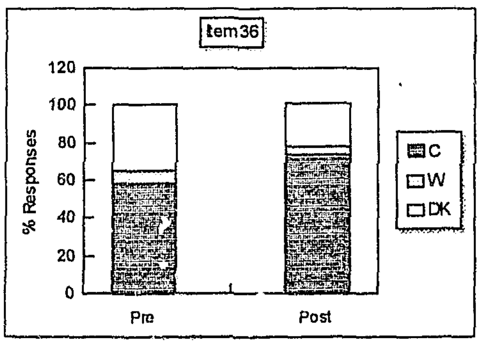
Knowledge Gain: -2%

Average Knowledge Gain for Good Prior Knowledge Items: 3%

B. Items in which Students had a Fair Prior Knowledge

Item 36

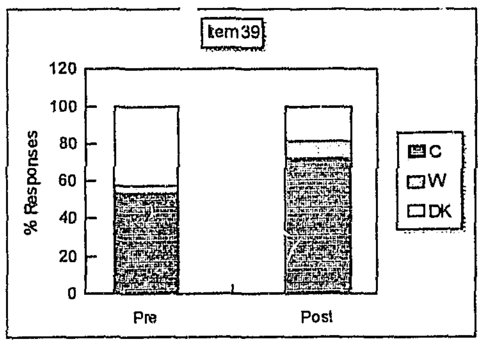
Both CFCs and nitrous oxide (N_2O) destroy ozone in the stratosphere. (T)



Knowledge Gain: 16%

Item 39

CFCs occur naturally in the atmosphere. (F)



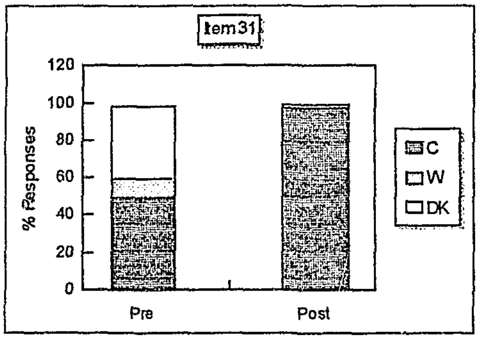
Knowledge Gain: 19%

Average Knowledge Gain for Fair Prior Knowledge Items: 18%

C. Items in which Students had a Poor Prior Knowledge

Item 31

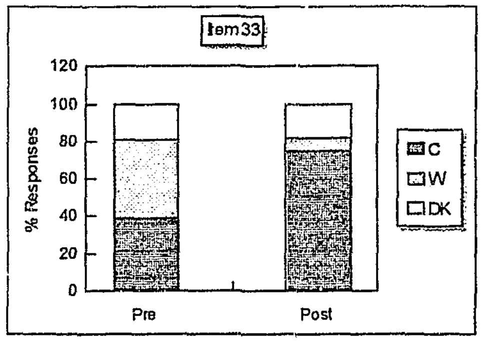
The chemical formula for ozone is O_3. (T)



Knowledge Gain: 48%

Item 33

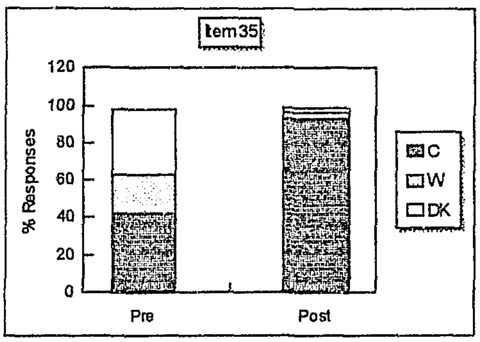
Once ozone is destroyed in the stratosphere, it can never be reformed. (F)



Knowledge Gain: 36%

Item 35

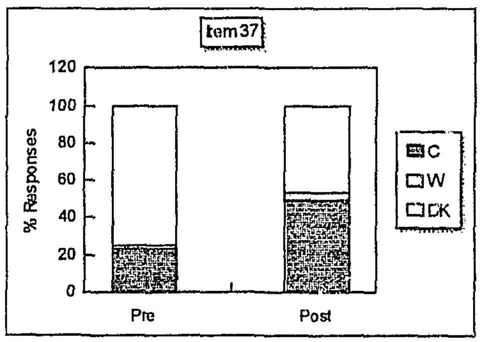
CFCs are compounds whose molecules consist of chlorine, fluorine and carbon atoms. (T)



Knowledge Gain: 51%

Item 37

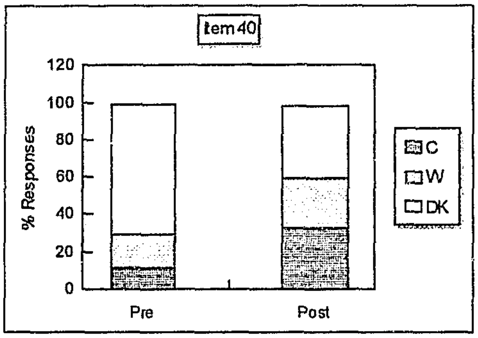
One chlorine atom released from a CFC molecule is capable of destroying approximately 100 000 ozone molecules. (T)



Knowledge Gain: 26%

Item 40

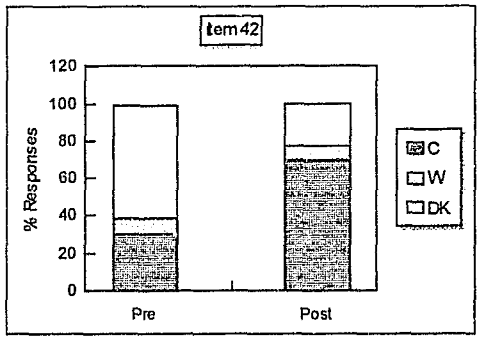
CFCs are unreactive in the troposphere but become reactive in the stratosphere. (T)



Knowledge Gain: 22%

Item 42

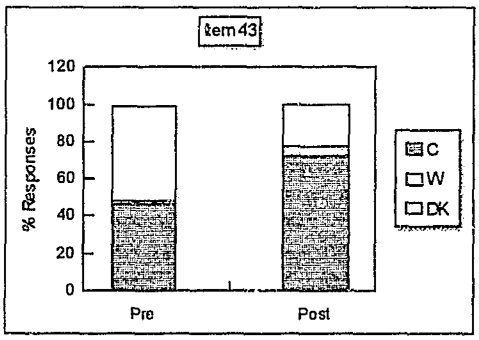
Ozone is the only substance in the atmosphere capable of absorbing radiation of wavelength 220-330 nm. (T)



Knowledge Gain: 40%

Item 43

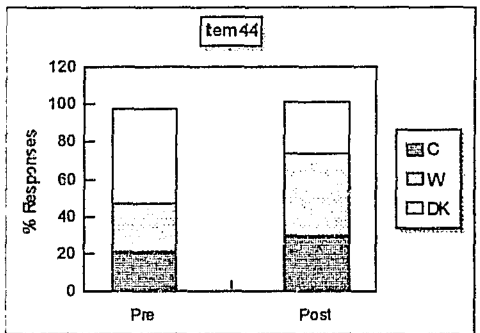
Solar radiation of wavelength 220 - 330 nm is harmful to life. (T)



Knowledge Gain: 26%

Item 44

A photochemical reaction can only be brought about by visible light. (F)



Knowledge Gain: 8%

Average Knowledge Gain for Poor Prior Knowledge Items: 32%

% DK (Pre-test) = 37%

% DK (Post-test) = 18%

Comments:

Pre-test Outcomes

This Unit was implemented using a fairly large sample of students.

There were 5 items in which students had a **good prior knowledge**. Their responses may have been largely influenced by the students' exposure to these issues via the media. Students appeared to be aware that the concentration of ozone is not the same throughout the atmosphere (item 32). This may have been because of the recent publicity about the hole in the ozone layer. Students' background knowledge in item 38 may have come from exposure to the media where refrigerators and aerosol sprays have been highlighted as devices which make use of CFCs. They seemed to have a good understanding that the blue colour of the sky is not due to the presence of ozone and that not all the radiation from the sun reaches the surface of the Earth. However these responses may have been based to some degree on "intelligent guesses" rather than a sound understanding of the phenomena. In item 45 many students responded that scientists were not infallible. This may have been due to the way in which their teacher presented science to them in the classroom.

The items in which students had a **fair prior knowledge** may have been a little more obscure to them. The response to item 36 is surprisingly good but once again may have been based on an intuition rather than understanding.

Most of the items in which students had a **poor prior knowledge**, required a deeper understanding of the chemical nature of ozone and CFCs and the reactions in which they take part. The destruction of ozone in the atmosphere involves relatively novel and abstract concepts. Students had probably had little or no previous exposure to these ideas. The response to item 35 is fairly consistent with the response of these students to item 9 in the Survey (reported earlier) where only 51% of the students felt sure that they understood the meaning of the term "CFCs".

The DK option was popular in the items for which students had a fair and poor prior knowledge.

Comparison of Pre- and Post-test Outcomes

There was an overall improvement in 11/15 of the items in the post-test.

For the items in which there was **good prior knowledge**, the average percentage knowledge gain in the post-test was 3%. Item 32 (dealing with the concentration of ozone in the atmosphere) showed a marked improvement (31%). In the items dealing with the origin of the blue colour of the sky, the quantity of solar radiation reaching the surface of the Earth and the fallibility of scientists there were negative shifts in the post-test. The origin of the colour of the sky (item 34) was mentioned in the introduction to Unit 4 but did not feature in the worksheets for the unit. From the fact that ozone absorbed some ultraviolet radiation, the students needed to **deduce** that not all the solar radiation that enters the atmosphere reaches the surface of the Earth (item 41). Although the students seemed very aware in the pre-test that scientists were not infallible, the teacher did not choose the worksheet which focussed on this issue. This may explain the small negative shift in item 45 in the post-test. In item 38 there was no change in the number of correct responses in the post-test but there was a shift from the DK option to the wrong option. This issue was also not in the worksheets chosen by the teacher as activities for this unit.

There were marked average knowledge gains in items in which students had a **fair or poor prior knowledge** (18% and 32% respectively.) As mentioned above these items dealt mostly with the **"chemistry"** of ozone destruction. Three items (37, 40 and 44) showed improvement but the percentage of correct responses in the post-test remained relatively low. Item 37 is a rather specific item whereas items 40 and 44 involve difficult concepts.

In the post-test there was a marked decrease in the number of DK responses. It is noteworthy that with the exceptions of items 31, 32, 33, 35 and 36, there was an increase in the number of wrong responses in the post-test. Thus in general as students moved away from the DK option in the post-test, some of them chose the incorrect option. This even occurred in some items in which there was a knowledge gain in the post-test. This shift is possibly due to the novel and rather complex nature of the topic dealt with in Unit 4.

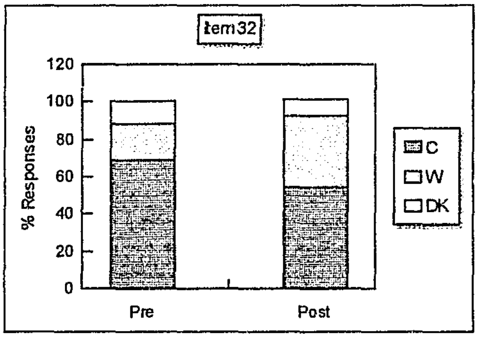
6.2.3. Analysis of Items for Unit 5 - Smog

This Unit was implemented by school US_2 (N = 26).

A. Items in which Students had a Good Prior Knowledge

Item 32

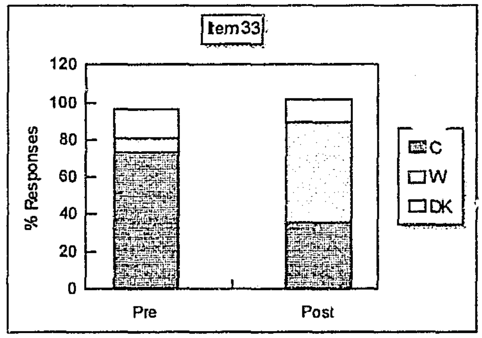
Smog is mainly an urban problem.(T)



Knowledge Gain: -15%

Item 33

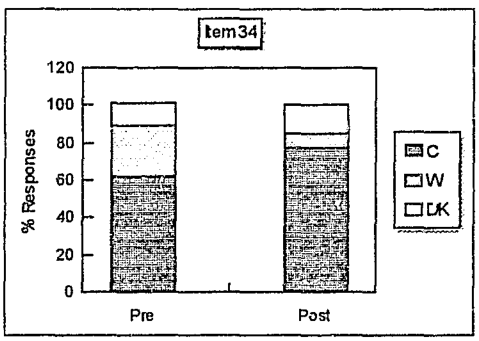
Smog only forms on a cold, wet day. (F)



Knowledge Gain: -38%

Item 34

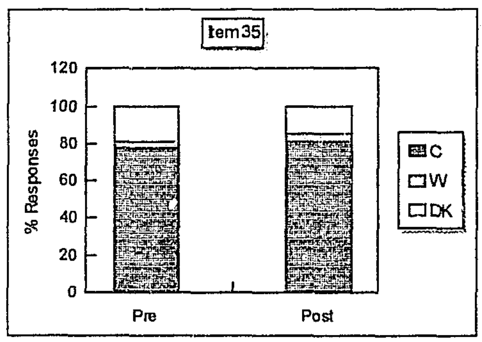
Smog is only the result of burning coal. (F)



Knowledge Gain: 15%

Item 35

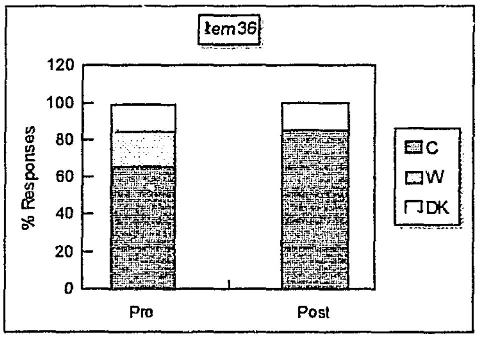
Smog is not a problem in South Africa.(F)



Knowledge Gain: 4%

Item 36

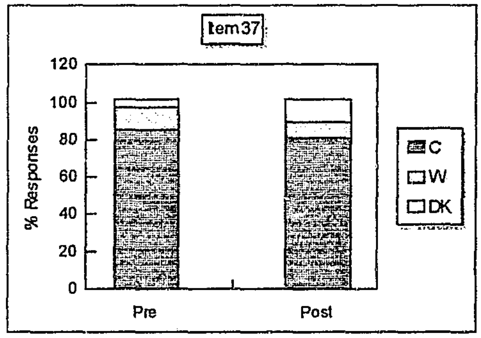
Weather plays an important role in the formation of smog.(T)



Knowledge Gain: 20%

Item 37

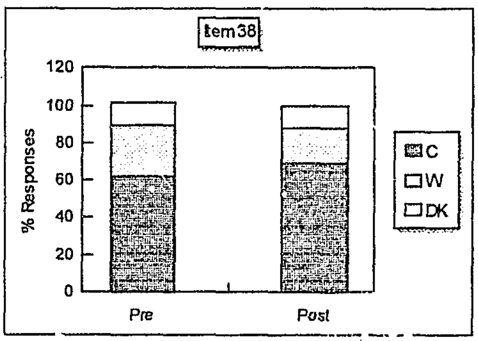
Smog can have a detrimental effect on health.(T)



Knowledge Gain: -4%

Item 38

Smog is only caused by industrial activity. (F)



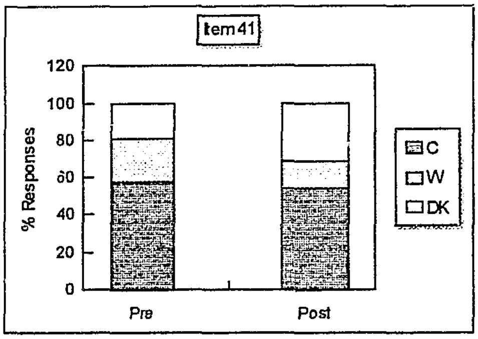
Knowledge Gain: 7%

Average Knowledge Gain for Good Prior Knowledge Items: -2%

B. Items in which Students had a Fair Prior Knowledge

Item 41

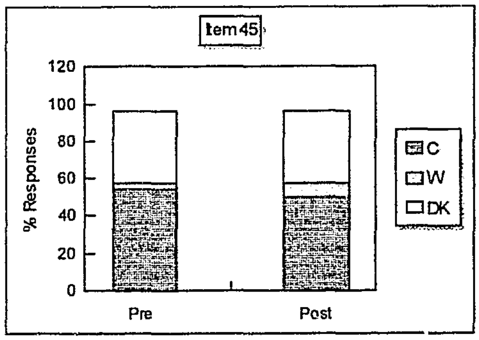
Sunlight and some of the gases from motor car exhausts. can result in smog formation. (T)



Knowledge Gain :-4%

Item 45

Science and technology have no methods for controlling photochemical smog.(F)



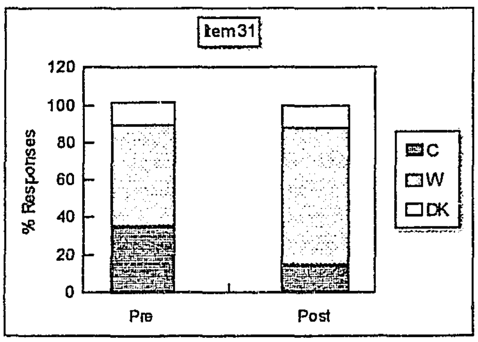
Knowledge Gain: -4%

Average Knowledge Gain for Fair Prior Knowledge Items: -4%

C. Items in which Students had a Poor Prior Knowledge

Item 31

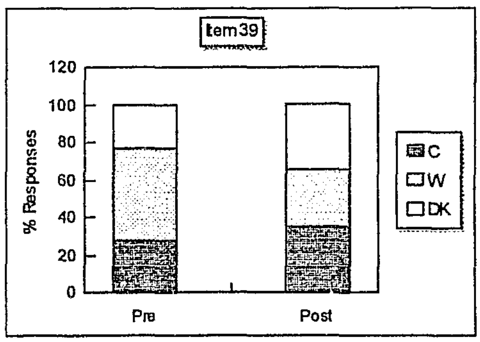
Smog is always a combination of smoke and fog. (F)



Knowledge Gain: -20%

Item 39

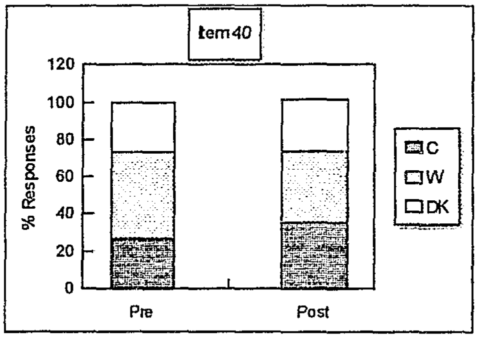
Ozone only has beneficial effects in the atmosphere.(F)



Knowledge Gain: 18%

Item 40

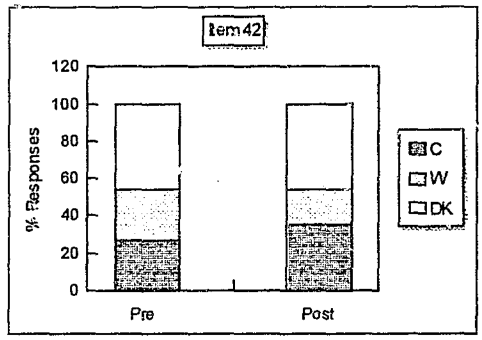
Ozone is not present in the lowest region (the troposphere) of the atmosphere.(F)



Knowledge Gain: 18%

Item 42

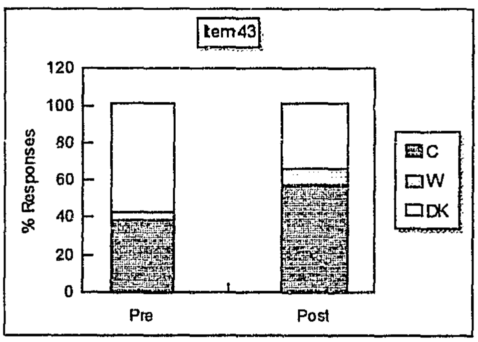
Nitrogen oxides are formed when nitrogen and oxygen in the air combine in the very hot parts of the motor car engine.(T)



Knowledge Gain: 18%

Item 43

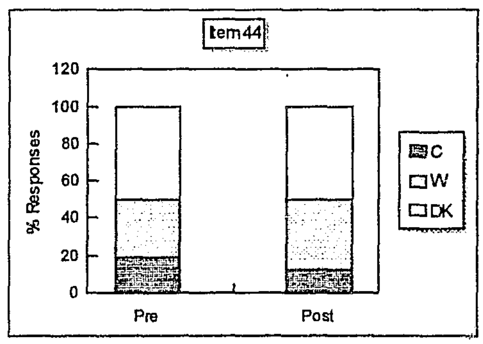
Hydrocarbon compounds released from car exhausts, are involved in the chemical reactions which produce photochemical smog.(T)



Knowledge Gain: 19%

Item 44

Ozone accumulates during the formation of photochemical smog.(T)



Knowledge Gain: -7%

Average Knowledge Gain for Poor Prior Knowledge Items: 8%

% DK (Pre-test) = 24%

% DK (Post-test) = 24%

Comments:

Pre-test Outcomes

Students responses seemed to indicated a **good prior knowledge** in 7 of the items. Students' observations and experience from living in a city where smog is a common phenomenon (especially in the dry cold winters) may have played a role in their answers.

The smog in cities such as Los Angeles and the use of catalytic converters have recently received a considerable amount of coverage in the media. This may have impacted on the students' responses to the two items in which they had a **fair prior knowledge**.

There were 6 items in which students had a **poor prior knowledge**. These items required a deeper knowledge of smog formation, in particular that of photochemical smog. Students were largely unaware that ozone was a component of photochemical smog in the troposphere. Few students realised that ozone has detrimental effects in the troposphere.

The "DK option" became steadily more popular as students' prior knowledge became poorer.

Comparison of Pre- and Post-test Outcomes

There was an improvement in 8/15 items in the post-test.

The average knowledge gain for the items in which there was **good prior knowledge** was -2%. There was an improvement in 4 of the 7 items in which students had good prior knowledge. The negative shifts in items 32, 33 and 37 are somewhat surprising. (In items 32 and 33 there were increases in the numbers of wrong responses. In item 37 there was an increase in the number of DK responses.) These three items were addressed in Worksheet 5(a) in the package which the teacher had chosen. Students appeared to become more aware that smog is a problem in South Africa (item 35) and that it is not just the combustion of coal that causes smog (item 34). There was also an increase in awareness that smog is not only caused by industrial processes (item 36).

Both items in which students had a **fair prior knowledge** showed a decline in the number of correct responses in the post-test with the average knowledge gain being -4%. Once again these were issues addressed in Worksheet 5(a) selected by the teacher as an activity.

The average knowledge gain for the **poor prior knowledge** items was 8%. Four of the items showed improvement. The improvement was rather small. Only one of the items (item 43) showed an improvement into the "fair knowledge" (between 50 and 59% correct responses) category. The percentages of correct responses in the post-test for the other three items were still less than 40%. The negative outcome for item 44 is surprising in the light of the improvement in item 40. It may indicate that students were not interrelating knowledge. Item 31 also showed a marked increase in the number of wrong responses and a decrease in the number of correct responses in the post-test. There are very similar trends in the outcomes in the post-test for items 31, 32 and 33, dealing with the phenomenon of photochemical smog. Worksheets 5(a) and 5(b), chosen by the teacher as activities, dealt with the formation of photochemical smog and the subsequent accumulation of ozone in the troposphere. Yet responses in the post-test indicate that students were still confused about these issues after teaching took place.

There was no overall change in the number of DK responses in the post test. This outcome is different from the outcomes for the previous two units.

The items for Unit 5 did not show the same degree of improvement as the outcomes for the items for the previous Units 3 and 4. The resource materials for Unit 5 did not appear to be as effective in the hands of the teacher at this school when compared with the outcomes for Units 3 and 4. Possible reasons for this are presented in the overall discussion on the unit specific items at the end of this chapter.

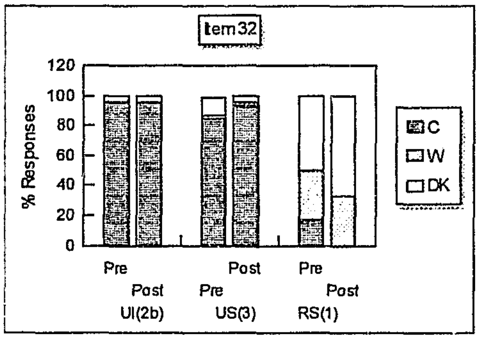
6.2.4. Analysis of Items for Unit 6 - The Enhanced Greenhouse Effect

This unit was implemented at schools UI_{2b} (N = 20), US_3 (N = 40) and RS_1 (N = 6). The items were classified according to the weighted average percentage response in the pre-test for **both urban schools.** (The rural students responded very differently to most items and their responses are discussed separately at the end of the comments on the urban schools' responses.)

A. Items in which Urban Students had a Good Prior Knowledge

Item 32

The possible global warming (that scientists are worried about) is the result of the Sun getting hotter.(F)



Urban Pre-test Average: 88%

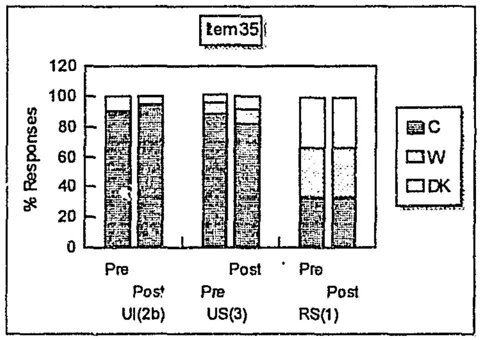
Urban Post-test Average: 93%

Urban Knowledge Gain: 5%

Rural Knowledge Gain: -17%

Item 35

The atmosphere is being warmed by energy being radiated from the Earth's surface. (T)



Urban Pre-test Average: 88%

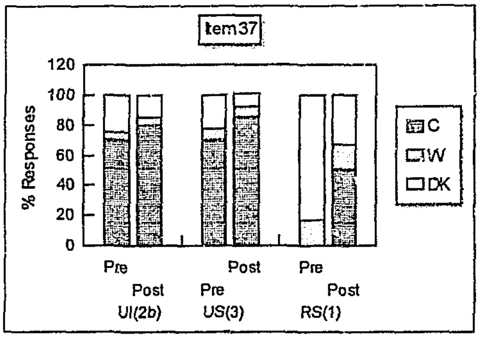
Urban Post-test Average: 87%

Urban Knowledge Gain: -1%

Rural Knowledge Gain: 0%

Item 37

Gases that contribute to the problem of an enhanced "greenhouse effect" include: carbon dioxide, ozone, nitrous oxide, methane and CFCs. (T)



Urban Pre-test Average: 70%

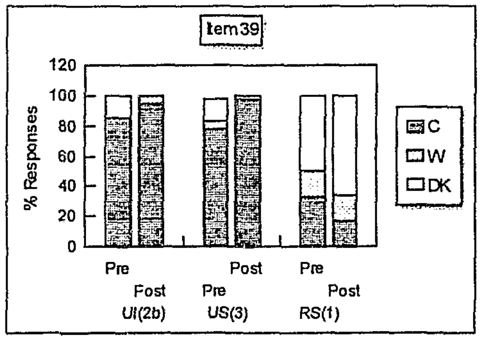
Urban Post-test Average: 83%

Urban Knowledge Gain: 13%

Rural Knowledge Gain: 50%

Item 39

The burning of coal and oil is a major contributor to the problem of an enhanced greenhouse effect. (T)



Urban Pre-test Average: 80%

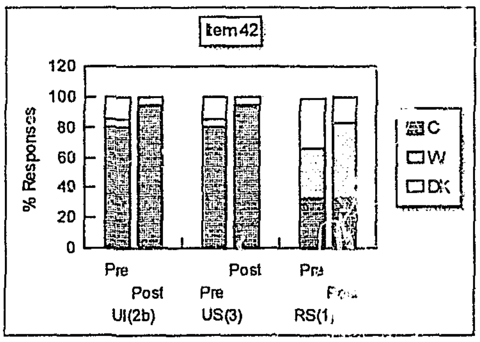
Urban Post-test Average: 97%

Urban Knowledge Gain: 17%

Rural Knowledge Gain: -16%

Item 42

The atmosphere prevents the Earth from having scorching hot days and freezing cold nights. (T)



Urban Pre-test Average: 80%

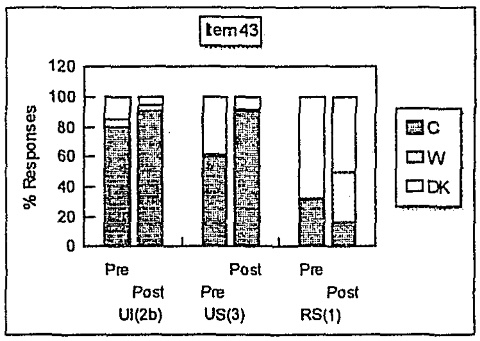
Urban Post-test Average: 95%

Urban Knowledge Gain: 15%

Rural Knowledge Gain: 0%

Item 43

Carbon dioxide concentrations in the atmosphere have increased rapidly since the Industrial Revolution. (T)



Urban Pre-test Average: 67%

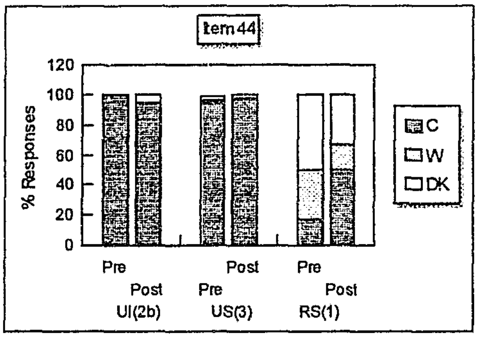
Urban Post-test Average: 90%

Urban Knowledge Gain: 23%

Rural Knowledge Gain: -16%

Item 44

Cutting down trees has no effect on the carbon dioxide in the atmosphere.(F)



Urban Pre-test Average: 97%

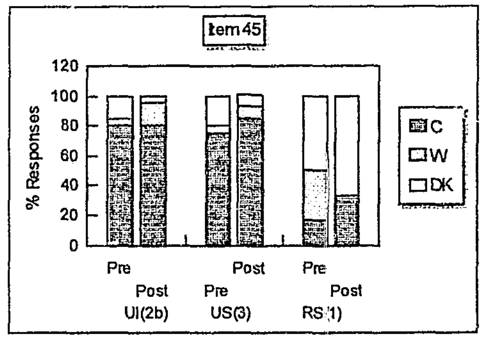
Urban Post-test Average: 97%

Urban Knowledge Gain: 0%

Rural Knowledge Gain: 33%

Item 45

If the average temperature of the Earth were to increase, the only effect would be the rising of the seas. (F)



Urban Pre-test Average: 77%

Urban Post-test Average: 83%

Urban Knowledge Gain: 6%

Rural Knowledge Gain: 16%

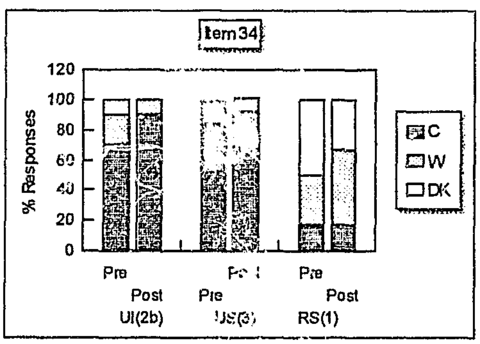
Average Knowledge Gain for Good Prior Knowledge Items (Urban Schools): 10%

(Rural School's Average Knowledge Gains will be commented on in the discussion)

B. Items in which the Urban Students had a Fair Prior Knowledge

Item 34

The atmosphere is warmed directly by the Sun's energy as it passes through the atmosphere.(F)



Urban Pre-test Average: 58%

Urban Post-test Average: 75%

Urban Knowledge Gain: 17%

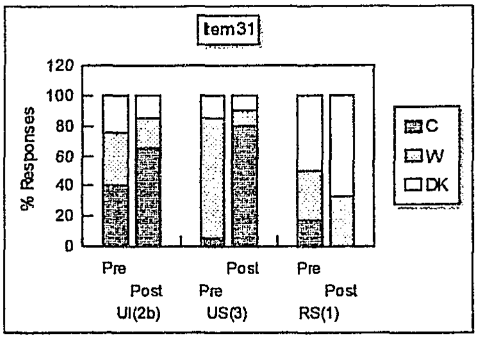
Rural Knowledge Gain: 0%

Average Knowledge Gain for Fair Prior Knowledge Items (Urban Schools): 17%

C. Items in which Urban Students had a Poor Prior Knowledge

Item 31

The "greenhouse effect" of the atmosphere is beneficial. (T)



Urban Pre-test Average: 17%

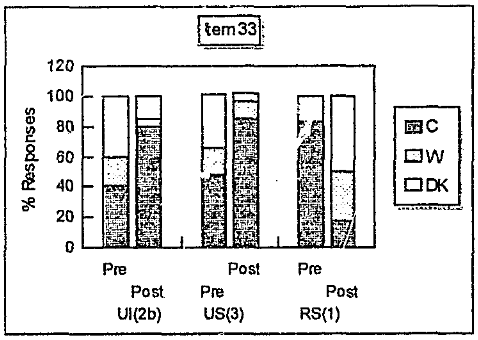
Urban Post-test Average: 75%

Urban Knowledge Gain: 58%

Rural Knowledge Gain: -17%

Item 33

Approximately 45% of the Sun's energy that enters the Earth's atmosphere, reaches the Earth. (T)



Urban Pre-test Average: 45%

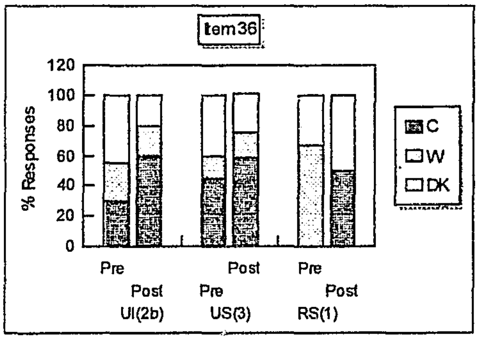
Urban Post-test Average: 83%

Urban Knowledge Gain: 38%

Rural Knowledge Gain: -66%

Item 36

All gases in the atmosphere are capable of absorbing infrared radiation (heat). (F)



Urban Pre-test Average: 40%

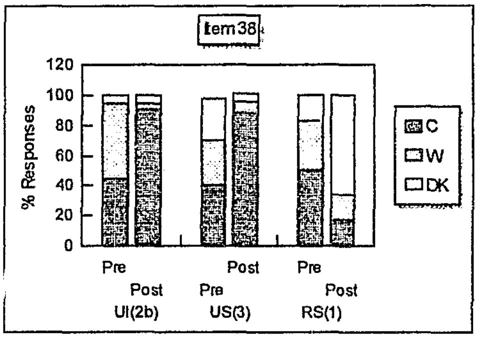
Urban Post-test Average: 58%

Urban Knowledge Gain: 18%

Rural Knowledge Gain: 50%

Item 38

Human activities such as agriculture and farming do not contribute to air pollution problems.(F)



Urban Pre-test Average: 42%

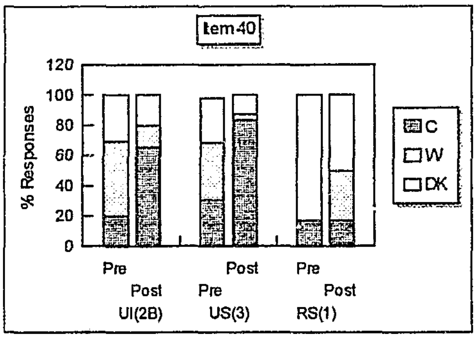
Urban Post-test Average: 88%

Urban Knowledge Gain: 46%

Rural Knowledge Gain: -33%

Item 40

Scientists can predict with certainty the consequences of an enhanced "greenhouse effect". (F)



Urban Pre-test Average: 27%

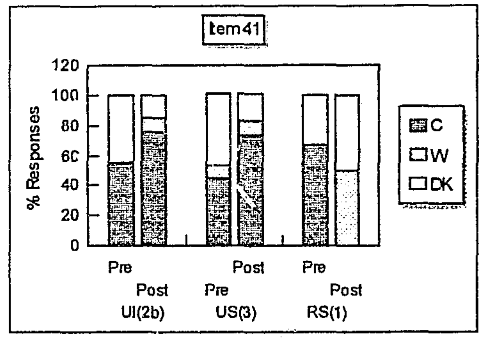
Urban Post-test Average: 77%

Urban Knowledge Gain: 50%

Rural Knowledge Gain: 0%

Item 41

Once carbon dioxide has been released into the atmosphere, it remains there forever. (F)



Urban Pre-test Average: 48%

Urban Post-test Average: 73%

Urban Knowledge Gain: 25%

Rural Knowledge Gain: -67%

Average Knowledge Gain for Poor Prior Knowledge Items (Urban Schools): 39%

(Rural School's Average Knowledge Gains will be commented on in the discussion)

School UI_{2b}	School US_3	School RS_1
% DK (Pre-test) = 20%	% DK (Pre-test) = 24%	% DK (Pre-test) = 46%
% DK (Post-test) = 9%	% DK (Post-test) = 13%	% DK (Post-test) = 42%

Comments:

URBAN SCHOOL RESPONSES

Pre-test Outcomes

There were 8 items in which students displayed a **good prior knowledge**. They appeared to know that possible global warming was not caused by the Sun getting hotter (item 32) and that the atmosphere was warmed by energy radiated from the Earth's surface (item 35). They seemed to understand that the concentration of carbon dioxide has increased rapidly since the Industrial Revolution (item 43) and that the burning of fossil fuels is a major contributor to the problem (item 39). Their good response to item 37 is somewhat surprising - it may have been an intelligent guess based on the inclusion of carbon dioxide in the list of "greenhouse gases". Students seemed to know that cutting down trees (item 44) contributes to the problem of an enhanced greenhouse effect. They were aware that the elevation of the level of the sea was not the only consequence of possible global warming (item 45). This background knowledge could have been gained from other school subjects and from media exposure.

There was only one item (item 34) in which students had a **fair prior knowledge**. Their response to this item was fairly similar to that for item 35 (dealing with the warming of the atmosphere) although there was a lower number of correct responses in the pre-test.

There were 6 items in which students had **poor prior knowledge**. In item 31, students did not realise that the greenhouse effect is beneficial. This correlates with the outcomes in the pre-test for the knowledge item (item 29) in the Survey (discussed in section 6.1.1., pages 137 and 138). Yet students did appear to know that the atmosphere prevents the Earth having scorching hot days and freezing nights (item 42 with 80% correct response in pre-test). Students did not know that activities such as agriculture and farming could contribute to the problem of air pollution (item 38). Many students felt that scientists could predict with certainty the consequences of an enhanced greenhouse effect (item 40). A fair number of students thought that carbon dioxide remained in the atmosphere forever (item 41).There was confusion about the percentage of energy from the Sun that reaches the surface of the Earth (item 33) and about gases in the atmosphere that absorb infrared radiation (item 36).

Comparison of Pre- and Post-test Outcomes

There were positive gains in all categories of items for this unit.

For the **good prior knowledge** items the average knowledge gain was 10%. Only item 35 dealing with the warming of the atmosphere by radiation from the surface of the Earth, showed a decline in the post-test. Item 44, with a 97% correct response in the pre-test, showed no knowledge gain. The issues addressed in items 35 and 44 were not topics of the activities chosen by the teachers at schools US_3 and UI_{2b}.

The only item in which there was **fair prior knowledge** (item 34), showed a 17% knowledge gain. The outcomes for this item are now much closer to the outcomes for item 35.

For the items in which there was **poor prior knowledge**, the average knowledge gain was very good ie. 39%. All items in this category showed marked improvement. The most substantial improvement was in item 31 dealing with the beneficial nature of the greenhouse effect. Students also became much more aware that scientists could not predict with certainty the consequences of possible global warming (item 40).

When the two urban schools are considered separately, there was improvement in 12/15 items at school UI_{2b}. (Items 32 and 45 had very good responses in the pre-test and showed no further improvement in the post-test). Only item 44 showed a little deterioration in the post-test. At school US_3 there was improvement in 14/15 items. There was a small negative shift in item 35 in the post-test. Interestingly, with the exception of items 43, 34 and 31, the pattern of pre- and post-test responses at the two urban schools was very similar. This consistency reflects well on the resource materials.

The percentages of DK responses for both schools were reduced by approximately half in the post-test.

RURAL SCHOOL RESPONSES

Pre-test Outcomes

There were two items (items 33 and 41) where the students appeared to have **good prior knowledge**. (These were items in which the urban students had poor prior knowledge!) However the outcomes in the post-test (discussed below) indicate that these outcomes were probably based on guessing.

There were no items in which the rural students had **fair prior knowledge**.

In all the rest of the items students manifested **poor prior knowledge**. This could have been as a result of poor English language skills and the lack of exposure to the media. The school is in a remote area of the country.

Comparison of Pre- and Post-test Outcomes

As discussed earlier, the outcomes of the post-testing should be viewed cautiously as the teacher administered the post-test three times.

The two items in which students responded well in the pre-test showed a large negative the post-test, -66% and -67% respectively. Students were probably guessing in the pre-te in fact had a poor prior knowledge of these items.

The average knowledge gain for all the items in the post-test (including the two discussed above) was -6%. Four items showed positive knowledge gains. These were items 36, 37, 44 and 45. Students appeared to understand that not all the gases in the atmosphere absorb infrared radiation and they indicated in item 37 they they knew which gases did. Students seemed to become aware that cutting down trees contributed to increased concentrations of carbon dioxide in the atmosphere and that the consequences of possible global warming would not only be the rising of the level of the sea.

The percentage DK responses (45%) in the pre-test were much higher than those at the other schools. In the post-test the situation was little changed - the percentage DK responses was 42%.

As will be noticed in the bar charts presented, in nearly all the items the responses in the pre- and post-tests of the students at the rural school were very different from the responses at the urban schools. The number of students at the rural school was small (only 6 students) and thus firm conclusions cannot be reached. However the outcomes from the rural school do suggest that little or no learning took place. In the post-test there was an improvement in only 4/15 items. The fact that the teacher at the rural school administered the Survey four times could also have contributed to the outcomes - students may have been bored and provided erratic answers in the post-tests.

These outcomes provide another glimpse of differences between the rural and urban schools taking part in this research study.

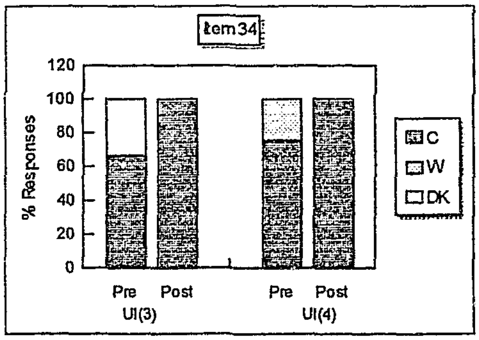
6.2.5. Analysis of Items for Unit 7 - Acid Rain

This unit was implemented by schools UI_3 *(N = 18) and* UI_4 (N = 4).The items were classified according to the weighted average percentage response in the pre-test for **both** schools. The average knowledge gains were calculated from the weighted average responses for **both** schools in the pre- and post-tests.

A. Items in which Students had a Good Prior Knowledge

Item 34

Acids such as sulphuric acid and hydrochloric acid have been detected in rain.(T)

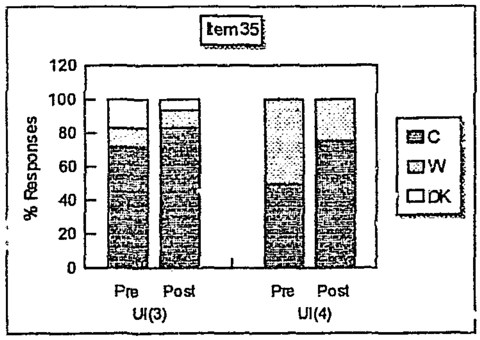


Pre-test Average: 68% Post-test Average: 100%

Knowledge Gain: 32%

Item 35

"Acid rain" is not a problem in South Africa.(F)

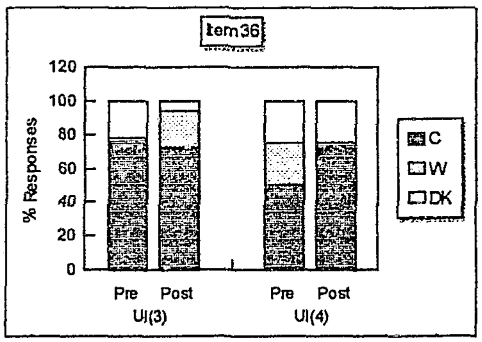


Pre-test Average: 68% Post-test Average: 82%

Knowledge Gain: 14%

Item 36

The rate of release of sulphur dioxide into the atmosphere as a result of human activities, exceeds the rate of release of sulphur dioxide from natural sources. (T)

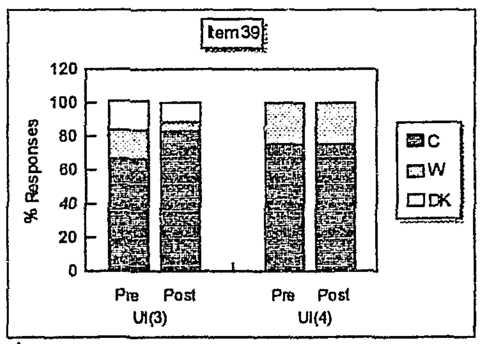


Pre-test Average: 73% Post-test Average: 73%

Knowledge Gain: 0%

Item 39

Some gases released from vehicle exhausts contribute to the problem of "acid rain". (T)

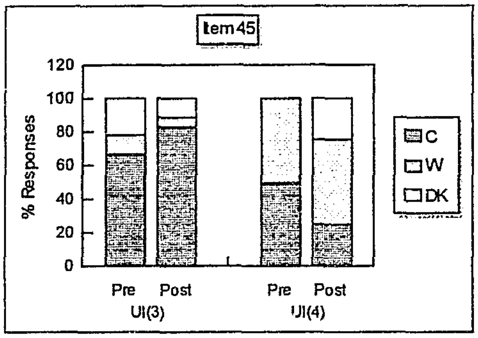


Pre-test Average: 68% Post-test Average: 82%

Knowledge Gain: 14%

Item 45

Damage by "acid rain" only occurs close to the source of gases causing this air pollution problem. (F)



Pre-test Average: 64%

Post-test Average: 73%

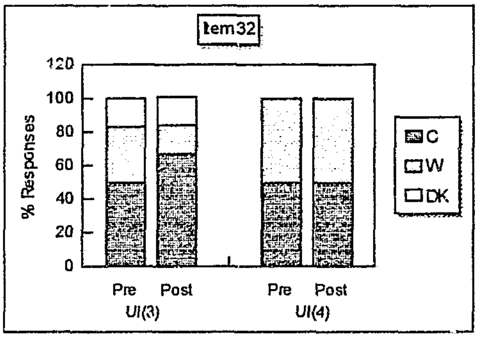
Knowledge Gain: 9%

Average Knowledge Gain for Good Prior Knowledge Items: 14%

B. Items in which Students had a Fair Prior Knowledge

Item 32

"Acid Rain" is a consequence of increased concentrations of carbon dioxide in the atmosphere. (F)

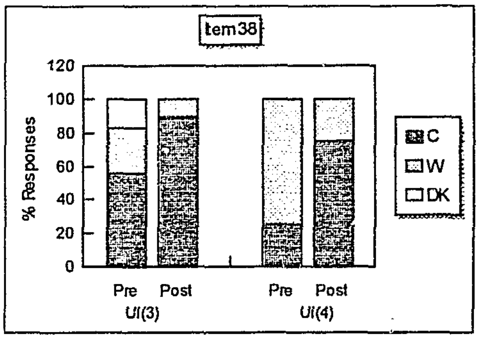


Pre-test Average: 50% Post-test Average: 64%

Knowledge Gain: 14%

Item 38

Combustion of fossil fuels (coal and oil) is a major contributor to the problem of "acid rain". (T)



Pre-test Average: 50% Post-test Average: 86%

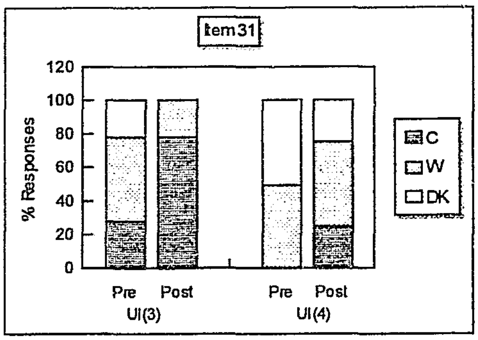
Knowledge Gain: 36%

Average Knowledge Gain for Fair Prior Knowledge Items: 25%

C. Items in which Students had a Poor Prior Knowledge

Item 31

Rain is naturally neutral with a pH of 7. (F)

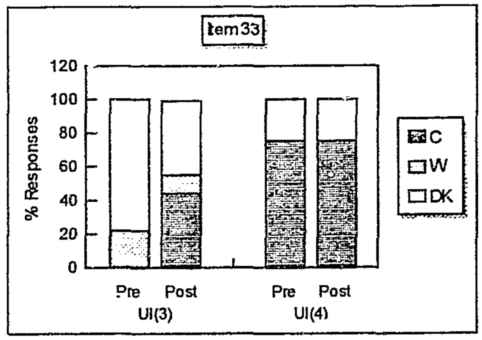


Pre-test Average: 23% Post-test Average: 68%

Knowledge Gain: 45%

Item 33

Rain with a pH = 2.1 has fallen in Britain.(T)

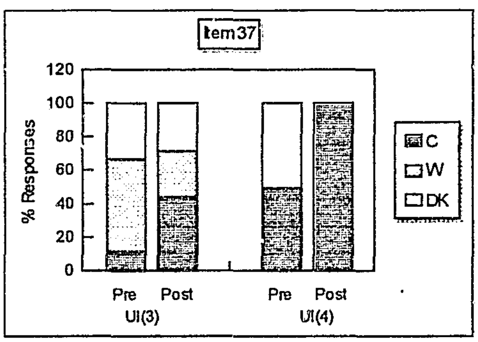


Pre-test Average: 14% Post-test Average: 50%

Knowledge Gain: 36%

Item 37

CFCs contribute to the problem of "acid rain".(T)

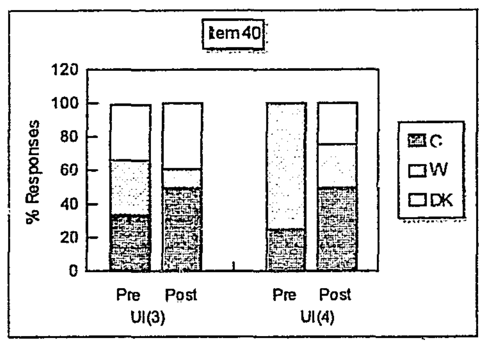


Pre-test Average: 18% Post-test Average: 55%

Knowledge Gain: 37%

Item 40

Industries contribute more than coal-fired power stations to the problem of "acid rain".(F)

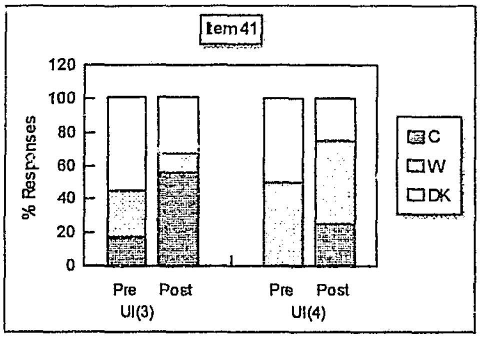


Pre-test Average: 32% Post-test Average: 50%

Knowledge Gain: 18%

Item 41

The contribution of irdustry to the total concentration of nitrogen oxides in the atmosphere, is greater than the contribution of transportation.(F)

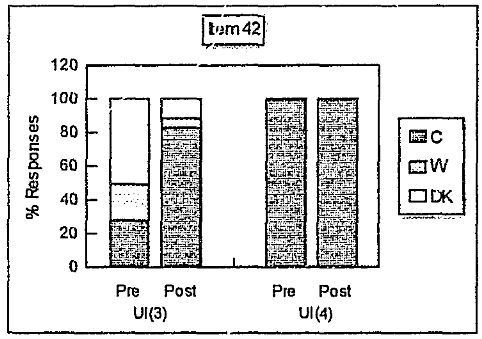


Pre-test Average: 14% Post-test Average: 50%

Knowledge Gain: 36%

Item 42

The death of fish in lakes in Europe and America has been a consequence of "acid rain".(T)

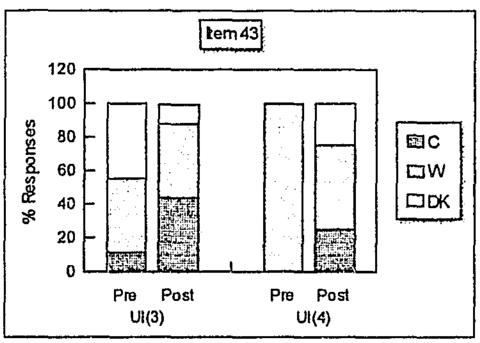


Pre-test Average: 41% Post-test Average: 86%

Knowledge Gain: 45%

Item 43

It is a fact that "acid rain" alone is responsible for the death of large numbers of trees in the forests of Europe America. (F)

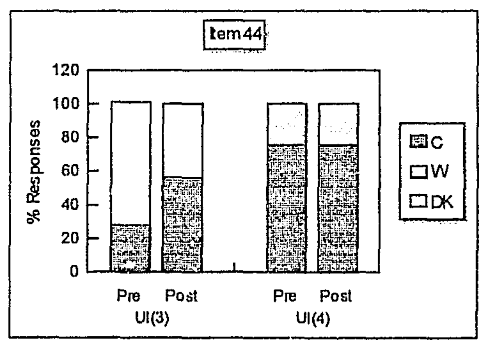


Pre-test Average: 9% Post-test Average: 41%

Knowledge Gain: 32%

Item 44

The use of tall chimney stacks (which dilute air pollutants) has overcome the problem of acid rain. (F)



Pre-test Average: 36% Post-test Average: 59%

Knowledge Gain: 23%

Average Knowledge Gain for Poor Prior Knowledge Items: 34%

School UI_3

% DK (Pre-test) = 36%

% DK (Post-test) = 17%

School UI_4

% DK (Pre-test) = 10%

% DK (Post-test) = 8%

Comments:

The discussion will deal largely with the average responses from both schools.

Pre-test Outcomes

There were 5 items in which students had **good prior knowledge**. Students realised that acid rain is a problem in South Africa (item 35) and that the damage by acid rain can occur far from the source (item 45). They seemed aware that some emissions from vehicle exhausts contribute to the problem of acid rain (item 39) and that acids such as sulphuric and hydrochloric acid have been detected in rain (item 34). Students appeared to know that the emission of sulphur dioxide from human activities exceeds that from natural sources (item 36). Again some of this background could have come from studies in other subjects and from exposure to the media.

There were 2 items in which students had **fair prior knowledge**. These items dealt with the facts that increased carbon dioxide concentrations do not contribute to the problem of acid rain (item 32) but that the combustion of fossil fuels is a major contributor to the problem (item 38).

Prior knowledge was **poor** in 8 items. It was particularly poor in items 33, 37, 41 and 43. These items dealt with the facts that rain with a pH of 2.1 has fallen, that CFCs contribute to the problem of acid rain, that transportation contributes more to the problem of air pollution than industry and that it is not only acid rain that contributes to the death of trees in the forests of Europe. Few students knew that the pH of rain is not normally 7 (item 31) and that coal-fired power stations contribute more to the problem of acid rain than industry (item 40). Many students did not know that the death of fish in some lakes in Europe was caused by acid rain (item 42) and that the use of tall chimneys does not solve the problem of acid rain (item 44). These items were much more specific and students had probably had little previous exposure to these ideas.

It is interesting to contrast what students **knew they did not know** with what they **thought they knew**. For example, the number of DK responses is high (and wrong responses low) on items 33 and 44 whereas the number of wrong responses is high (and DK responses fairly low) on items 31, 37 and 43.

Comparison of Pre-and Post-test Outcomes

There were positive average knowledge gains for all categories of items.

The average knowledge gain for **good prior knowledge** items was 14%. With the exception of item 36 where there was no knowledge gain, all other items in this category showed improvement. Item 36 dealt with the comparison of the release of sulphur dioxide from human activities and from natural sources. This issue was not part of the worksheets chosen by the teachers that implemented this unit but it was mentioned in the introduction to the unit.

The average knowledge gain for the items in which there was **fair prior knowledge** was 25%. Both items in this category showed improvement.

The average knowledge gain for the **poor prior knowledge** items was 34%. All items in this category showed marked improvement.

When considering the outcomes of the schools separately, there was an improvement in 14/15 items at school UI_3. Only item 36 which dealt with the rate of release of sulphur dioxide into the atmosphere, showed a small deterioration in the post-test. At school UI_4 there was an improvement in 9/15 items. (There was already a 100% correct response in item 42 in the pre-test.) It must be borne in mind that the number of students at this school was small. In addition English was not the mother tongue for any of the students at this school.

The DK responses at school UI_3, were reduced from 36% to 17% in the post-test. The DK option was much less popular in the pre-test at school UI_4 and the decrease in this option was small in the post-test.

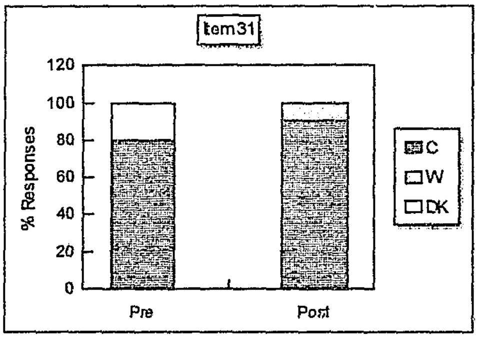
6.2.6. Analysis of Items for Unit 8 - Control of Air Pollution.

This unit was implemented by school US_4 (N = 10).

A. Items in which Students had a Good Prior Knowledge

Item 31

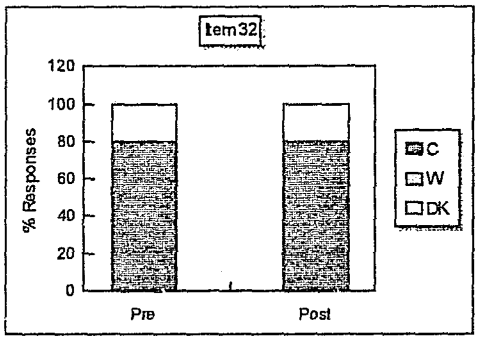
There are natural processes which remove air pollutants from the atmosphere.(T)



Knowledge Gain:10%

Item 32

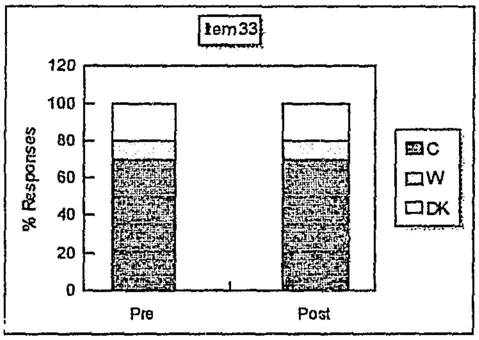
All air pollutants remain in the atmosphere for the same length of time.(F)



Knowledge Gain: 0%

Item 33

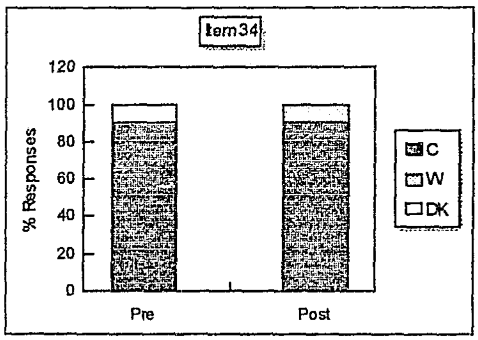
For the concentrations of substances in the atmosphere to remain constant, the rates at which air pollutants are released into the atmosphere should be equal to the rates they are removed from the atmosphere. (T)



Knowledge Gain: 0%

Item 34

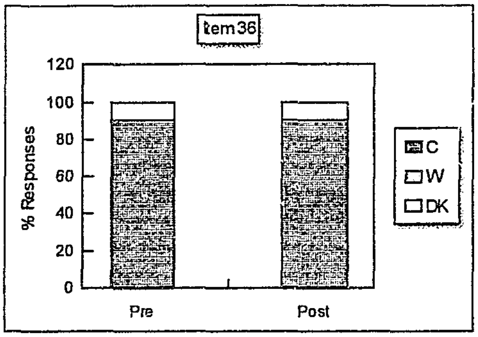
Air pollution results when the rates at which air pollutants are released into the atmosphere, exceeds the rates at which natural processes remove air pollutants from the atmosphere.(T)



Knowledge Gain: 0%

Item 36

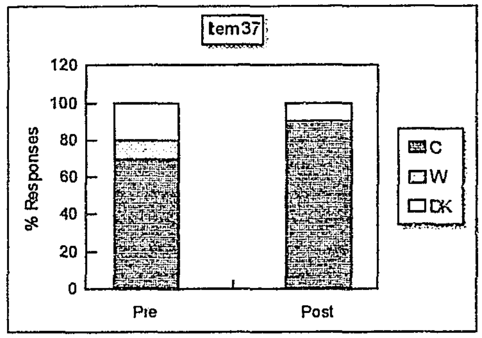
In South Africa, no research is conducted into air pollution problems. (F)



Knowledge Gain: 0%

Item 37

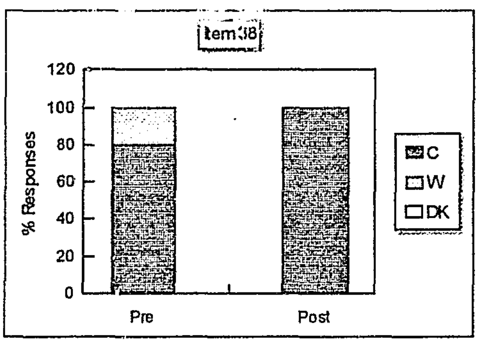
International agreements have been reached concerning some air pollution problems. (T)



Knowledge Gain: 20%

Item 38

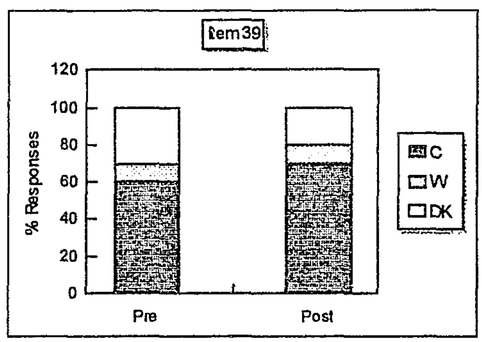
South Africa has never manufactured CFCs. (F)



Knowledge Gain: 20%

Item 39

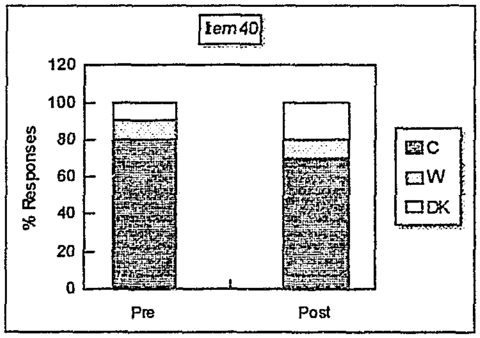
CFCs are compounds that do not occur naturally. (T)



Knowledge Gain: 10%

Item 40

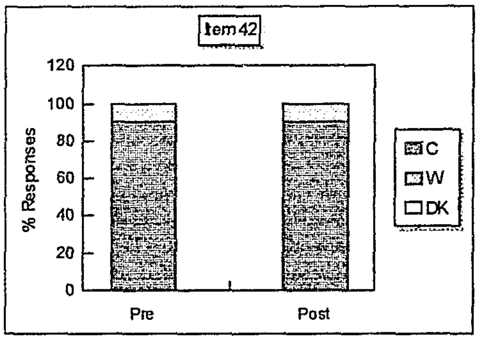
The production of CFCs in South Africa has been reduced. (T)



Knowledge Gain: -10%

Item 42

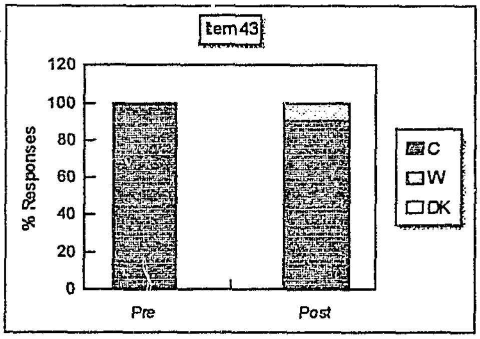
If the production of CFCs is stopped, the air pollution problems associated with them will be immediately solved. (F)



Knowledge gain: 0%

Item 43

The destruction of ozone in the stratosphere is a global air pollution problem.(T)



Knowledge Gain: -10%

Average Knowledge Gain for Good Prior Knowledge Items: 4%

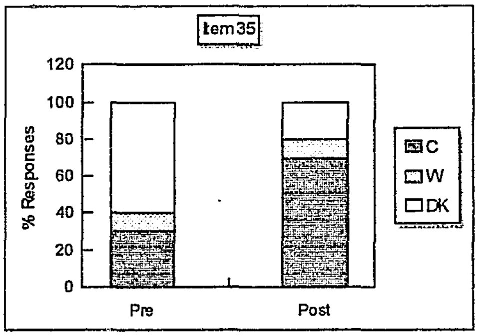
B. Items in which Students had a Fair Prior Knowledge

There were no items in this category.

C. Items in which Students had a Poor Prior Knowledge

Item 35

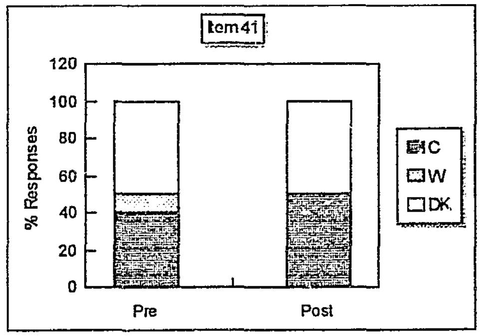
There is no law in South Africa to control air pollution. (F)



Knowledge Gain: 40%

Item 41

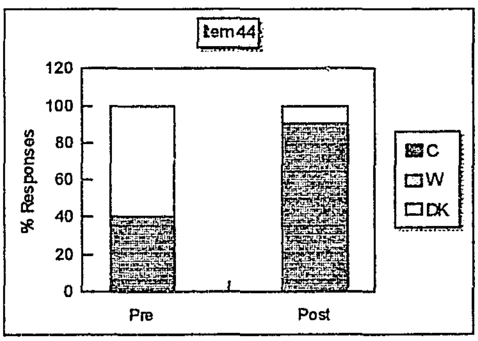
It is proposed that no CFCs will be produced by the year 2000.(T)



Knowledge Gain: 10%

Item 44

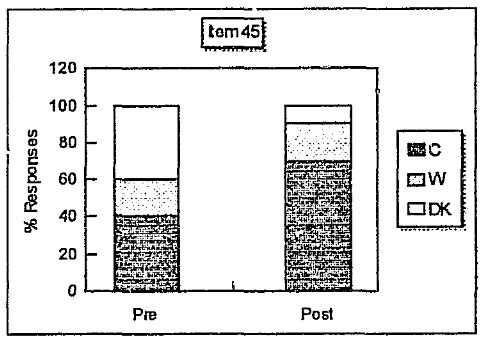
The Montreal Protocol is an international agreement to reduce CFC production. (T)



Knowledge Gain: 50%

Item 45

All the nations of the world have signed an agreement to reduce CFC production. (F)



Knowledge Gain: 30%

Average Knowledge Gain for Poor Prior Knowledge Items: 33%

% DK (Pre-test) = 23%

% DK (Post-test) = 12%

Comments:

The sample of students taking part in the implementation of this Unit was small.

Pre-test Outcomes

There were 11 items in which students had a **good prior knowledge**. This represents a better prior knowledge than that shown by students in the previous units. The demands of the items for this unit may not have been as great as those for most of the other units. In addition the teacher at this school reported that the students claimed they had studied air pollution previously in biology and geography.

There were no items in which students had a **fair prior knowledge**.

The items in which students had a **poor prior knowledge** focussed mostly on fairly recent international agreements (items 44 and 45) and proposed changes in CFC production in the future (item 41). Students seemed unaware that there was a law controlling air pollution in South Africa (item 35).

Comparison of Pre- and Post-test Outcomes

The average knowledge gain for the **good prior knowledge** items was 4%. Four items (31, 37, 38, and 39) showed a positive shift in the post-test. These items dealt with the facts that there are natural processes to remove air pollutants from the atmosphere, that international agreements have been reached concerning air pollution problems, that South Africa has manufactured CFCs and that CFCs do not occur naturally. The 5 items which showed no change in the post-test focussed on the longevity of air pollutants in the atmosphere (item 32), the concept of steady state (items 33 and 34), research into air pollution problems in South Africa (item 36) and the long-term effects of CFCs in the atmosphere (item 42). There were negative shifts in item 40 dealing with the reduction in production of CFCs in South Africa, and in item 43 dealing with the fact that the destruction of ozone is a global air pollution problem. The issues focussed on in items 32, 36, 40 and 43 were not directly dealt with in the worksheets selected by the teacher but they were discussed in the introduction to the unit. Background for items 33, 34 and 42 was presented in worksheets 8 (a) and 8(b) selected by the teacher.

There was an average knowledge gain of 33% in items in which students had a **poor prior knowledge**. All items in this category showed a positive shift in the post-test.

For this school, there was an overall improvement in 8/15 items (There was already a 90% correct response in items 34, 36 and 42 in the pre-test leaving little room for improvement.)

In the post-test the number of DK responses was almost halved.

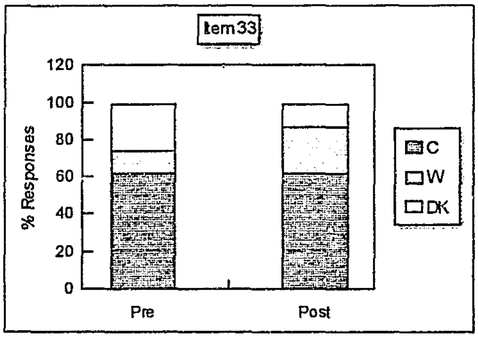
6.2.7. Analysis of Items for Unit 9 - Response by Industry

This Unit was implemented by school UI_6 (N = 8).

A. Items in which Students had a Good Prior Knowledge

Item 33

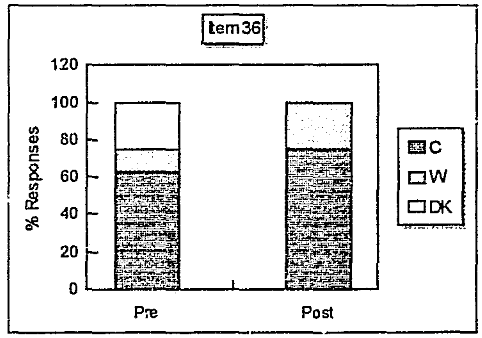
At present, there are no techniques available for reducing the release of sulphur dioxide into the atmosphere. (F)



Knowledge Gain: 0%

Item 36

The use of tall chimney stacks by industry is always a solution to air pollution problems.(F)



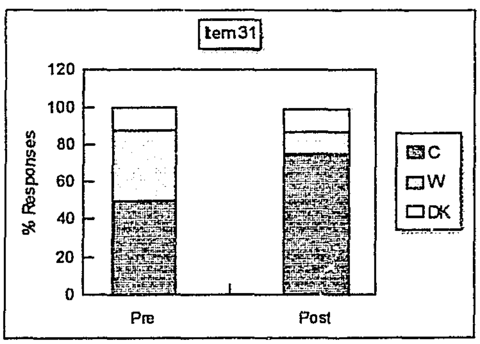
Knowledge Gain: 12%

Average Knowledge Gain for Good Prior Knowledge Items: 6%

B. Items in which Students had a Fair Prior Knowledge

Item 31

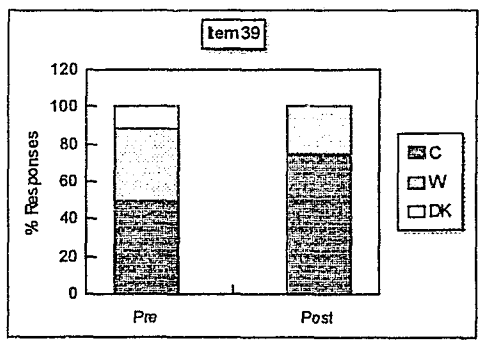
There are no methods available for controlling the release of particulates into the atmosphere. (F)



Knowledge Gain: 25%

Item 39

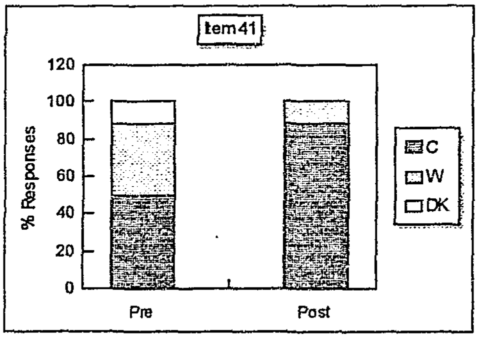
Fly-ash from coal-fired power stations can reduce the quantity of fertilisers farmers need to use. (T)



Knowledge Gain: 25%

Item 41

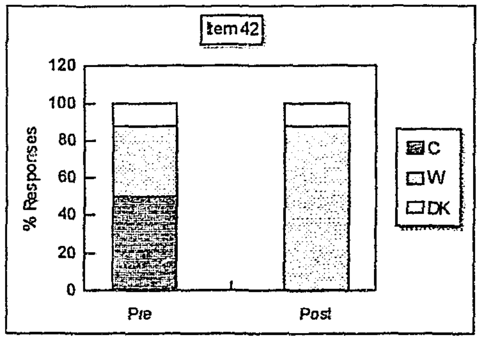
In some areas of South Africa, the air pollution from domestic fires exceeds air pollution from coal-fired power stations. (T)



Knowledge Gain: 38%

Item 42

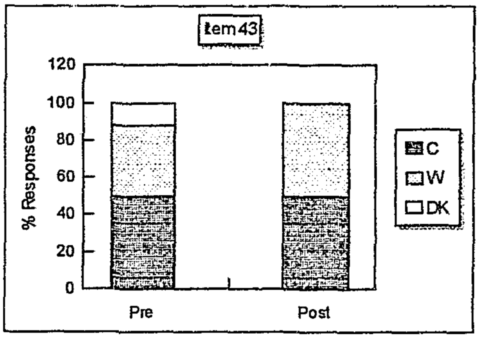
SASOL only produces petrol from coal. (F)



Knowledge Gain: -50%

Item 43

The only use for coal is to supply us with energy when the coal is burnt. (F)



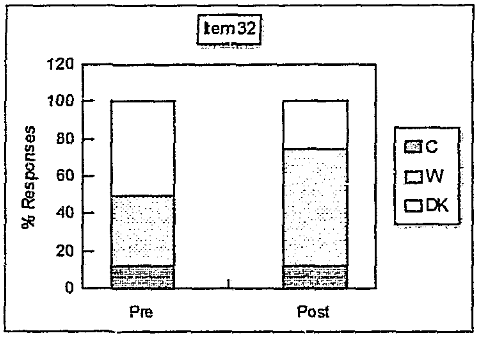
Knowledge Gain: 0%

Average Knowledge Gain for Fair Prior Knowledge Items: 8%

C. Items in which Students had a Poor Prior Knowledge

Item 32

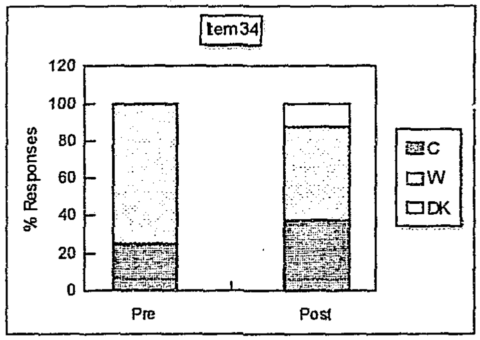
Cyclones are very efficient devices for reducing air pollution. (F)



Knowledge Gain: 0%

Item 34

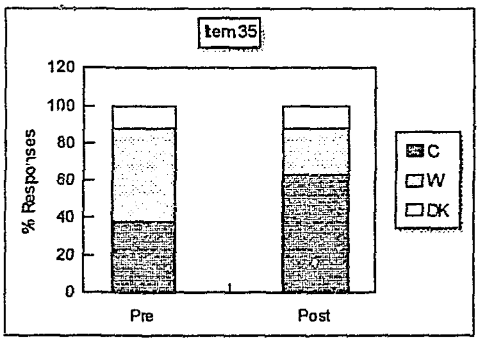
Industry could make use of technology which would eliminate air pollution completely. (F)



Knowledge Gain: 13%

Item 35

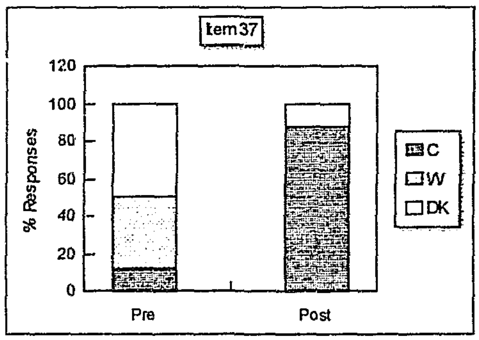
The cost of installing and using technology to reduce air pollution, is small compared with other costs faced by industry. (F)



Knowledge Gain: 25%

Item 37

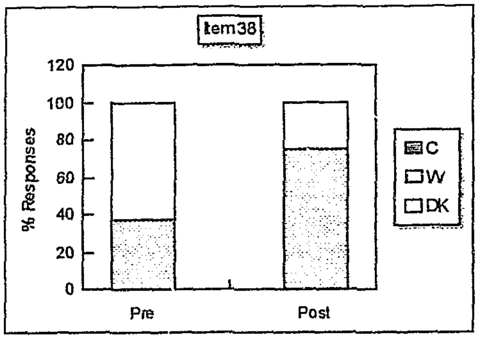
Catalytic convertors cannot be used in South Africa because there are lead compounds in our petrol. (T)



Knowledge Gain: 76%

Item 38

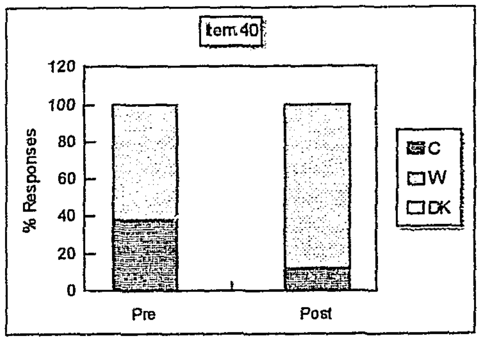
ESKOM does not use technology to reduce the release of sulphur dioxide into the atmosphere. (T)



Knowledge Gain: 0%

Item 40

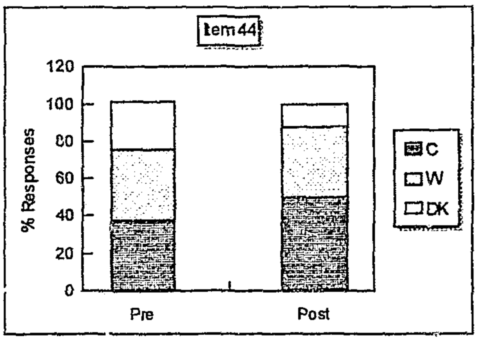
Supplying electricity to towns in South Africa, has totally reduced air pollution from coal fires. (F)



Knowledge Gain: -26%

Item 44

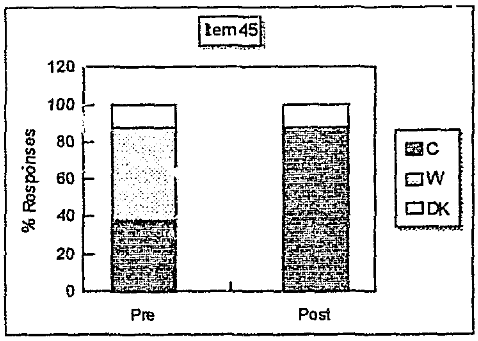
If power stations use improved technology to control air pollution, electricity could become too expensive for many people. (T)



Knowledge Gain: 12%

Item 45

Industry never monitors the quantity and nature of the air pollutants produced by its activities. (F)



Knowledge Gain: 50%

Average Knowledge Gain for Poor Prior Knowledge Items: 19%

%DK (Pre-test) = 20%

%DK (Post-test) = 9%

Comments:

A small sample of students took part in the implementation of this Unit.

Pre-test Outcomes

There were only 2 items (and only by a small margin) in which students had **good prior knowledge**. These items dealt with the availability of techniques to reduce sulphur dioxide pollution and the fact that tall chimney stacks do not always provide a solution to air pollution problems.

Students had a **fair prior knowledge** about issues such as the availability of methods to control the emission of particulates, the reduction in the quantity of fertilisers used by farmers because of fly-ash from coal-fired power stations, the magnitude of the contribution of domestic fires in South Africa to the problem of air pollution and other uses of coal besides combustion.

There were 8 items in which students had **poor prior knowledge**. These items required more detailed knowledge about specific technologies used by industry, the cost of installing such technologies and the impact of technology on the problem of air pollution.

Comparison of Pre- and Post-test Outcomes

There was an improvement in 9/15 items in the post-test.

The average knowledge gain for the two **good prior knowledge** items was 6%. This knowledge gain was due to an increase in the number of correct responses in item 36. The average knowledge gain is rather misleading because in both items there were increases in the number of wrong responses Item 33 dealing with techniques to reduce sulphur dioxide pollution, showed no improvement. In fact some students shifted from the DK response to the wrong response. This issue was dealt with in the worksheets selected by the teacher.

The average knowledge gain for the **fair prior knowledge** items was 7%. Students became more aware that there are methods for controlling the emission of particulates, that fly-ash is beneficial to farmers and that the contribution to air pollution by domestic fires in South Africa can exceed air pollution from coal-fired power stations. Item 43, dealing with other possible uses for coal, showed no improvement. (In fact, again, students shifted from DK responses to wrong responses.) In the post-test, there was a large negative shift in item 42, dealing with the fact that other products besides petrol are manufactured from coal by SASOL. Background for topics dealt with in items 42 and 43 was presented in the worksheets selected by the teacher.

The average knowledge gains for the 8 **poor prior knowledge** items was 19%. Five items (items 34, 35, 37, 44 and 45) showed an improvement in the post-test. The big improvements in items 37, 45 and to a lesser extent item 35, show that some specific learning occurred. Two items (items

32 and 38) showed no change in the number of correct responses but showed a marked increase in the number of wrong responses! Item 40 showed a sharp negative shift in the post-test. This item dealt with the fact that supplying electricity to towns in South Africa had not reduced air pollution completely. Some background for this item had been provided in the activities selected by the teacher.

The DK option was not very popular in the pre-test (only 20% of responses). In the pre-test there were relatively high percentages of wrong responses in 13/15 items (namely items 31, 39, 41, 42, 43, 32, 34, 35, 37, 38, 40, 44, and 45). In the post-test the total percentage of DK responses was 9%. Yet once again there were relatively high percentages of wrong responses in 10/15 items (namely items 33, 36, 39, 42, 43, 32, 34, 38, 40 and 44). The high percentages of wrong responses in the pre- and post-test could indicate that, contrary to instructions, students were guessing. On the other hand, the English language skills of the students may have played a role - English was not their mother tongue. Students may have thought that they knew the correct answer.

6.2.8. Overall Discussion of Outcomes of Unit Specific Items in the Survey

The outcomes of the adminstration of this part of the Survey are summarised in the table below.

Table 6.1. Outcomes for Unit Specific Items in Survey

Unit and Topic	Prior Knowledge	No of Items	Average Knowledge Gain	DK Responses	
				Pre-test	Post-test
3 Combustion	Good	4	-3%	[1](UI$_1$) 39%	(UI$_1$) 21%
	Fair	2	17%		
	Poor	9	23%	(UI$_{2a}$) 40%	(UI$_{2a}$) 27%
4 Depletion of Ozone in Stratosphere	Good	5	3%		
	Fair	2	18%	(US$_1$) 37%	(US$_1$) 18%
	Poor	8	32%		
5 Smog	Good	7	-2%		
	Fair	2	-4%	(US$_2$) 24%	(US$_2$) 24%
	Poor	6	8%		
6 Enhanced Greenhouse Effect	Good	8	10%	(UI$_{2b}$) 20%	(UI$_{2b}$) 9%
	Fair	1	17%		
	Poor	6	39%	(US$_3$) 24%	(US$_3$) 13%
	Good	2	-67%		
	Fair	0	N/A	(RS$_1$) 46%	(RS$_1$) 42%
	Poor	13	4%		
7 Acid Rain	Good	5	14%	(UI$_3$) 36%	(UI$_3$) 17%
	Fair	2	25%		
	Poor	8	34%	(UI$_4$) 10%	(UI$_4$) 8%
8 Control of Air Pollution	Good	11	4%		
	Fair	0	N/A	(US$_4$) 23%	(US$_4$) 12%
	Poor	4	33%		
9 Response by Industry	Good	2	6%		
	Fair	5	8%	(UI$_6$) 20%	(UI$_6$) 9%
	Poor	8	19%		

[1] School implementing unit is shown in brackets

The analysis of the outcomes of the administration of this part of the Survey reveals some very rational trends. There was variation in the prior knowledge possessed by students with regard to content and issues dealt with in Units 3 - 9. This prior knowledge could broadly be classified as **good, fair** and **poor**. **Table 6.1.** shows that the number of items in each category varied from unit to unit and could have been affected by the nature of the topic for the unit, the demands of the items themselves and the school and classroom context. Exposure to the media may also have played a role. For instance, the urban schools (US_3 and UI_{2b}) appeared rather well-informed about the enhanced greenhouse effect (Unit 6) whereas the students at rural school RS_1 (where there was little or no exposure to the media) appeared to have little background knowledge for this topic.

An *Inventory of Unit Specific Items* (Appendix, page A31) was constructed using the outcomes of the pre-test of these items in the *Survey on Air Pollution.* This inventory provides some insights into the state of students' prior knowledge with regard to air pollution (and how this knowledge changed after students had used materials from the package). Generally, the items in which students had **good** or **fair prior knowledge** were those where *simple factual knowledge* was required. Students probably gained this knowledge from exposure to the media, from other subjects such as geography or biology, or from their own experience of problems associated with air pollution. The items in which students had **poor prior knowledge** were generally those which required deeper knowledge of issues and processes and the ability to make more informed comparisons. Students were unlikely to have gained this background from the more superficial or biased treatment of these issues in the media. The more detailed chemical knowledge required could not have been gleaned from subjects such as geography and biology.

Comparison of the pre- and post-test outcomes showed how this knowledge changed after students had used the resource materials. As would be expected the largest average knowledge gains were made on the items for which students had poor prior knowledge. Apart from the outcomes at the rural school RS_1, the negative shifts in the post-tests were small. The negative shifts were probably due to guessing. *Guessing must have played a role in the outcomes for all items.* However its effect was more apparent in the **good** and **fair prior knowledge** items where the knowledge gains were small. The larger knowledge gains in the **poor prior knowledge** items masked the effects of guessing.

With the exception of schools US_2 (Unit 5), RS_1 (Unit 6) and UI_4 (Unit 7), there was a marked decrease in the DK responses in the post-test. This trend probably indicates that students were becoming more confident about their answers and better informed after they had interacted with the resource materials.

For some items there was no change or even a negative shift in the post-test. The reasons for this are not clear cut. In some instances this was because teachers had not selected activities which dealt with the particular concept or issue being highlighted in the item. However there were occasions where the worksheet selected by the teacher did cover the concepts and still there was no improvement in the post-test. In this study it was impossible to assess what background the teachers had incorporated from the introduction to each unit in their lessons.

Knowledge gains in all categories of item could have been affected by a number of factors:

1. The Nature of the Topic

   An example of this is to be found in the outcomes for school US_2 (Unit 5). The knowledge gains for Unit 5 (Smog) were small in comparison to those for the other units shown in **Table 6.1.**. The concept of photochemical smog played a major role in this unit. This must have been a new concept for most students. The chemistry involved in the formation of photochemical smog is complex and many of the compounds taking part in the reactions were most likely new to the students. The teacher reported that the students found the topic difficult. She had approached the topic through the graph exercise (Worksheet 5c, Unit 5) in the package. She also reported that students found graph interpretation difficult. It may not have been possible in the time available to deal thoroughly with the underlying new and complex concepts.

   Interestingly the students thought they knew a lot about the issue! The percentage of DK responses in the pre-test was low (24%). After using the resource materials there were negative shifts in the good and fair prior knowledge items. There was no change in the percentage of DK responses in the post-test. This was unlike the trend for the other units at all other schools (with the exception of RS_1). These outcomes indicate that the learning which took place in school US_2 (Unit 5) was not substantial. Reasons for this need to be identified. The attitude of the teacher and students to the materials (discussed below) may have played a role. However some of the demands of this unit may be unrealistic.

2. The Attitude of Students and Teachers

The teacher at school US_2 who had implemented Unit 5 (discussed above) reported that the students were very restless and that their enthusiasm for Unit 5 was poor (Chapter 5). The teacher herself was not as enthusuastic about the package as most of the other teachers (Chapter 5). She also commented that students could pick up on her lack of confidence. This may have impacted on the implementation of the package with the class. As mentioned above the knowledge gains for this school in the post-test were small.

Students at school US_4 reported to their teacher that they knew a great deal about air pollution. (They did well in the pre-test, too!) The teacher also reported that she lacked background and confidence (Chapter 5). However in contrast to the teacher discussed above, this teacher rated the package highly and appeared very enthusiastic about the package (Chapter 5). Some of the most substantial gains in knowledge were made at this school.

Teachers implementing Units 3, 4, 6 and 7 had rated the package highly (Chapter 5). The outcomes of the post-testing of items for these units show substantial gains especially in the fair and poor prior knowledge categories of items.

3. The School Context

The prior knowledge of the rural students appeared to be very different to that of the urban students. This is shown not only by the outcomes of the pre-testing but also by the popularity of the DK option (46% in the pre-test). These students probably had little or no exposure to the media. The outcomes of the post-testing at the rural school have to be treated cautiously but there are indications that the knowledge gains were small. This is further substantiated by the very small decline in the number of DK responses in the post-test (a decline of 4%). Other factors such as the qualifications of the teacher and the English language skills of the teacher and students may also have played a role in the performance of students at this school.

4. Time Restrictions

The time for implementation was limited. Teachers had to make choices of activities and so could not deal with all the concepts and issues tested in the Survey items.

5. Limitations of Items in the Survey

Poor outcomes for some items in the post-test could have their origin in the nature of the items themselves. The wording of certain items may have been obscure or difficult for the students (especially those for whom English was not their mother tongue). Examples of such items are item 36 (Unit 3, page 151) and item 42 (Unit 9, page 188). In addition the rather specific demands of some items may be unrealistic for students at high school level eg. item 32 (Unit 9, page 189).

In spite of the shortcomings and problems discussed above, there are indications from these Survey outcomes that the implementation of the package by many teachers was very thorough and that students increased their understanding of air pollution. Some aspects in which this learning took place were:

- the contribution of burning coal in households and power stations, to the problems of air pollution (Unit 3)
- the chemical nature of ozone and CFCs and their reactions in the stratosphere; the role played by ozone in the stratosphere (Unit 4)
- the beneficial nature of the greenhouse effect in the atmosphere; the rapid increase in the concentrations of carbon dioxide in the atmosphere; the contribution of activities such as farming and agriculture to the problem of an enhanced greenhouse effect (Unit 6)
- that scientists are not infallible (Unit 6)
- the nature of acid rain; an understanding of the substances and activities which contribute to the problem; some consequences of the problem of acid rain (Unit 7)
- the laws and agreements reached to control air pollution (Unit 8)
- problems that prevent catalytic convertors being used on motor vehicles in South Africa; the cost of installing technology to reduce air pollution; the fact that industries do monitor the quantity and nature of their air pollutants (Unit 9).

CHAPTER 7
FINAL DISCUSSION

The discussion focusses on the processes of **designing, implementing** and **evaluating** the resource package. The overall outcomes of each of these processes are presented. The **relationships** between some of these outcomes are drawn. **Limitations** of the research are pinpointed and **suggestions** made for further research.

7.1. DESIGNING THE PACKAGE

Materials development theses are not common in many countries (Tamir, 1992). Yet Tamir suggests that this method of developing materials has many merits. The quality of such materials is guaranteed because the development has been closely supervised. It is also an inexpensive way of producing resource materials.

Considerable research into the topic of air pollution formed the background to the design of the resource package. Choices were made on how to approach the topic. The STS air pollution package described in this thesis does not represent any **single** one of the approaches (see Literature Survey, page 14) suggested by Ziman (1994). Instead, in the package the different approaches are evident in different units or parts of units, both in the background knowledge for the teachers and in the activities offered for the students. This reflects the objective of providing choice for the teacher.

During the design of the package, decisions were made as to the principles, concepts and issues of the topic air pollution that would be included and how these would be presented. The sequencing of these principles, concepts and issues and their interrelationship with each other was carefully planned. Attention was paid to the scientific terminology associated with the topic. One of the major thrusts of the design of the air pollution package was towards improving the students' scientific literacy.

Overall the air pollution resource package is a **synthesis of knowledge and understanding** based on the research and analysis of information in a number of sources and aimed at the needs of senior secondary education. The **success** of the synthesis from a purely scientific point of view was tested by the experts who evaluated the resource package. The **usefulness** of the synthesis was assessed during the trial implementation and evaluation of the resource package in the different school environments. Using the teaching resource materials, teachers and students were able to focus on the issues and complexities of the problems of air pollution. In addition opportunities were contrived in the various activities for students to interact with each other and with the teacher to develop understanding of the topic.

The air pollution package presented in this thesis is in the first stage of development as described by Williams (1994). During the trial implementation, the materials formed the basis of a new topic and a new approach to education for some teachers to consider, test and critique. At the present time, the topic has not been introduced because of the political change in South Africa and subsequent changes in education policy and curricula in the schools. Thus the further stages in the process as described by Williams could not come into play. However in the interim the materials have been used as a resource and adapted by some educators and developers for use in other initiatives in South Africa eg. in teaching resource material for the topic *The Environment* in most Colleges of Education and in a chapter on the environment in *Topics in Science and Technology* (Smith et al, 1998).

Further aspects of the design of the package are dealt with in the final discussion of the implementation and evaluation of the package.

7.2. IMPLEMENTING THE PACKAGE

Although a range of schools was selected for the trial implementation, the schools that finally took part in the trial implementation largely represented two extremes. At one extreme were the urban schools (both state and independent schools). These generally resembled schools in developed, industrialised countries. The urban schools had reasonably good science facilities and the teachers were experienced and, with the exception of the teacher at school UI_6, well-qualified. The exposure to the media (TV, newspapers and magazines) for both teachers and students at the urban schools was probably generally extensive. At the other extreme, the rural schools resembled those in developing countries. The rural schools in this study were remote with poor science facilities. Teachers were under-qualified. Students probably had little or no exposure to the media. (There was no electricity at some schools and little or no access to libraries, newspapers and magazines.) At these schools the exposure of the teachers to the media was probably only marginally better. These two extremes give some indication of the great diversity in schools in South Africa.

The implementation by the researcher served to substantiate several of the issues (eg. shortage of time, reluctance of the students to study a topic that did not "count for marks") commented on by the teachers during their implementation. These issues are discussed later. It also provided an opportunity for the researcher to see parts of the materials in action. One of the major objectives of the materials was to develop **process skills**. The implementation by the researcher and some of the teachers provided insights into the ways some of these process skills were being addressed by the materials. Some of the process skills were:

- **Graphing Skills**

  The researcher observed that students found the plotting of graphs and pie charts difficult. Teachers also reported that students found graph plotting (School US_1) and graph interpretation (School US_2) difficult.

- **Numerical Problem Solving Skills**

  The researcher observed that students found the solving of a gas law problem, which interrelated many concepts learnt earlier in their science course, difficult.

- **Creative Writing Skills**

  The teacher at school UI_1 commented that her students enjoyed writing a newspaper article to accompany a photograph in Worksheet 3(b) of the package.

- **Conceptual Thinking Skills**

  The teacher at school US_4 gained some insights into students' ideas about a gas warming. She made the following statement:

  I was shocked to discover that some of my students thought that the molecules of a gas get bigger when the gas is warmed! (Worksheet 1 (c), Task 2)

The resource materials were themselves non-prescriptive with regard to teaching strategy. The data provided on the evaluation sheets revealed that all teachers (with the exception of the teacher at school UI_4) employed a variety of teaching strategies during the implementation of their units. Even the rural teachers reported using some group work.

Analysis of some of the responses by the teachers in the evaluation sheets provided some answers to the research question:

What factors played a role during the trial implementation of the resource package?

Some answers appear to be:

1. **The Topic: Air Pollution was not a topic in the physical science syllabus at the time of trial implementation.**

   This fact contributed to

   i. <u>Difficulty Finding Teachers to Participate in Implementation</u>

      There were no immediate benefits in terms of improved knowledge, skills and performance in the forthcoming end-of-year examinations for the teachers and students. The rather nebulous promise "of teachers being at an advantage when the topic was introduced in the near future" did not prove to be an attractive incentive for most busy teachers.

   ii. <u>Time Constraints</u>

      The timing of the trial implementation was set to coincide with the proposed time of the year the topic would be taught in the amended standard 9 syllabus. Most teachers chose to postpone the time of trial implementation until late October when they had completed the standard 9 syllabus. This seemed to incur great time constraints. Eight of the ten teachers reported that lack of time prevented them from implementing the package as they would have liked. Evidence of this time pressure is to be found in recorded statements from the teachers:

We were very short of time so things were hurried. (School US_2)

I was very short of time so did not present this unit as I would have liked. (School UI_4)

Not enough time. (School US_3)

Short of time. (School UI_4)

Needed more time. (School US_3)

It would have been more fun if we had had more time. (School UI_3)

Time was a big problem for me and compelled me to lecture. (School UI_4)

I didn't do any practical work because of lack of time. (School UI_3)

In contrast, the teachers at schools UI_1 and UI_6, had completed their standard 9 syllabus in good time and did not appear to experience the same time pressures as those reported above. These two teachers reported that both they and their students enjoyed the package:

My class (only 8 students) had completed the std 9 syllabus so we were able to do many activities. My students really seemed to enjoy the package. (School UI_6)

I had a small group of students (only 5). We had completed the std 9 syllabus so had lots of time to spend on the package. The package is really outstanding, full of fun, information and stimulation. (School UI_1)

The researcher also found that the shortage of time impacted on her implementation.

iii. Pressures from the Students

Feedback from the teachers indicated that many of the students were reluctant to spend time on a topic that was not included in the syllabus, that did not count towards their final assessment and that would not directly improve their performance in the forthcoming examinations. The following statements from teachers reveal this lack of enthusiasm on the part of the students:

Students were restless because they wanted to do revision for the end of the year examinations. (School US_3)

I would have liked to do more but students wanted to do end of the year revision. (School US_4)

My students were anxious to get back to their revision for the examinations. They kept asking "Is this for marks?" and "Why are we doing this?" (School UI_3)

The researcher also noted this resistance on the part of the students in her implementation at school UI_2 and noted statements from students such as *"Why are we doing this now?"* and *"Does this count for marks?"*

2. Societal Issues in South Africa at the Time of the Trial Implementation

Political unrest in South Africa led to a very unsettled climate in many of the schools. Students and teachers were involved in stayaways and protests about conditions in schools and educational policy. It was for this reason that the schools in the urban townships were not approached to participate in the trial implementation. However the unrest spread to the rural schools as well. There was a fear among some teachers who had inititally been very enthusiastic and willing to participate in the trial implementation that they would be victimised if they did not comply with the stayaway and attempted to go ahead with the trial implementation. This was particularly the case in rural district A. Teachers in this region advised the researcher that it might not be safe to travel to their schools to run workshops in preparation for trial implementation.

3. The Geographical Location of the Schools

The researcher was able to maintain close contact with teachers at the urban schools involved in the trial implementation. These schools could be easily visited if problems arose or if teachers requested additional materials or apparatus for experiments. The researcher personally collected the evaluation sheets and student response cards from the teachers at the end of the trial implementation. In contrast, it was difficult for the researcher to maintain contact with and offer support to the teachers at the rural schools who had agreed to participate in the trial implementation. There was no telephone service to two of the schools and contact had to be maintained by means of a very poor postal service. Teachers were asked to post their evaluation sheets and student response cards in addressed, stamped envelopes. Without the "face-to-face" contact of the researcher during and at the end of the exercise it was easier for teachers in the rural schools to opt out of the process. It may be argued that schools like those in the rural sample described in this thesis, should not have been used in the trial implementation because of their remoteness. South Africa is a vast country and these "remote" schools represent a large number of the schools in South Africa. It was considered to be of great value to investigate how teachers and students at some of these schools interacted with the air pollution materials. Schools in rural district B were selected because of the established contact with one of the education officers in this region and the science centre in the district provided some necessary infrastructure for the running of the workshops.

4. The Pressures of Preparing for a New Topic.

Because air pollution was a new topic in the standard 9 syllabus, the teachers participating in the trial implementation had little or no background for the topic. This must have placed an additional burden on the busy teachers. Indications of the lack of background and need for preparation are found in the statements:

I wouldn't have managed without the answers! (School US_4)

Preparation was very demanding and the students pick up one's lack of confidence, and

One needs to be very well-prepared to teach this unit. (Both comments from school US_2)

Comments made by other teachers showed that teachers were acquiring some of the new background from the resource material:

I found the unit enlightening - I hadn't thought of nature causing air pollution. (School US_1)

I learnt a lot from this unit. (School US_4)

Interestingly, the newness of the topic and lack of background did not appear to affect most teachers' confidence. Of 27 possible responses assessing teachers' confidence with the various units, 20 responses showed that the teachers'confidence was "good" and only one teacher reported that her confidence with Unit 1 was "*poor but will improve with time*".

5. The Interdisciplinary Nature of the Topic

Teachers' awareness of the interdisciplinary nature of the topic is revealed in statements such as:

This topic links with other topics eg. philosophy, and adds human interest to the study of science. (School US_3)

This unit overlaps with physics, biology and geography. (School UI_5)

Geography teachers would enjoy involvement in a package like this. (School UI_1)

One teacher requested some additional information from biology:

I need more information about anaerobic decay. (School US_3)

Teachers did not appear critical of the interdisciplinary nature of the materials. However it seems that the students viewed this as a shortcoming. They appeared resistant to relating content from other disciplines to topics studied in the science class!

Students stated that they had studied much of the content in this unit in standard 8 geography. (School US_3)

Students were not interested when we discussed the atmosphere . They thought we were learning geography in a physical science lesson! They became interested when they could link air pollution to chemistry. (School RS_2)

I thought the package was very interesting but the students were unhappy about doing the package. Some said, "I gave up geography so that I didn't have to do this and now we have to do it in science" or " We did all of this in biology in standard 8 . Now we're doing it all over again". (School US_4)

During her trial implementation of two units of the package at school UI_2 , the researcher experienced very similar comments from the students about the overlap of the topic with other disciplines.

6. Language Demands

The language demands of the package will be discussed more fully in the discussion of evaluation of the resource package. However, there are some indications that language may have impacted on the trial implementation in some schools, particularly the two rural schools, RS_1 and RS_2. English was not the mother tongue of these two teachers at the rural schools. This probably contributed to the errors in the administration of the Survey on air pollution at both these schools and the incompleteness of the evaluation at school RS_2. Further evidence of misunderstanding is provided in the statement from the teacher at school RS_2:

"*... introduction is not interesting to the students. I suggest that you shorten the introduction for students seem to participate much more in the body of the lesson.*"

This statement seems to indicate that the teacher misunderstood the function of the introduction to each unit. It had been stated verbally at the workshop and in writing in the "implementation kit" that the introduction to each unit was to provide background information for the **teachers**. It was not intended for use by the students at all!

The rural teachers' lack of familiarity with research methods may also have played a role.

7. **The Lack of Equipment**

None of the urban teachers reported this as a problem but rural teachers stressed it often and appeared to perceive it as a major problem. Some of their statements are quoted here:

Could not do practical activities because of lack of equipment. (Unit 1, school RS_1)

Shortage of laboratory equipment is a problem. (Unit 2, school RS_1)

Lack of practical equipment restricted my choice of activity. (Unit 6, school RS_1)

Our school is in a remote area of which it is difficult to even borrow some equipments from neighbouring schools. I think if we can get enough equipments things will be well. (Overall comment about package, school RS_1)

This finding is in keeping with the findings reported by Webb (1993) that some teachers do not perceive their own role as being central to the implementation of novel projects but perceive that success rests in external factors such as resources, equipment, and being able to do demonstrations.

8. **The Nature of the Workshops to Prepare Teachers**

The purpose of the workshops to prepare teachers for the trial implementation, was largely to **inform** the teachers about the new topic. The focus was on some of the new content for the topic, the design characteristics of the materials, a number of new practical activities and instructions with regard to implementing and evaluating. No time was spent addressing teachers' beliefs about effective teaching strategies for successfully implementing the new topic and resource materials (Beasley, 1992) nor addressing the beliefs of teachers about the rationale of STS education (Cronin-Jones, 1991; Mitchener and Anderson, 1989). There are indications that these inadequacies could have impacted on the implementation:

- The well-qualified teacher at school UI_4, used the teacher-centred "chalk and talk" strategy throughout his implementation of the three units of the package although he had a very small class!
- The rather veiled comment, *"This was the <u>real</u> chemistry part,"* from the teacher at school US_2, after using Unit 5 of the package, indicates a possible resistance on the part of the teacher to the STS approach of the resource materials.

The demands of the trial implementation on the **rural** teachers appeared to be greater than on the urban teachers. Rural teachers reported to the researcher that the trial implementation and evaluation of the resource materials was a novel experience for them. Most of their teaching was centred around one well-used, familiar textbook. After the "one-off" workshop, the only support for the rural teachers was the written instructions in their "implementation kits". Nganunu (1992) and Cronin-Jones (1991) stressed that such **written** guides to new curricula and materials may not be enough. The fact that half the teachers from this sample did not implement their section of the package or contact the researcher, could indicate that these teachers did not feel adequately prepared by the workshop.

7.3. EVALUATING THE PACKAGE

In the formative evaluation of the package, data were collected from three sources:

- Some experts
- Teachers from the sample of schools selected for implementation
- Outcomes of the administration of the *Survey on Air Pollution* as a pre- and post-test.

7.3.1. Evaluation by Some Experts

The package was evaluated by the experts in answer to the broad research question:

Is the resource package an accurate and balanced representation of the topic: Air Pollution and the problems and issues associated with it?

This type of evaluation depended on the interest and goodwill of the busy people approached. The geography professor and the chemistry lecturer were unable to evaluate the package because of their work pressures.

The geography lecturer and tutor performed a thorough assessment. They rated the package highly. Its applicability to their discipline is indicated by the fact that the lecturer requested a copy for herself because she felt she could use some of the activities in her classes. The few changes suggested by the lecturer with regard to temperature inversions were not implemented as it was felt that the detail was not necessary in a package as a resource in **chemistry**. The rather emotive response by the geography tutor to Worksheet 8(c) "Greenies" convinced the researcher that the controversial aspects of the activity made it ideal for incorporation in a resource of this nature. No changes were made to the cartoon.

The evaluation by the professor involved in air pollution research was very valuable. His high rating of the package, the minor changes suggested and his ongoing interest in it are indications of the worthiness of the package.

The evaluation by the journalist was interesting. It was anticipated he might be rather negative because one of the activities which shows the inaccuracy of media reporting (Worksheet 2(e), page 53, Resource Package) is based on a newspaper article written by him! He rated the package as excellent and a valuable resource for environmental centres.

The evaluation by the above experts from a range of disciplines is more discipline-focussed than that of the teachers but it does provide some insights and answers to the research question posed. It also provides some impressions of the scope of applicability of the package. From the evaluations of the experts it appears that the package is an accurate, balanced and worthwhile teaching resource for the topic air pollution.

7.3.2 Evaluation by the Teachers

The evaluation by the teachers was sought to find an answer to the broad research questions:

1. ***Can teachers and students in the different school environments effectively use the materials?***
2. ***Is the package a suitable teaching resource for a standard 9 chemistry class?***

The success of the evaluation depended on the willingness and ability of the teachers to participate in the research process. Teachers needed to reflect not only about the materials themselves but also about the process of implementing them. It also required the teachers to follow instructions given to them verbally in the workshops and in writing in the instruction sheets in the "implementation kits" that they took with them. They then were required to communicate their perceptions in writing in the completed evaluation sheets to the researcher. Most of the urban teachers were reasonably familiar with this process as they had implemented new materials before. Those urban teachers for whom this was a novel experience eg. the teacher at school UI_6, seemed to cope well with the exercise and their feedback provided rich insights for the researcher. The role of "researcher" however seemed foreign to the rural teachers in the research sample. As mentioned earlier, errors occurred during the evaluation process. For example not all evaluation sheets were completed and not all evaluation sheets were returned to the researcher. Reasons for these problems may have been that the rural teachers were unfamiliar with research procedures and did not appreciate the importance of some of the instructions they were given. Critical assessment was a novel exercise for these teachers as well. The shortcomings in the English language skills of these teachers may also have impacted on the process. Unfortunately these errors in the evaluation process resulted in the loss of data that could have been very helpful and insightful for the researcher.

The outcomes of the evaluation by the teachers (Chapter 5) reveal that in general teachers rated the units of the package highly. **Table 7.1.** below summarises the overall rating of units by teachers.

Table 7.1. Rating of the Materials by Teachers

Unit	No. of Teachers Using	No. of Teachers Rating as:			
		Excellent	Good	Average	Poor
1	10	5	4	-	1
2	10	6	3	1	-
3	1	1	-	-	-
4	1	-	1	-	-
5	1	-	-	1	-
6	2	1	1	-	-
7	2	-	1	1	-
8	1	1	-	-	-
9	1	1	-	-	-

The teachers generally suggested very few changes to the units of the package that they implemented. Some of the suggested changes or improvements to the **units** were:

1. The teacher at school US_1 suggested that the units in Worksheet 1(d) be changed to SI units. The teacher at UI_4 felt the content in this Unit was a bit difficult.
2. The teacher at US_1 suggested that Unit 2 might lend itself to a video presentation.
3. The teacher at school US_2 found Unit 2 longwinded (probably she was referring to the introduction). Her views were reiterated by the teacher at school UI_3 who felt that *"maybe in this unit there is too much information."*
4. In contrast some teachers, using other units, wanted more information! For example the

teacher at school UI_3 wanted more information about the SASOL process in Unit 3.

5. The teacher at school US_1 found the processes for the generation/destruction of ozone in the atmosphere difficult to remember but did not suggest any ways of improving this.

Overall comments about the design of the **package** included very few suggestions for improvement. Some of these were:

1. The package is too long and teachers would have to choose a theme and follow it through the package (teacher at school US_1). The teacher at school US_2 echoed this sentiment with the view that the package was too detailed.
2. The teacher at school US_3 felt that notes outlining the aims of each activity might help teachers to make choices with regard to activities.
3. **Table 5.21.** (see page 124) provides insights as to the language demands of the package. The teachers and students who have English as their mother tongue seemed to find the language requirements suitable. However there are indications that at some schools, particularly those where English was not the mother tongue of the teacher **and** the students, the language demands of the package were problematic. It appears from the responses of the teachers at the rural schools that the English language skills of the teachers themselves hampered their response concerning the language demands of the package!

The highly favourable rating given by most of the teachers at the **urban** schools, their comments in the evaluation sheets and their relatively few suggestions for changes and improvements, appear to show that in general these teachers were able to use the materials effectively and that they are a suitable teaching resource for standard 9. However there are indications that **rural** teachers did not find it as easy to interact with the materials. Teachers did not state this openly but the outcomes described here and in earlier parts of the thesis seem to indicate that this is the case. The researcher is unable to conclude whether or not the materials in their present form are a suitable resource for standard 9 classes in the rural areas described in this thesis.

7.3.3. Evaluation using the Outcomes of the Administration of the Survey as a Pre- and Post-test

This part of the evaluation depended on the extensive use of the Survey in an effort to find an answer to the research questions:

1. ***Do the materials enable teachers to provide a meaningful learning experience for the students?***
2. ***Do the materials enable teachers to improve the students' scientific literacy?***

"Meaningful learning" was probed further by the questions:

a. ***Do the materials enable teachers to improve the students' understanding of the concepts, principles and terminology associated with air pollution?***

b. ***Do the materials enable teachers to increase the students' awareness of and concern about air pollution?***

c. ***Do the materials enable teachers to bring about change in the students' beliefs, attitudes and opinions, that leads to a more balanced outlook concerning the issues related to air pollution?***

There are limitations associated with the design and use of the Survey and these are discussed in section 7.6. that follows.

The administration of the Survey once again required that teachers become involved in the research process. In most urban schools the pre-and post-testing was carried out adequately. However as discussed earlier, the process did not run smooothly in the rural schools.

In the search for answers to the research questions, responses to the pre-and post-tests for the **core knowledge and attitudinal items** will be dealt with in some detail. All schools were required to respond to these items whereas the unit specific items in the Survey were only answered by students at schools which implemented the relevant additional unit. The **unit specific items** will not be dealt with in as much detail in this discussion.

Discussion of Outcomes of the Pre-tests

The administration of the Survey as a pre-test provided insights as to the preconceptions, beliefs, attitudes and opinions of the students with regard to air pollution. These findings formed a base line against which the change, after students had used the materials, could be assessed (Aikenhead, 1994c). They also revealed the conceptual and affective context in which the materials were implemented.

The following outcomes of the pre-tests for the **knowledge items** in the Survey indicate that the students had little background for the topic of air pollution.

1. Students had very little knowledge concerning the nature and physical features of the atmosphere.
2. Many students thought that the atmosphere was unreactive.
3. There was a perception that air pollutants are substances that do not occur naturally and that they are only gaseous substances.
4. Students had very little understanding of the extent or scope of air pollution.
5. There was a perception that air pollution was mainly the result of the activities of industry, science and technology.
6. Many students appeared confused about the concept of the greenhouse effect. This is in keeping with the findings of Boyes and Stanisstreet in the UK (1993) and those reported by the Foundation for Research Development in South Africa (1996). Students did not distinguish between the terms "greenhouse effect" and "**enhanced** greenhouse effect".

Where evidence is available for the **knowledge items**, there are indications that the prior knowledge of the rural and urban students was very similar. There is also evidence that in general the teachers (both urban and rural) were only slightly better informed than their students.

The responses to the **attitudinal items** in this study were classified into some broad categories in an attempt to find answers to the research questions posed on page 212. These categories of response which follow are closely related to a number of the objectives of the package listed in Chapter 3.

1. **Concern about Air Pollution**

Students professed to being concerned about air (and water) pollution. They seemed slightly less concerned about soil erosion and exposure to nuclear radiation. Many students claimed that they were more concerned about air pollution than economic and political issues. (Their responses could have been influenced by the focus of the Survey.)

Although students appeared concerned about air pollution, they had mixed feelings about whether the inclusion of this topic in science lessons would increase their interest in science. The negative response of many students may have been because the topic was not yet part of the syllabus.

2. **Awareness of Air Pollution**

Students seemed very aware of air pollution in their local area and in the country and their own involvement in the problem. It is interesting to note, however, that although students seemed aware of their own involvement in air pollution problems, when asked to identify the main source of air pollution, the majority of students chose industry, science and technology!

3. **Understanding of Terms/Phrases**

When asked to assess their understanding of terms and phrases, more than 60% of students indicated that they understood the meaning of the term "greenhouse effect" and the phrase "hole in the ozone layer". Slightly fewer students indicated that they understood the meaning of the term CFCs. These self-perceptions are not consistent with the performance of students in items (eg. items 1 and 29 in the Survey) which tested their understanding of these terms in a deeper context.

There are other instances where what students claimed they understood or knew, is not borne out by their responses to the Survey. For example, students at schools UI_2 and US_4 claimed they knew all about air pollution from prior lessons in geography and biology. Yet in the individual responses from these schools, students did not perform well in items dealing with the understanding of what air pollution is, the scope of air pollution, the percentage of carbon dioxide in the atmosphere and the greenhouse effect. These findings are in keeping with those of Shamos (1995), who found a large disparity between what citizens in the USA **believe** they know and what they **actually** know. This may indicate a deficiency in students' understanding of "understanding". Perhaps the media foster the belief that they communicate "understanding" when in fact they do not.

4. **Balanced Outlook**

Students appeared reasonably critical of the media's ability to report air pollution issues accurately. They were less critical of the environmentalists' ability to predict the consequences of air pollution.

Students' perceptions about the role played by industry in the problem of air pollution are revealed in their responses to several items in the Survey. About 50% of students felt that industry is concerned about air pollution. More than 60% of students felt that industrial development should not be stopped in order to preserve the environment. Many students felt that air pollution was controllable. Students felt ambivalent about paying more for commodities in order to improve air pollution control.

5. **Beliefs concerning Air Pollutants**

Some responses to items in this part of the Survey reveal further beliefs that students have concerning air pollutants. Most students appeared to understand that it is not only the pollutants that can be seen or smelled that are important, but they were confused about the longevity of pollutants in the atmosphere.

For the **attitudinal items** where information is available, there are indications of differences in the responses of urban and rural students to these items. The rural students tended to agree with the statements presented to them. In addition the responses of urban students were generally similar to those of the urban teachers. The responses of the rural students often differed from those of the rural teachers.

The responses by smaller numbers of students to the **unit specific items** provide insights with regard to students' perceptions about more specific issues and problems associated with air pollution namely:

- Combustion
- Depletion of ozone in the stratosphere
- Smog
- The enhanced greenhouse effect
- Acid rain
- The control of air pollution
- The response by industry

The pre-test outcomes reveal that for all these issues students had a good/fair prior knowledge for items which required simple factual knowledge. This knowledge could have been acquired in a variety of ways eg. informally from the media or formally from the teaching of other subjects like geography and biology. Students exhibited poor prior knowledge when items required deeper knowledge and understanding. For the items on the enhanced greenhouse effect, there were some indications that differences existed between the responses of the rural and urban students.

Discussion of Outcomes of the Post-tests

The post-test outcomes allowed the change in students' knowledge, beliefs, attitudes and opinions to be gauged.

When the chi-square test for significance was applied to the pre-and post-test responses for the core **knowledge items**, significant improvements were shown to have occurred in all nine items (although the level of significance for one of the items had to be viewed with caution). However, the percentage of correct responses for difficult items remained rather low. Amongst these difficult items were those dealing with what air pollutior , the extent/scope of air pollution, the greenhouse effect and reactivity of the atmosphere. .:ems dealing with knowledge about the nature and physical features of the atmosphere showed a good number of correct responses in the post-test. One of the most interesting changes was that in item 7 dealing with the activities responsible for air pollution. In the post-test the majority of students chose the activities of the broad range of society, ie. the rich, the poor, science, technology and industry (and no longer just science, technology and industry as opted for in the pre-test), as contributing to air pollution. This change could indicate that students were becoming more balanced in their outlook once they had become better informed.

When the chi-square test for significance was applied to the outcomes for the **attitudinal items** it was found that the changes in some of the items were statistically significant. However where students had responded strongly in one direction in both the pre-test and the post-test, the chi-square test may not be a valid test (because of too few counts in some of the cells). In such cases the statistical significance of the change must be viewed with caution.

An analysis of the post-test outcomes for the attitudinal items is presented in the same categories as those developed for the pre-test items.

1. **Concern about Air Pollution**

Students became more concerned about air pollution and soil erosion. There was less of an increase in their concern for water pollution and nuclear radiation. There were statistically significant increases in the concern for all four of these environmental issues although the level of significance for air and water pollution must be viewed with caution. Students concerns about air pollution also increased relative to their concerns about economic and political issues. This change was significant.

Students felt that the inclusion of the topic: Air Pollution in the science syllabus would not increase their interest in science. The change was significant. This outcome was possibly the result of the reported reluctance of students to study the topic because of examination pressure, because they felt it did not count towards their assessment and because some students felt that they had studied the topic before in other disciplines. However this outcome may also reflect on the resource materials themselves (see later section 7.4.).

2. **Awareness of Air Pollution**

Students became more aware of air pollution and of the involvement of all of society in the problem. The increase in their awareness of air pollution in the country as a whole was not significant. There was an increase in their awareness about local air pollution and about their involvement in the problem. The level of significance of these increases must be viewed with caution.

3. **Understanding of Terms/Phrases**

Students claimed increased understanding of the terms and phrases, "greenhouse effect", "hole in the ozone layer" and "CFCs". The level of significance of the claimed increase in understanding on all these items must be viewed with caution.

4. ***Balanced Outlook***

Students became more critical of the media's reporting of environmental issues although the significance of this increase must be viewed with caution. Students became more critical of the ability of environmentalists to predict the consequences of air pollution. This change was significant.

There was a significant increase in the perception that industry is concerned about air pollution. There was also a small increase in the already strong perception that industrial development should not be stopped. The significance of this increase must be viewed with caution. There was a strengthened perception that air pollution can be controlled. The significance of this increase must be viewed with caution. There was a significant increase in the perception that we should be prepared to pay more for commodities in order to improve the control of air pollution.

5. **Beliefs concerning Air Pollutants**

The belief among students that air pollutants are not only substances that can be smelled or seen was increased in the post-test though not significantly. There was an improvement in students' understanding that air pollutants do not remain in the atmosphere forever. The change was significant.

When considering the changes in the **core knowledge and attitudinal items** it is interesting to observe that the resource materials appeared to bring about a greater improvement in students' knowledge than changes in attitude. In several of the attitudinal items this was probably due to the fact that students had already responded strongly in one direction in the pre-test and thus there was little room for further change in that direction in the post-test. "Knowledge-based" attitudinal items (eg. item 15 dealing with the longevity of air pollutants in the atmosphere) did show significant gains in the post-test. Another contributing factor may have been that attitudes are often entrenched and thus more difficult to change.

When comparing the pre- and post-test responses of the students to the **unit specific items**, it is important to relate these outcomes to the Learning Objectives which accompanied Units 3 - 9. These Objectives serve as learning outcomes for each unit. Many of these outcomes include verbs such as *describe, explain, name, list* or *compare.* Although the items in the Survey are set in the *"True/False/I don't know"* mode, it is argued that students were required to make **informed** choices. Thus many of the **actions** highlighted by the *verbs* in the Learning Objectives were **prerequisites** for students to be able to make correct responses to items in this part of the Survey. Therefore the student achievement data gathered unit-by-unit in this study focuses on some of the procedural and conceptual knowledge highlighted in the Learning Objectives in these units.

The analysis of the responses to the **unit specific items** was different. **Knowledge gains** for the various categories of item (ie. good, fair and poor prior knowledge items) were calculated. The trends that emerged were very rational in that the biggest knowledge gains were for those items in which the students had the poorest prior knowledge. The analysis of this part of the Survey showed that some of the most substantial gains in understanding were made by students in the following areas:

Combustion:	The contribution of burning coal in power stations and households to the problems of air pollution.
The Depletion of Ozone:	The chemical nature of ozone and CFCs and their reactions in the stratosphere. The role played by ozone in the stratosphere.
The Enhanced Greenhouse Effect:	The beneficial nature of the greenhouse effect. The increase in the concentration of carbon dioxide in the atmosphere. The contribution of other activities eg. farming and agriculture to the problem of global warming.
Acid Rain:	The nature of acid rain, and an understanding of substances and activities which contribute to the problem. An understanding of some consequences of acid rain.
Control of Air Pollution:	The laws and agreements reached to control air pollution.
Response by Industry:	The problems that prevent catalytic converters being used on motor vehicles in SA. The cost of installing technology to reduce air pollution. The fact that some industries do monitor the quantity and nature of their air pollutants.
Science as a Human Activity:	Scientists are fallible.

In some of the core knowledge and unit specific items although there was an increase in the number of correct responses in the post-test, the percentage of correct responses still remained rather low. Stanisstreet and Boyes (1994) also found that many preconceptions held by students about these issues were rather resistant to change. Stanisstreet and Boyes suggest that global environmental issues are very complex and difficult because:

- concepts such as global warming and ozone depletion are very abstract and thus cannot be seen or felt.
- the issues are multidisciplinary and require an understanding of several traditional science concepts.
- the outcomes of many problems are uncertain. Experts do not agree about possible outcomes and some even feel the problems have not been proven to exist.
- some of the predicted consequences of problems require an understanding of difficult concepts such risk, chance and probability.

Unfortunately it is not possible to comment on any differences in responses to items in the post-test by the rural and urban students. The post-test responses of the rural students were either incomplete or unreliable. It is also not possible to compare teachers' responses after implementation to those of the students in the post-test. Neither the urban nor rural teachers were post-tested.

The analysis of the pre-and post-test results does provide some answers to the research questions posed:

- The materials **did enable** teachers to improve the students' understanding of the concepts, principles and terminology associated with air pollution.
- The materials **did enable** teachers to increase the students' awareness of and concern about air pollution.
- The materials **did enable** teachers to bring about change in some of the students' beliefs, attitudes and opinions regarding air pollution. This change resulted in a more balanced outlook about some air pollution issues.

Stanisstreet and Boyes (1994) suggest that environmental education should "mature" students' views towards informed concern. In this study it appears that after using the resource materials for air pollution, students' views indeed "matured" in this direction.

Thus in answer to the broad research questions posed:

1. The resource materials **did enable** the teachers to provide a meaningful learning experience for the students.
2. There are firm indications that the resource materials **did enable** teachers to improve students' scientific literacy with regard to the topic: Air Pollution.

7.4. RELATING THE OUTCOMES OF EVALUATION TO THE DESIGN OF THE PACKAGE

A valuable aspect of the pre- and post-test outcomes is that they informed the researcher about possible changes or modifications to the package. Care was taken to ensure that prevalent erroneous preconceptions as revealed in the outcomes of the pre-tests, **were** addressed either in the **introduction** or in the **activities** for each unit. Examination of the post-test outcomes provided an assessment of the effectiveness of the materials in helping the teacher address these preconceptions. For some of the items in the Survey (particularly those in the unit specific sections of the Survey) the post-test outcomes revealed no change in students' knowledge or, in some cases, negative shifts. For example an analysis of the unit specific items for Unit 5. Smog, revealed that the knowledge gains for this unit were not as great as for other units. In addition for some other units, the post-test outcomes revealed that some issues dealt with in the introduction but not in the activities for students, showed little improvement. These and other outcomes could direct possible changes and improvements in the materials in the future.

The negative overall response by students to Item 24 in the Survey could indicate that the materials in their present form need some revision. However changes in this regard would ideally be informed by research using observations of classroom interactions of teachers and students with the materials.

This first draft of the materials (as used in this pilot study) focussed largely on the **content** (Eijkelhof, 1994; Williams, 1994). A second draft of the materials would presumably focus on **teaching strategies**. In this way the *student-centred approach* (in keeping with the constructivist philosophy about learning) would be made more explicit to the teachers. The introduction of more "hands-on" practical activities would also improve the package.

Further changes to the package would:

- address and correct errors in the introductions to the units, worksheets and answers eg. page 7, where it is stated that icecaps and glaciers are part of the liquid state.
- provide safety precautions for the handling of eg. potassium dichromate, concentrated nitric acid and potassium permanganate (pages 23, 80 and 131 of the package).

7.5. RELATING OUTCOMES OF EVALUATION TO IMPLEMENTATION

Table 7.2. that follows, summarises a number of aspects of evaluation and implementation at the various schools namely:

- the number of *knowledge items out of a total of 9 in which there was an improvement* in the post-test (shown as **Know. Items** in the Table)
- the average percentage gains for these knowledge items (shown as **Av. Gains %**)
- the number of unit specific items out of a total of 15 in which there was an improvement in the post-test (shown as **Spec. Items**)
- the average percentage gains for these items (shown as **Av.Gains %**)
- the number of students taking part in the implementation
- the time spent on implementation of parts of the package, in hours
- the teacher's qualifications and experience
- the mother-tongue of the teachers and students (shown as **Lang. Teachers** and **Lang. Students**)
- the teachers' ratings of units 1, 2 and the other unit they implemented
- the teachers' confidence (as reported by the teachers) with the materials
- the students interest in the units (as assessed by the teachers)

NB. Outcomes for the attitudinal items have not been included as there was no correct score assigned to these items.

Table 7.2. Summary of Aspects of Implementation and Evaluation

School	UI_1	UI_{2a}	UI_{2b}	UI_3	UI_4	UI_6	US_1	US_2	US_3	US_4	RS_1
Know. Items Av. Gains (%)	6/9 24	7/9 12	8/9 40	7/9 21	4/9 7	5/9 18	6/9 20	6/9 9	8/9 26	9/9 14	3/9 <1
Spec. Items Av. Gains (%)	9/15 24	10/15 12	12/15 19	14/15 28	9/15 17	9/15 13	11/15 20	8/15 - 0.2	14/15 24	8/15 11	4/15 -10
No of Students	5	16	20	18	4	8	57	26	40	10	6
Time Spent /h	14	3.5	3.5	3	3	15	10.5	4.4	4.5	4.5	3.5
Teachers' Qualifications Experience/yrs	BScEng 25	N/A	N/A	MScHDE 5	BScHons HDE 3	Part BSc 4	BScHDE 14	BScHons HDE 18	BScBEd HDE 9	BScHDE 7	Part BA 8
Lang. Teachers Lang. Students	EL1 EL1, EL2	EL1 EL1, EL2	EL1 EL1,EL2	EL1 EL1,EL2	EL2 EL2	EL2 EL2	EL1 EL1	EL1 EL1	EL1 EL1	EL1 EL1	EL2 EL2
Teachers' Ratings of: Units 1, 2 and one other unit	Excellent Excellent Excellent	N/A	N/A	Good Good Good	Poor Good Average	Excellent Excellent Excellent	Good Good Good	Good Average Average	Excellent Excellent Excellent	Excellent Excellent Excellent	Good Excellent Good
Teachers' Confidence with 3 units	Good, Good Good	N/A	N/A	Good Good Average	Good Good Good	Good Good Good	Good Average Average	Average Good Good	Good Good Good	Poor Average Average	Good Good Good
Students' Interest in 3 units	Good V Good Good	N/A	N/A	Average Average Average	Poor Average Average	Good Good Good	Average Average Good	Average Average Poor	Good Average Good	Poor Poor Poor	Average Average Average

The summary allows some of the profiles of schools, teachers and students presented in ... ,ter 4, to be related to some outcomes of the evaluation by the teachers and to some outcon of the administration of the Survey on air pollution. The following observations are made:

1. The **number of students** taking part in the implementation at the various schools did not appear to impact heavily on the achievements of the students in the items in the Survey. For example at schools US_1 and US_3 reasonably large numbers of students were involved. At schools UI_1 and US_4 small numbers of students took part in the implementation. At all these schools the achievements of the students in the post-test and the average percentage gains were similar.
2. The **time spent** on implementation did not seem significant with regard to achievement in the Survey items. For example teachers at schools UI_1 and UI_6 spent 14 and 15 hours respectively on implementation. The achievements of the students at these schools was not very different from those at schools such as UI_3 and US_3 where teachers spent 3 - 5 hours on implementation.
3. The **qualifications and experience of the teachers** at the urban schools did not appear to play a significant role in the achievements of the students. For example at school UI_6 the teacher was not fully qualified and he only had 4 years experience, yet his students seemed to achieve better results in the Survey than those of the students at school US_2, where the teacher was very well qualified and experienced.
4. The **teachers' confidence with the materials** did not appear to influence the students' achievements. For example the teacher at school US_4 seemed the least confident yet her students achieved as well in the Survey as those where the teachers claimed to be the most confident.
5. The **impact of the mother tongue of teachers and students** in the **urban schools** on the achievement of students in the Survey is not clear. At schools UI_2 and UI_3 English was the mother-tongue of the teachers while the language status of the students was mixed. At both these schools, students achieved well in the items in the Survey. At schools UI_4 and UI_6 English was not the mother tongue of either the teachers or the students. The achievement of the students at school UI_6 in the Survey was reasonably good, especially if the knowledge gains are taken into account. The achievement of the students at school UI_4 was not quite as good.

It has previously been noted that the English language skills at the **rural school** RS_1 were a problem. As discussed earlier, the administration of the Survey as a post-test was also very problematic at this school and thus it is difficult to draw any firm conclusions from the outcomes of the student achievement in the Survey.

6. It appears as if the **enthusiasm of the teachers** (as deduced from the teachers' ratings of the units they implemented) **and students** (as deduced from the teachers' assessment of their interest in the materials) played a role in the achievement of students. The teachers at schools UI_4 and US_2 were not as enthusiastic about the materials as the teachers at the other schools. These teachers also reported that their students were not very interested in the materials. The achievements of the students at these two schools were not as good as those of students at the other urban schools.

   It is interesting to note that at school US_4 the teacher was very positive about the materials but her students were not. However students at this school achieved well in the Survey.

Thus it would seem that the teachers' enthusiasm for the materials was the one consistently important factor during the implementation of the materials. Teachers had volunteered to implement and evaluate the resource materials so the question arises as to why the two teachers described above did not appear as enthusiastic as some of the other teachers. It has been mentioned that the implementation placed many demands on the teachers. Thus it seems likely that some teachers would "wilt" before others. In addition there are small indications (discussed earlier) that the teacher at school US_2 was rather resistant to the STS approach of the materials. Finally there is always the matter of personal preference. The resource materials possibly appealed to some teachers but not to others.

7.6. LIMITATIONS AND SHORTCOMINGS OF RESEARCH

Reflection on some aspects of techniques used in this pilot study reveals the following limitations: They are:

1. The two extremes of urban and rural schools which finally formed the research sample in this study are not representative of all schools in South Africa.
2. At times, outcomes are described for small numbers of students and teachers. Any conclusions drawn from these samples may not be applicable to larger samples of classes and teachers.
3. Teachers' responses were generally communicated by means of the evaluation sheets. Interviews with some teachers could have provided deeper insights into teachers' comments, problems and attitudes towards the resource materials.
4. In the evaluations sheets, some of the scales used to assess teachers' responses to the materials were flawed. The scales *Yes, Average, Not really* and *Good* and *Poor* (see Appendix, page A19) are confusing and may have caused muddled responses by mixing criterion-referenced and norm-referenced considerations.
5. The loss and failure to replace the *chemistry department* evaluator represents a weakness in the evaluation of the materials by the experts. However, this is off-set to some extent by the fact that two advisors in the development of the package were professors in chemistry.
6. The evaluation by the experts was conducted in a somewhat unstructured manner. The experts chose to respond to the researcher in a rather informal face-to-face way. During the evaluation process, each expert tended to focus his/her comments largely on aspects of the package that were his/her areas of interest. The use of a more structured response sheet for the expert evaluation may have improved this form of evaluation but not have allowed the personal emphases to emerge.
7. Limitations imposed by the extensive use of the Survey:
    a. Some of the items could have been ambiguous (for example Item 6, see Appendix, page A4). The students may not have interpreted the items in the same way as the researcher (Aikenhead, 1988). The possible ambiguity was probably further enhanced by the poor English language skills of some of the students and teachers.
    b. The structure of some of the items was complex in terms of both number of concepts being tested and the use of language. This may have impacted negatively on the students' responses to such items.

c. The Survey only revealed **what** the students answered but not **why** they responded in that manner. Interviews with students and teachers and more in depth classroom observations could have provided valuable insights into students' reponses and shortcomings of the Survey items themselves.

d. Some of the wording of the items in the Survey needs modification. For example, in Items 27 and 30 in the Survey (see Appendix, pages A7 and A8) the wording should read *"Which diagram is the most correct representation of .... "*.

7.7. SUGGESTIONS FOR FURTHER RESEARCH

Most of the outcomes in this research are reported from urban schools. Fewer insights were gained from rural schools. The suggestions are made that

- more research be conducted into the classroom interactions of teachers and students (particularly at rural schools) with new curricula and teaching materials.
- the apparent differences in the beliefs, attitudes and opinions of urban and rural students with regard to environmental topics, as indicated in this study, be further probed.
- methods of preparing teachers for the implementation and evaluation of new curricula and teaching materials be further researched and developed. Particular attention should be paid to schools where teachers are under-qualified, facilities inadequate and the English language skills of teachers and students poor.

CHAPTER 8

CONCLUSIONS, RELEVANCE AND RECOMMENDATIONS

The overall **conclusions** from this research are reached and the **relevance** of the outcomes to curriculum change and improving scientific literacy in South Africa is argued. **Recommendations,** in these regards, are suggested.

8.1. CONCLUSIONS

The environmental nature of the topic: Air Pollution with its controversial issues, uncertain consequences regarding many problems and the interrelationship of aspects of science, technology and society, made it an ideal topic for an STS approach. In keeping with this approach, the package addresses the knowledge, process skills and affective domains. The package is a synthesis of knowledge and understanding constructed from the research and analysis of resources existing at the time of development. The development of the package was based on the "centre-periphery" model.

The processes of designing, implementing and evaluating the resource materials were closely interrelated. The materials, in the first stage of development, initiated the processes of implementation and evaluation. Outcomes of the implementation and evaluation revealed some of the complexities of the South African context with its diversity of region and variety of school contexts. These outcomes informed the researcher of changes and modifications that might be made if there were wider use of the resource package.

The implementation took place against the backdrop of political and social unrest in South Africa during 1991. The structured plans of implementation went awry as the exercise proceeded. In the end, the sample of schools participating came from two extremes: an urban extreme with generally good facilities, well-qualified, experienced teachers and a rural extreme with under-qualified teachers and poor facilities. The research revealed that many other factors besides the socio-political ones, impacted on the implementation of parts of the package by these urban and rural teachers. These were:

- The preparation for a new topic for which teachers had little or no background
- Time constraints
- Pressures from some students who were resistant to the topic because it did not count for marks, or who felt they had studied it all before in geography and biology
- Pressures on students and teachers because of forthcoming examinations
- The inadequate preparation for the topic by the "one-off" workshop
- The enthusiasm of the teachers for the resource materials
- The language demands of the package for students and teachers who had poor English language skills
- The remoteness of some of the schools and the consequent difficulties on the part of the researcher to keep in touch

Considerable effort must have been spent by the teachers because of the demands placed on them by the implementation. The demands must have been particularly great for the rural teachers for whom the tasks of implementing and evaluating a teaching resource for a new topic were novel. In spite of these hurdles, many teachers completed very successful implementations and provided valuable feedback to the researcher. At schools where the implementation did not proceed as envisaged by the researcher, the unexpected outcomes provided insights into the realities of the different school settings.

In the formative evaluation of the resource package, evidence was provided regarding the value of the teaching materials. The experts, from a range of disciplines, rated the resource package as an accurate and balanced representation of the topic. Their evaluation indicated the scope of applicability of the **subject matter** in the package extending from its usefulness in first year geography classes at university level to the whole package being worthwhile for environmental centres. Teachers evaluated the **subject methodology** as presented in the resource package. The majority of the teachers rated the package highly as a suitable resource for standard 9 chemistry classes. There were some reservations as some teachers suggested small changes in some of the activities or in the introduction which provided background for the teacher. There are indications that for some teachers the package in its present form is too detailed. There is also evidence that the language demands of the materials were great for some teachers and students. The administration of the Survey as a pre-test revealed the state of prior knowledge, beliefs, attitudes and opinions of teachers and students with regard to the topic: Air Pollution. In general teachers and students were ill-informed about the topic and had a rather superficial knowledge of concepts and terminology associated with it. There were indications that the rural students differed from the urban students with regard to some of the affective aspects of the topic. Comparisons of the responses of students in the pre- and post-tests allowed the evaluation of the package as a resource to promote meaningful learning and to improve scientific literacy. The criteria for the evaluation of the package were closely related to some of the objectives of the design of the package. This evaluation revealed that after using just three units of the package and a variety of worksheets and activities, there were significant changes in students' knowledge of concepts related to the topic. Changes occurred in the affective domain, too. The awareness and concern of students about air pollution increased. There were changes in students' attitudes to the roles played by society, science and technology in the problems of air pollution. Students appeared to become more critical of the media and the abilities of environmentalists to predict with certainty the consequences of air pollution.

In a much broader sense, this research showed that students became better informed about an environmental topic where aspects of science, technology and society are intertwined in the issues, problems and search for solutions. They approached the topic with background or "lay ideas" gained largely via the media or through informal discussions with others (Eijkelhof, 1994; Solomon, 1992). Often these media presentations are slanted and anti-scientist. For sensationalism, the adverse effects of science and technology receive more attention than the benefits. Most journalists have a very superficial understanding of the scientific principles and concepts involved and terminology is carelessly and inaccurately used. The confusion is further enhanced by the fact that environmental issues are very complex. Some of the concepts involved are highly abstract, the issues are interdisciplinary in nature and the consequences are uncertain (Stanisstreet and Boyes, 1994). Although research suggests that these "lay ideas" are entrenched (Eijkelhof, 1994; Stanisstreet and Boyes, 1994), this study indicates that by using carefully constructed teaching resource materials teachers are able to change students' attitudes and enable students to develop more balanced outlooks as they acquire a deeper, more accurate understanding of the principles, concepts and terminology involved in the topic. In terms of the methods of assessment employed in this research, the students [illegible] ns of becoming more scientifically literate.

8.2. RELEVANCE OF THE OUTCOMES OF THIS RESEARCH FOR:

- **CURRICULUM CHANGE AND**
- **IMPROVING SCIENTIFIC LITERACY IN SOUTH AFRICA**

This research study is a case study of small-scale curriculum change. Although the field work upon which this research is based was conducted in 1991, the outcomes are still very relevant to South Africa at the present time (1998).

The rationale and strategy of the STS education approach in general, and the aims and objectives of the teaching resource package on air pollution in particular, are reflected in the critical and specific outcomes proposed in *Curriculum 2005* with its emphasis on the development of skills, knowledge, attitudes and values for responsible citizenry. In addition aspects of science, technology and society are addressed and integrated in a number of learning areas eg. the Natural Sciences, the Human and Social Sciences, and Technology. Scientific and technological literacy is highlighted as a crucial outcome of the new curriculum.

The recent studies conducted by the Foundation for Research Development (FRD, 1996) and the Human Sciences Research Council (1998), which indicate that the understanding of science and technology among school students and citizens in South Africa is very poor in comparison with that in the developed countries, also highlight the need for improved scientific and technological literacy. South Africans generally do not appear to appreciate the benefits of science and technology and the majority of the population is suspicious of and sometimes averse to science (FRD, 1996). South Africa is a developing country and science and technology will play an important role in its development. Therefore it is crucial that South Africans become better informed about the role of science and technology in their lives. The FRD advises that nationwide scientific literacy campaigns be developed and that research be conducted to reveal the obstacles which hamper the success of such campaigns. The design and trial implementation of the teaching resource package on the topic: Air Pollution, clearly indicates a possible way forward. It is not a short route, but it seems likely to be successful. This route involves large scale implementation of this kind of STS teaching resource package within the school curriculum. The "obstacles" encountered in the trial implementation of this study, will also hamper the large scale implementation.

Indeed there are indications that many of the "obstacles" encountered in the trial implementation of the resource package **are still prevalent** in some South African schools. Reports from school principals and teachers at some schools in the Northern Province[1] (Adler et al, 1998), provide some of the following insights:

- Teaching and learning are disrupted at times by boycotts by students (on issues related to the organisation of the schools) and by teachers (on issues related to employment conditions).
- There have been some improvements at schools eg. new classrooms being built and some new equipment being provided. However some of the changes are very rudimentary so that many schools are still under-resourced with facilities that are inadequate. This is illustrated by the following quote:

  The rondavels and incomplete classrooms have no effective doors or windows in the dry (sic) *and dust of the far Northern Province, classrooms are always very dusty, noise cannot be filtered out and there is no electricity......... On very cold, or windy or very rainy days schooling in these conditions must be impossible.* (page 65)
- Some teachers feel very remote and experience a *"sense of being cut off"*. There has been very little contact with the new Department of Education in their region. In fact most teachers have not been visited by anyone from the Department since 1993!

Some teachers and principals in this region report that there are **additional changes** that they have to cope with. For example:

- The move from an authoritarian approach in the schools to a more democratic approach has resulted in some students being difficult to discipline and teachers feeling demoralised.
- During student boycotts, the disruptions have led to vandalism with new equipment being broken or stolen.
- The introduction of governing bodies to the schools has resulted in disruptions because of preparations for meetings and difficulties in reaching consensus on the running of the schools.

---

1 The Northern Province was formerly part of the Transvaal province. This is the region in which schools in rural districts A and B described in this thesis are situated.

At urban schools in Gauteng (schools similar to the urban sample used in this research) there has been a dramatic increase in staff turnover. This has largely been due to some of the most qualified and competent teachers opting for voluntary severance packages. Schools have been unable to find replacement teachers who are suitably qualified and experienced.

The sweeping changes envisaged in *Curriculum 2005* will place **additional heavy demands** on teachers functioning under some of the conditions described above. Some of these demands are:

- using an **outcome-based** curriculum in place of a **content-based** curriculum
- using unfamiliar resources instead of familiar text books
- gaining background for the new, often interdisciplinary content
- using a variety of novel teaching strategies
- developing new strategies for assessment
- developing one's own relevant, contextualised teaching resources

The requirement of the new curriculum that teachers develop their own teaching resources is of particular concern. Materials development is not a trivial task. It took the researcher,working full-time under the guidance of her supervisors, one year to develop the first draft of the materials for a topic. Likewise Vinjevold (1997), in *The Role of Materials in the New Curriculum*, reports that a highly experienced materials' developer working in a very supportive school environment with ready access to resources, found that the process was difficult, time-consuming and impossible to sustain. It took a month to develop one good activity!

The demands brought about by these curriculum changes will be superimposed on the normally hectic and busy reality that is part of everyday life in any classroom. The demands will be greatest on the most vulnerable teachers. Those are the under-qualified teachers (almost half of the teachers in South Africa) who often teach in crowded, poorly-resourced schools far from an infrastructure that could support and guide them. (It was teachers like these who experienced great difficulty in implementing and evaluating the resource materials on the topic: Air Pollution.)

Adequately preparing teachers for these vast changes will not be possible. Financial resources are very limited. At present 80-90% of the education budget is spent on salaries (Vinjevold,

1997) leaving little over for running workshops and structuring support systems to assist teacher" to cope with *Curriculum 2005.* There are indications in this research study that teachers in the rural schools needed more preparation and support than the urban teachers and yet it was difficul because of the geographical location of the schools to accomplish this. Adler et al (1998) repo.. similar early findings with the implementation of *Curriculum 2005.* Dissemination of information regarding *Curriculum 2005* already appears different in urban and rural schools. Teachers in Gauteng report adequate access to information and preparation for the new curriculum. In contrast some teachers in the rural schools report that only a few teachers were invited to preparatory workshops and that information on the new curriculum is scant in their region.

In this study on small curriculum change, the researcher found indications that the **enthusiasm of the teachers** for the introduction of the new topic and the resource materials was a factor in successful implementation. It is highly likely that teachers are enthusiastic about curriculum changes and resource materials that are **intelligible, plausible** and **fruitful** (Thorley and Stofflett, 1996; van den Hoek, 1997). To be **intelligible**, teachers must understand the curriculum changes and how to use the new resources. To be **plausible**, teachers must perceive the changes and new resources to be relevant to their knowledge and skills and the context of the schools in which they work. To be **fruitful** teachers must perceive that the changes and new resources offer ways for improving teaching and learning (Thorley and Stofflett, 1996; van den Hoek, 1997). It appears that the promoters of *Curriculum 2005* have paid scant attention to these very important considerations.

In the light of the sweeping curriculum changes, as proposed in *Curriculum 2005*, and the need for nationwide literacy campaigns, as advised by the FRD and the HSRC, several recommendations can be made as a result of the outcomes of this research study.

8.3. RECOMMENDATIONS

1. *Curriculum 2005* and the FRD and HSRC reports stress the need for improved scientific literacy among South African citizens.

   How can this be achieved?

   The recommendation is made that more STS teaching resource materials which have the development of scientific literacy as one of their main objectives, be designed and implemented in South African schools.

2. *Curriculum 2005* requires that teachers move away from *"the (often single) subject level based textbook towards...a range of materials and media...."* (Department of Education, 1997b).

   How is this to be accomplished?

   The recommendation is made that government set in motion the development of teaching resources (such as the one described in this thesis) which are urgently needed to meet the demands of the new curriculum. The developmental model used in this research where the teaching resource materials were developed under supervision as part of a thesis, should be considered as a low cost but very effective (albeit slow) method of contributing to teaching materials development.

3. *Curriculum 2005* proposes that teachers design their own teaching materials that are relevant to the context of their school and students. The outcomes of this research indicate that this requirement will place unrealistic demands on the teachers both in terms of time and competence.

   How can the goal set by the new curriculum be achieved?

   The recommendation is made that teachers have ready access to a variety of teaching resources that they can adapt and modify to suit their own teaching context. This will help ensure that the scientific content is accurate, and that the materials are relevant to the school context and within the language-skill capabilities of the students. The use of articles from local newspapers and magazines alongside these resources should be encouraged. Such articles are a rich source of the "lay ideas" and "lay terminology" held by the public. Eijkelhof (1994) stresses the importance of addressing these lay ideas and terms in the classroom alongside the scientific terminology and concepts.

4. Constructivism is a major thrust of the new curriculum. Thus, it will be important to reveal the prior knowledge, beliefs and attitudes that students (and teachers) possess particularly about topics in which aspects of science, technology and society are closely related.

   How can the prior knowledge, beliefs and attitudes of students and teachers be revealed?

   The recommendation is made that more instruments like the *Survey on Air Pollution* be designed and administered. Analysis of the outcomes will inform the developers of the new curriculum and teaching materials.

5. The *Report on Further Education* (Department of Education, 1997b) recognises that teachers play a pivotal role in the implementation of new curricula and that in-service training (INSET) programmes should enable teachers to learn new concepts, knowledge, attitudes and skills to cope with the curriculum changes.

   How will this be accomplished?

   The recommendation is made that to inform the promoters of curriculum change and the developers of INSET programmes, more research be conducted into the implementation and evaluation of **small modules of new curricula and teaching materials**. The outcomes of such research will reveal greater insights into the problems and demands faced by teachers in this regard. Feedback must be gained from the teachers and students themselves as to what obstacles hinder the implementation of curriculum innovations in the different school contexts in South Africa.

6. The vast changes being embarked upon in *Curriculum 2005* will place **much heavier** demands on the teachers than those in this research study. These demands will be particularly great on under-qualified teachers in remote, poorly-resourced schools. It appears highly unlikely the implementation of *Curriculum 2005* will achieve the results envisaged by its promoters.

   How, then, can curriculum change come about in South African schools?

   The recommendation is made that curriculum changes for education in South Africa should be **incremental** and **not on the large scale** envisaged by the promoters of *Curriculum 2005.* Small-scale piloting of modules of new curricula and teaching resources in a representative sample of schools should precede large-scale implementation. Curriculum change [illegible] be based on an in-depth understanding of the complexities and realities of the South African context and not on unrealistic, over-optimistic *expectations.*

REFERENCES

Adler, J., Lelliott, T. & Reed, Y. (1998). Mixed-Mode FDEs and Their Effects: A study of the Classroom Practices of Primary and Secondary Mathematics, Science and English Language Teachers in the University of the Witwatersrand Further Diplomas in Education Programme, An Interim Report, Faculty of Education, University of the Witwatersrand, Johannesburg.

African Explosives and Chemical Industry (AECI). (1989). Prospect, 28(4).

Aikenhead, G.S. (1979). *Science: A Way of Knowing,* Science Teacher, 46(6), 23-25.

Aikenhead, G. S. (1987). *High School Graduates Beliefs about Science-Technology-Society. III. Characteristics and Limitations of Scientific Knowledge,* Science Education, 71(4), 459-487.

Aikenhead, G.S. (1988). *An Analysis of Four Ways of Assessing Student Beliefs about STS Topics,* Journal of Research in Science Teaching, 25(8), 607-629.

Aikenhead, G. S. (1994a). *The Social Contract of Science: Implications for Teaching Science* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 11- 20.

Aikenhead, G.S. (1994b). *What is STS Teaching?* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 47-59.

Aikenhead, G.S. (1994c). *Consequences to Learning Science Through STS: A Research Perspective* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 169-186.

Aikenhead, G.S. (1994d). *Collaborative Research and Development to Produce an STS Course for School Science,* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 216-227.

Aikenhead, G.S., Fleming, R.W. & Ryan, A.G. (1987). *High-School Graduates' Beliefs About Science- Technology-Society. I. Methods and Issues in Monitoring Student Views,* Science Education, 71(2), 145-161.

Ajeyalemi, D. (1990). *Science and Technology in Perspective*, in Science and Technology Education in Africa: Focus on Seven Sub-Saharan Countries, ed. D. Ajeyalemi, Lagos: University of Lagos Press, 4-12.

Ajeyalemi, D.(1992). *The Status of STS in Africa*, in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 116-118.

American Chemical Society. (1988). ChemCom - Chemistry in the Community, Dubuque: Kendall/Hunt, 332-397.

Banerjee, A.C. & Yager, R.E. (1992). *Improvement in Student Perceptions of Their Science Teachers, The Nature of Science, and Science Careers with Science/Technology/Society Approaches,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 102-109.

Barrow, G. (1972). General Chemistry, Belmont: Wadsworth.

Beasley, W.F. (1992). *Curriculum Innovation and Teacher Development: The Unbalanced Chemical Equation,* Journal of Chemical Education, 69(1), 57-58.

Benkenstein, H. (1990). Environmental Constraints on Future Mining and Use of Coal, paper presented at the Coal Outlook Conference, Mintek, Johannesburg, South Africa.

Binadja, A. (1992). *Development of Science Process Skills When Science is Taught with a Focus on Science/Technology/Society,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 97-101.

Bodmer, W. (1989). *Scientific Literacy for Health and Prosperity,* School Science Review, 70(253), 9-21.

Bodner, G.M. (1986). *Constructivism: A Theory of Knowledge,* Journal of Chemical Education, 63(10), 873-877.

Boyes, E. & Stanisstreet, M. (1993). *The 'Greenhouse Effect': Children's Perceptions of Causes, Consequences and Cures,* International Journal of Science Education, 15(5), 531-552.

Bradley, J. D. & Brand, M. (1990). The First Course on an Optional Physical Science Topic for TED Science Teacher Leaders and Some of its Implications, University of the Witwatersrand, unpublished notes.

Bradley, J. D. & McCarogher, K. (1996). *Phoenix - from Ashes to Flight in South Africa,* in Synergy: 5 Case Studies on Education-Industry Partnerships, ed R. Isuyama and M. Mapletoft, Chemical Industry Education Centre, University of York, 53- 69.

British Coal Corporation. (1987). Clean Use of Coal, Stroud: Greenaway Publications.

Bronze, L., Heathcote, N. & Brown, P. (1990). The Blue Peter Green Book, London: BBC Books, Sainsbury's.

Brunke, E.G., Scheel, H.E. & Seiler, W. (1990). Measurements of Tropospheric Trace Gases at Cape Point, South Africa since 1978, paper presented at the International Conference on Air Pollution held in Pretoria, South Africa, under the auspices of the National Association for Clean Air.

Bybee, R.W. (1987). *Science Education and the Science-Technology-Society (S-T-S) Theme,* Science Education, 71(5), 667-683.

Bybee R.W. & Mau, T. (1986). *Science and Technology Related Global Problems: An International Survey of Science Educators*, Journal of Research in Science Teaching, 23(7), 599-618.

Byrne, M. & Johnstone, A. (1988). *How to Make Science Relevant*, School Science Review, 70(251), 43-46.

Campbell, B., Lazonby, J., Millar, R., Nicolson, P., Ramsden, J. & Waddington, D. (1994). *Science: The Salters' Approach - A Case Study of the Process of Large Scale Curriculum Development*, Science Education, 78(5), 415-447.

Campbell, I.M. (1986). Energy and the Atmosphere, 2nd ed. New York: John Wiley and sons.

Carson, R. (1962). Silent Spring, Boston: Houghton Mifflin.

Centre for Education Policy Development (CEPD). (1995). *An Approach to Developing a Flexible Core Curriculum for Science and Technology Compulsory General Education,* in Curriculum Frameworks for Science and Technology and Mathematics, Centre for Education Policy Development, Macmillan, Cape Town, South Africa.

Chambers. (1971). Dictionary of Science and Technology, ed. T.C. Collocott. Edinburgh: W & R Chambers.

CHEMSA. (1990). *First Prozone Plant Opened in Africa*, A Special Report, 16(7), 166.

Chen, D. & Novik, R. (1984). *Scientific and Technological Education in an Information Society,* Science Education, 68(4), 421-426.

Clark, W.C. (1989). *Managing Planet Earth,* Scientific American, 261(3), 19-26.

Collins. (1990). Cobuild English Language Dictionary, 3rd ed. London: Collins.

Corcoran, E. (1991). *Cleaning up Coal*, Scientific American, 264(5), 70-80.

Council for Scientific and Industrial Research (CSIR). (1991). *The Situation of Waste Management and Pollution Control in South Africa,* report to the Department of Environment Affairs by the CSIR Programme for the Environment, Pretoria. Report CPE 1/91.

Crocker, R.K. & Banfield, H. (1986). *Factors Influencing Teacher Decisions on School, Classroom and Curriculum,* Journal of Research in Science Teaching, 3(9), 805-816.

Cronin-Jones, L.L. (1991). *Science Teacher Beliefs and Their Influence on Curriculum Implementation: Two Case Studies,* Journal of Research in Science Teaching, 28(3), 235-250.

Department of Internal Affairs. (1985). Education Bulletin, 9, Cape Town, South Africa.

Department of Education. (1997a). Discussion Document: Curriculum 2005, Pretoria, South Africa.

Department of Education. (1997b). Report of the National Committee on Further Education: A Framework for the Transformation of Further Education and Training, Pretoria, South Africa.

Department of Health and Welfare. (1984). Air Pollution in South Africa, Pretoria, South Africa.

Department of National Health and Population Development. (No date given). National Policy for the Protection of the Ozone Layer, Pretoria, South Africa.

Department of National Health and Population Development. (No date given). Draft Air Pollution Control Policy, Pretoria, South Africa.

Dlamini, B., Lubben, F. & Campbell, B. (1994). *Teacher Growth Through Curriculum Innovation: An African Experience,* in UYSEG in Africa, ed B. Campbell, a collection of papers presented at the annual conference of the Southern African Association for Research in Mathematics and Science Education, Durban, 29-42.

Driver, R., Guesne, E. & Tiberghien, A. (1985). *Children's Ideas and the Learning of Science,* in Children's Ideas in Science, ed, R.Driver, E. Guesne and A. Tiberghien, Milton Keynes: Open University Press, 1-9.

Dutkiewicz, R.K. (1990). Clean Coal Processes for Power Generation, paper presented at the International Conference on Air Pollution held in Pretoria, South Africa, under the auspices of the National Association for Clean Air.

Eijkelhof, H.M.C. (1994). *Toward a Research Base for Teaching Ionizing Radiation in a Risk Perspective,* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 205-215.

Eijkelhof, H.M.C. & Kortland, K. (1988). *Broadening the Aims of Physics Education* in Development and Dilemma in Science Education, ed. P.J. Fensham, New York: Falmer Press, 282-305.

Elliott, J.J. & Melchior, M.T. (1978). *Petroleum,* Kirk-Othmer Encyclopedia of Chemical Technology. 17 3rd ed. New York: John Wiley and sons, 119-131.

Els, C.J. (1990). Strategies for Dealing With the Eastern Transvaal Highveld Acidic Deposition Situation, paper presented at the International Conference on Air Pollution held in Pretoria, South Africa, under the auspices of the National Association for Clean Air.

ESKOM. (1989). Koeberg, a General Information Brochure of The Electricity Supply Commission, South Africa.

Fensham, P.J. (1988). *Familiar but Different: Some Dilemmas and new Directions in Science Education,* in Development and Dilemma in Science Education, ed. P.J. Fensham, New York: Falmer Press, 1-26.

Fleming, R. (1987). *High-School Graduates' Beliefs about Science-Technology-Society. II. The Interaction Among Science, Technology and Society,* Science Education, 71(2), 163-186.

Fleming, R. (1989). *Literacy for a Technological Age,* Science Education, 73(4), 391-404.

Foundation for Research Development (FRD). (1996). *Public Understanding of Science,* in South African Science and Technology Indicators, Pretoria: Directorate for Science and Technology Policy, Foundation for Research Development, 149-169.

Fuggle, R.F. & Rabie, M.A. (1983). Environmental Concerns in South Africa (Technical and Legal Perspectives), Cape Town: Juta and Co.

Fullan, M.G. (1995). Successful School Improvement - The Implementation Perspective and Beyond, 2nd ed. Buckingham: Open University Press.

Gandar, M. (1990). *Making Energy Environment Friendly,* Earthyear 90: Environmental Issues Facing South Africa.

Gardner, P.L. (1996). *The Dimensionality of Attitude Scales: A Widely Misunderstood Idea,* International Journal of Science Education, 18(8), 913-919.

Gerrans, G.C. (1986). Memorandum on Some Aspects of University Teaching and Learning, Paper prepared at University of East Anglia.

Gibbons, J. H., Blair, P.D. & Gwin, H. L. (1989). *Strategies for Energy Use,* Scientific American, 261(3), 86- 93.

Goldsmith, E. & Hildyard, N. (1990). The Earth Report 2. Monitoring the Battle for Our Environment, London: Mitchell Beazley.

Graedel, T.E. & Crutzen, P.J. (1989). *The Changing Atmosphere,* Scientific American, 261(3), 28-36.

Hammerman, E. & Voelker, A.M. (1987). *Research Based Objectives for Environmental Education: Consensus on the Past; A Base for the Future,* Science Education, 71(1), 29-40.

H[illegible] J. (1992). *Science Education Reform in Korea,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 111-115.

Harris, E. A. (1993). The Design, Implementation and Evaluation of a Teaching Resource Package on Chemical Bonding, MSc Dissertation, University of the Witwatersrand, Johannesburg.

Hart, E.P. & Robottom, I.M. (1990). *The Science-Technology-Society Movement in Science Education: A critique of the Reform Process,* Journal of Research in Science Teaching, 27(6), 575-588.

Haukoos, G.D. & Penick, J.E. (1987). *Interaction Effect of Personality Characteristics, Classroom Climate, and Science Achievement,* Science Education 71(5), 735-743.

Hill, G. (1991). Science Education 2010, paper presented at the SAATPS National Convention on Mathematics and Natural Science Education in Cape Town, South Africa, July.

Hobbs, J.C.A., De Reuck, A.J. & Graupner, O.F. (1989). Environmental Impact Management: A Determining Factor of Energy Futures in Southern Africa, paper presented at the World Energy Conference 14th Congress, Montreal.

Hobbs, J.C.A & Boland, B. (1991). *Owning the Environmental Problem: From Rhetoric to Action in Business,* Institute of Personnel Management (IPM) Journal, February, 14.

Hodson, D. (1993). *In Search of a Rationale for Multicultural Science Education,* Science Education, 77(6), 685-711.

Hodson, D. & Reid, D. (1988). *Changing Priorities in Science Education. Part I,* School Science Review, 70(250), 101-108.

Hofstein, A. (1989). Making School Chemistry More Relevant by Introducing Chemical Industry into the Curriculum, paper presented at the South African Chemical Institute 30th Convention, 1989.

Hofstein, A., Scherz, Z. & Yager, R.E. (1986). *What Students Say About Science Teaching, Science Teachers and Science Classes in Israel and the U.S.,* Science Education, 70(1), 21-30.

Holbrook, J.B. (1992). *Teaching Science the STS Way,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 9-13.

Hord, S. (1987). Evaluating Educational Innovation, New York: Croom Helm.

Horgan, J. (1991). *Up in Flames,* Scientific American, 264(5), 7-9.

Huang, D.S. (1992). *STS in the Preparation of Elementary Science Teachers,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 40-46.

Human Sciences Research Council (HSRC). (1981). Teaching of the Natural Sciences and Mathematics, Report of the Work Committee, Pretoria, South Africa.

Human Sciences Research Council (HSRC). (1998). Mathematics and Science Literacy of Final-Year School Students in South Africa, A Report on the Performance of South African Students in the Third International Mathematics and Science Study (TIMSS), Pretoria, South Africa.

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

Hunt, J. A. & Lenton, G. (1992). *SATIS 16-19 on Trial in the UK,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 19-25.

Hunt, J. A. & Phillips, P.S. (1991). *SATIS 16-19: The Chemistry Component,* Chemistry in Britain, 27, 1130-1132.

Huntley, B., Siegfried, R. & Sunter, C. (1989). South African Environments into the 21st Century, Cape Town: Human & Rousseau.

Imenda, N.S. (1990). *Swaziland,* in Science and Technology Education in Africa: Focus on Seven Sub-Saharan Countries, ed. D. Ajeyalemi, Lagos: University of Lagos Press, 70-85.

International Council of Scientific Unions (Committee on Teaching Science) (ICSU) (1991). The Changing Atmosphere and The Global Carbon Cycle, Prototype Units of Education in Global Change.

International Union of Pure and Applied Chemistry (IUPAC). (1987). Compendium of Chemical Terminology, Oxford: Blackwell Scientific Publications.

International Union of Pure and Applied Chemistry (IUPAC). (1990). *Glossary of Atmospheric Chemistry Terms (Recommendations 1990)*, Pure and Applied Chemistry, 62(11), 2167-2219.

Jacob, A.T. (1991). *Chlorofluorocarbons and the Hole in the Ozone Layer,* Topics in Chemistry. Institute for Chemical Education, University of Wisconsin (Madison).

Jegede, O.J. (1994). *African Cultural Perspectives and the Teaching of Science,* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 120-130.

Jegede, O.J. (1997). *School Science and the Development of Scientific Culture: A Review of Contemporary Science Education in Africa,* International Journal of Science Education, 19(1), 1-20.

Jenkins, E. (1990). *Scientific Literacy and School Science Education,* School Science Review, 71(256), 43-51.

Jones, M. (1988). *In Search of the Safe CFCs,* The New Scientist, 118(1614), 56-58.

Kahn, M. (1995). *Some Policy, Process and Implementation Issues facing Science Education and Training in Post-Apartheid South Africa,* International Journal of Science Education, 17(4), 441-452.

Keyfitz, N. (1989). *The Growing Human Population,* Scientific American, 261(3), 71-77.

Koballa, T.R. (1992). *Persuasion and Attitude Change in Science Education,* Journal of Research in Science Teaching, 29(1), 63-80.

Kornberg, H. (1991) *Science and Environmental Awareness,* School Science Review, 72(261), 7-14.

Kortland, K. (1992). *Environmental Education: Sustainable Development and Decision-Making,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 32-39.

Kyle, W.C. (1995). *Scientific Literacy: Where Do We Go From Here?* Journal of Research in Science Teaching, 32(10), 1007-1009.

Kyle, W.C., Bonnstetter, R.J. & Gadsen, T. (1988). *An Implementation Study: An Analysis of Elementary Students' and Teachers' Attitudes towards Science in Process-Approach vs Traditional Science Classes,* Journal of Research in Science Teaching, 25(2), 103-120.

Laburn, R.J. (1990). The Air Around Us, paper presented at World Environment Day Symposium, held in Randburg, South Africa, under the auspices of The Associated Scientific and Technical Societies of South Africa, The Society of Professional Engineers, The Habitat Council and The Environmental Planning Professions Interdisciplinary Committee.

Layton, D. (1994). *STS in the School Curriculum: A Movement Overtaken by History?* in STS Education International Perspectives on Reform, ed. J. Solomon and G. Aikenhead, New York:Teachers College Press, 32-44.

Lean, G., Hinrichsen, D. & Markham, A. (1990). Atlas of the Environment, London: Arrow Books.

Lederman, N.G. & Zeidler, D.L. (1987). *Science Teachers' Conceptions of the Nature of Science: Do They Really Influence Teaching Behaviour?* Science Education, 71(5), 721-734.

Leggett, J. (1990). Global Warming. The Greenpeace Report, Oxford: Oxford University Press.

Lenton, G. (1990). *SATIS 16-19: A Preliminary Review of School Trials,* School Science Review, 71(257), 135-140.

Lewin, K.M. (1992). Science Education in Developing Countries: Issues and Perspectives for Planners, Paris: International Institute for Educational Planning, UNESCO.

Lewis, J. (1981). Science in Society, London: Heinemann Educational Books.

Lovelock, J.E. (1989) Gaia - A New Look at Life on Earth, Oxford:Oxford University Press.

Lubben, F., Campbell, B. & Dlamini, B. (1994). *A Technological Approach to Science Teaching: Some Reactions of Swazi Secondary School Students,* in UYSEG in Africa, ed B. Campbell, a collection of papers presented at the annual conference of the Southern African Association for Research in Mathematics and Science Education, Durban, 43-58.

MacNeill, J. (1989). *Strategies for Sustainable Economic Development,* Scientific American 261(3), 105-113.

Manahan, S.E. (1979). Environmental Chemistry, 3rd ed. Boston: Willard Grant Press.

Matsie, W.M. (1988). Problems Encountered in Southern African Educating Rural and Urban Blacks on Clean Air , paper presented at the International Conference on Residential Air Pollution held in Pretoria , South Africa, under the auspices of the National Association of Clean Air.

McGraw-Hill. (1984). Dictionary of Scientific and Technical Terms, 3rd ed. New York: McGraw-Hill Book Co.

McIntosh, W.J. & Zeidler, D.L. (1988). *Teachers' Conceptions of the Contemporary Goals of Science Education,* Journal of Research in Science Teaching, 25(2), 93-102.

Meyer, C. (1991). *Public Perceptions of Some Chemical Topics (Part Three),* CHEMSA, 17(3), 61-62.

Miller, J. D. (1983). *A Conceptual and Empirical Review,* Daedelus, 96(1), 29-48.

Miller, J. D. (1989). Who is Scientifically Literate? Paper presented to the AAAS Science Education Forum, American Association for the Advancement of Science, Washington, DC.

Mitchener, C.P. & Anderson, R.D. (1989). *Teachers' Perspective: Developing and Implementing an STS Curriculum,* Journal of Research in Science Teaching, 26(4), 351-369.

Myers, L.H. (1992). *STS and Science Concepts,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 76-80.

Nae, N., Hofstein, A. & Samuels, D. (1980). *Chemical Industry - A New Interdisciplinary Course for Secondary Schools,* Journal of Chemical Education, 57(5), 366-368.

National Education Policy Initiative (NEPI). (1992). Science Curriculum Report, occasional paper, Johannesburg: Centre for Education Policy Development.

Nganunu, M. (1988). *An Attempt to Write a Science Curriculum with Social Relevance for Botswana,* International Journal of Science Education, 10(4), 441-448.

Nganunu, M. (1992). *Inclusion of Indigenous Technology in School Science Curricula: A Solution for Africa?* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 119-124.

Ngcatshe, S.M. (1988). Impressions and Aspirations of the Black People in the Western Cape, paper presented at the International Conference on Residential Air Pollution held in Pretoria, South Africa, under the auspices of the National Association of Clean Air.

Ogunniyi, M.B. (1986). *Two Decades of Science Education in Africa,* Science Education, 70(2), 111-122.

Pearce, F. (1982). *The Menace of Acid Rain,* New Scientist, 95(1318), 419-424.

Pedersen, J.E. (1992). *The Jurisprudential Model of Study for STS Issues,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 26-31.

Pedretti, E. & Hodson, D. (1995). *From Rhetoric to Action: Implementing STS Education through Action Research,* Journal of Research in Science Teaching, 32(5), 463-485.

Penick, J.E. (1992). *STS Instruction Enhances Student Creativity,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 81-86.

Phillips, P. & Pickering, P. (1991). *Ozone in the Atmosphere: II The Lower Atmosphere,* School Science Review, 72(260), 79-86.

Pimentel, C.G.& Coonrod, J.A. (1987). Opportunities in Chemistry Today and Tomorrow, Washington: National Academy Press.

Preston-White, R.A., and Tyson, P.D. (1988). The Atmosphere and Weather of Southern Africa, Cape Town: Oxford University Press.

Project Ecos (1991). *These Are Our Worst Nightmares,* Star Newspaper, Johannesburg, South Africa, February 7.

Ramontja, R.M. (1988). Health Education on Control of Air Pollution, paper presented at the International Conference on Residential Air Pollution held in Pretoria, South Africa, under the auspices of the National Association of Clean Air.

Ramsden, J. (1992). *Going in Through Both Ears and Staying There: The Salters' Approach to Science,* The Australian Science Teachers Journal, 38(2), 13-18.

Ramsden, J. (1994). *Curriculum Development and Research in Science Education: The Salters' Experience,* in UYSEG in Africa, ed. B. Campbell, a collection of papers presented at the annual conference of the Southern African Association for Research in Mathematics and Science Education, Durban, 7-18.

Ramsey, J. (1993). *The Science Education Reform Movement: Implications for Social Responsibility,* Science Education, 77(2), 235-258.

Robottom, I. (1989). *Social Critique or Social Control: Some Problems for Evaluation in Environmental Education,* Journal of Research in Science Teaching, 26(5), 435-443.

Robottom, I. & Hart, P. (1993). *Towards a Meta-research Agenda in Science and Environmental Education,* International Journal of Science Education, 15(5), 591-605.

Rubba, P.A. & Harkness, W.L. (1993). *Examination of Preservice and In-Service Secondary Science Teachers' Beliefs about Science-Technology-Society Interactions,* Science Education, 77(4), 407-431.

Ruckelshaus, W.D. (1989). *Toward a Sustainable World,* Scientific American, 261(3), 114-120.

Ryan, A.G. (1992). *VOSTS: A Way of Expanding Classroom Assessment to Meet the STS Agenda in Secondary School Science,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 57-66.

Ryan, C. (1991). *Clearing the Air: Special Report commissioned by ESKOM,* Leadership, 10(3), 73-80.

Sabar, N. (1986). *Is the Disappointment in the Implementation of New Science Curricula Justified?: A Study Quantifying Descriptive Data,* Journal of Research in Science Teaching, 23(6), 475-491.

Sarre, P., Smith, P. & Morris, E. (1991). One World for one Earth. Saving the Environment, London: Earthscan Publications Ltd in association with The Open University.

SASOL. (1991). SASOL NEWS, 3(2).

Schibeci, R.A. (1981). *Do Teachers Rate Science Attitude Objectives as Highly as Cognitive Objectives?* Journal of Research in Science Teaching, 18(1), 69-72.

Schibeci, R.A. (1986). *Images of Science and Scientists and Science Education,* Science Education, 70(2), 139-149.

Schneider, S. H. (1989). *The Changing Climate,* Scientific American, 261(3), 38-47.

Schumacher, S. & McMillan, J.H. (1993). Research in Education: A Conceptual Introduction, New York: HarperCollins College Publishers.

Shamos, M.H. (1995). The Myth of Scientific Literacy, New Brunswick, NJ: Rutgers University Press.

Shrigley, R.L., Koballa, T.R. & Simpson, R.D. (1988). *Defining Attitude for Science Educators,* Journal for Research in Science Teaching, 25(8), 659-678.

Shymansky, J.A. & Kyle, W.C. (1992). *Establishing A Research Agenda: Critical Issues of Science Curriculum Reform,* Journal of Research in Science Teaching, 29(8), 749-778.

Slanina, S. (1991). *Uncertainties in Atmospheric Carbon Dioxide Concentrations,* Chemistry International, 13(1), 10-14.

Smith, C., Keogh, M., Mahlatsi, L., Mashimbye, E., McCarogher, K., Ogude, A., Pomario, W., van den Hoek, A-K., White, M. (1998). Topics in Science and Technology, Sandton: Heinemann.

Smith, D. (1987). Electricity a Bright Idea!, a South African Broadcasting Corporation Educational Publication.

Smith, N. (1988). *In Support of an 'Applications-first' Chemistry Course: Some Reflections on the Salter's GCSE Scheme,* School Science Review, 70(250), 108-114.

Solomon, J. (1983). Science in a Social Context (SISCON) in Schools, Oxford: Basil Blackwell.

Solomon, J. (1988). *The Dilemma of Science, Technology and Society Education,* in Development and Dilemma in Science Education, ed. P.J. Fensham, New York: The Falmer Press, 266-281.

Solomon, J. (1992). *The Classroom Discussion of STS Issues: Public Understanding of Science in the Making,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 67-75.

Solomon, J. (1994a). *Conflict between Mainstream Science and STS in Science Education,* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 3-10.

Solomon, J. (1994b). *Toward a Map of Problems in STS Research,* in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 187-193.

South African Association of Teachers of Physical Science (SAATPS). (1978). A Science Policy for South Africa, document produced at Workshop in Cape Town, South Africa, July.

Spedding, D.J. (1974). Air Pollution, Oxford: Clarendon Press.

Stanisstreet, M. & Boyes, E. (1994). *Children and the Environment: Awareness for Understanding?* Education Forum, Science Education Newsletter, (114), Manchester: The British Council.

Stoker, H.S. & Seager, S.L. (1972). Environmental Chemistry, London: Scott Foresman.

Stolarski, R.S. (1988). *The Antarctic Ozone Hole,* Scientific American, 258(1), 20-26.

Strauss, W.& Mainwaring, S.J. (1984). Air Pollution, London: Edward Arnold.

Sutman, F.X. (1992). *Chemistry in the Community - ChemCom: A Five Year Evaluation,* Journal of Chemical Education, 69(7), 564-567.

Tamir, P. (1992). *Integrating Research and Curriculum Development: Curriculum Development in Israel,* Studies in Science Education, 20, 183-188.

The Royal Society of Chemistry (Education Division). (1998). Research in Assessment XIII, An Updated Report on the Skills Test Survey of Chemistry Degree Course Entrants by the Assessment Subject Group, London: The Royal Society of Chemistry.

Toon, O.B. & Turco, R.P. (1991). *Polar Stratospheric Clouds and Ozone Depletion,* Scientific American, 264(6), 40-47.

Trowbridge, L. & Bybee, R. (1990). Becoming a Secondary School Science Teacher, New York: Merrill.

Tyson, P.D., Kruger, F.J. & Louw, C.W. (1988). Atmospheric Pollution and its Implications in the Eastern Transvaal Highveld, South African National Scientific Programmes Report No 150, Council for Scientific and Industrial Research, Pretoria.

Van Den Hoek, A-K. (1997). Instructional Materials in Science Curriculum Change in South Africa, PhD thesis, University of the Witwatersrand, Johannesburg.

Varrella, G.F. (1992). *Greater Ability to Apply Concepts using a Science/Technology/Society Approach to Teaching Science,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 87-92.

Vinjevold, P. (1997). *The Role of Materials in the New Curriculum*, JET Bulletin, (7), Johannesburg: Joint Education Trust, 8-9.

Volk, T.L. (1984). *Project Synthesis and Environmental Education*, Science Education, 68(1), 23-33.

Vorres, K.C. (1978). *Coal*, Kirk-Othmer Encyclopedia of Chemical Technology, 6 , 3rd ed. New York: John Wiley and sons, 423-487.

Waks, L.J. & Barchi, B.A. (1992). *STS in U.S. School Science: Perceptions of Selected Leaders and Their Implications for STS Education*, Science Education, 76(1), 79-90.

Walberg, H.J. (1991). *Improving School Science in Advanced and Developing Countries*, Review of Educational Research, 61(1), 25-69.

Walker, D. (1990). *The Evaluation of SATIS*, School Science Review, 72(259), 31-39.

Walmsley, B. (1991). *The Impact of the Green Movement on the Chemical Industry in the UK and the USA, and Industry's Response*, ChemSA, 17(8), 195-199.

Wayne, R.P. (1985) Chemistry of Atmospheres: An Introduction to the Chemistry of the Atmospheres of Earth, the Planets and their Satellites, Oxford: Clarendon Press.

Webb, C. (1993). *Teacher Perceptions of Professional Development Needs and the Implementation of the K-6 Science and Technology Syllabus*, Research in Science Education, 23, 327-336.

Whittle, P., Gray, B., Hodzi, R. & Manana, L.(1993). Innovative Ideas and Techniques for Science Educators in Africa, Zomba: ICSU.

Williams, B. (1994). *Teacher-Assisted STS Learning*, in STS Education International Perspectives on Reform, ed. J. Solomon and G.Aikenhead, New York:Teachers College Press, 60-67.

Winter, G. (1990). Environmentalist Management. An innovative management model, paper presented at an Environmental Seminar: Environmental Responsibility - The Business Dimension, Megawatt Park, Johannesburg, South Africa.

Yager, R.E. (1986). *Searching for Excellence*, Journal of Research in Science Teaching, 23(3), 209-217.

Yager, R.E. (1992a). *Science-Technology-Society as Reform* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 2-8.

Yager, R.E. (1992b). *The Constructivist Learning Model: A Must for STS Classrooms,* in The Status of Science-Technology-Society Reform Efforts around the World, ed. R.E. Yager, International Council of Associations for Science Education Yearbook, 14-17.

Yager, R.E. & Penick, J.E. (1986). *Perceptions of Four Age Groups Toward Science Classes, Teachers and the Value of Science,* Science Education, 70(4), 355-363.

Yager, R.E. & Penick, J.E. (1987). *Resolving the Crisis in Science Education: Understanding Before Resolution,* Science Education, 71(1), 49-55.

Yager, R.E. & Penick, J.E. (1988). *Changes in Perceived Attitudes toward the Goals for Science Instruction in Schools,* Journal of Research in Science Teaching, 25(3), 179-184.

Yager, R.E. & Tamir, P. (1993). *STS Approach: Reasons, Intentions, Accomplishments, and Outcomes,* Science Education, 77(6), 637-658.

Author White M D
Name of thesis Designing, Implementing And Evaluating A Science-Technology-Society (Sts) Teaching Resource Package On Air Polution Volume 1 White M D 1998

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.