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2014-03-20
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The development and evaluation of a package for teaching critical thinking skills in biology

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A research project submitted to the Faculty of Science, University of the Witwatersrand, as partial fulfilment of the requirements for the degree of Master of Science

Johannesburg, February 1998

ABSTRACT

This study focused on the teaching of the skills of critical thinking to Standard Seven pupils by means of a specific teaching package designed for the purpose.

The teaching package was designed to determine whether critical thinking skills which are taught as an explicit and stated goal of each lesson, and then applied in the context of the subject being taught, in this case biology, will be more effectively learned. A secondary objective was to determine whether the skills learned by this means would transfer to another subject domain. Five specific principles of critical thinking were identified and selected for the teaching package. Each of these was incorporated in a specific lesson on critical thinking which was followed by a lesson on a biological topic which applied the particular principle. The lessons on critical thinking were linked to the topic of Health, a section of the Standard Seven biology syllabus.

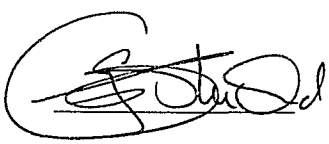
A non-random sample consisting of 58 girls in Standard Seven at a girls' school was used for the investigation, with 38 girls assigned to the experimental group and 20 to the comparison group. A pre-test on critical thinking was given to determine the initial level of ability of the pupils in critical thinking. A post-test on critical thinking was administered at the end of the intervention period to determine whether the intervention had brought about an improvement in critical thinking. The data from the test instruments was analysed by means of an analysis of covariance (ANCOVA). When a non-random sample is used, ANCOVA adjusts for possible initial differences between the experimental and comparison groups with regard to the covariate.

The results suggest that the pupils in the experimental group, who were exposed to the teaching intervention, improved their critical thinking skills in a number of categories, when compared with the comparison group as well as with their own initial ability level. The gain in mean scores on the post-test by the experimental group, having corrected for initial group differences, were statistically significant for the *"total number of thinking skills used"* ($p < 0.0001$) and for the *"number of principles of critical thinking applied"* ($p = 0.03$). Analysis of individual principles of critical thinking showed a statistically significant gain for the principle *"gather complete information before drawing a conclusion"* ($p < 0.0001$) and for the principle *"question the methods by which the information was derived"* ($p < 0.05$), while the mean scores for the other principles showed no statistically significant gain.

Analysis of the results of the test for transferability of the skills of critical thinking to another subject domain found that the pupils in the experimental group, when tested on critical thinking through the medium of geography, achieved results which were statistically significantly better than the comparison group ($p < 0.0005$). This suggests that there was a transfer of the skill of critical thinking to another subject domain.

DECLARATION

I declare that, apart from the assistance acknowledged, this is my own unaided work. It is being submitted as a partial requirement for the degree of Master of Science at the University of the Witwatersrand, and has not been submitted before for any degree or examination in any other university.



Charles Orsmond

18th day of FEBRUARY 1998

ACKNOWLEDGEMENTS

I should like to express my thanks and appreciation to a number of people for the assistance and encouragement given to me during the course of this research.

In particular, I am grateful and indebted to my supervisor, Dr Martie Sanders, for the many hours she spent checking my work. I have learnt a great deal from her meticulous attention to detail and accuracy, her sense of logic and structure, and her wisdom. I appreciated her patience and understanding of the pressures and time constraints under which I was working, and wish to thank her for her support. I am also grateful for the materials and lesson ideas which she allowed me to use in preparing the teaching package.

I wish to thank my wife for all her assistance and support during the time that I was involved in the research. Her patience in listening to my ideas and questions, and the time spent checking and proof-reading the drafts, and the encouragement given, helped to make this research possible.

I wish to thank all those people from St. Andrews School who helped make this research possible.

- Mr Simmonds, the headmaster of the school, for allowing me to use the school for the research project.
- A special word of thanks to the two teachers who taught the classes involved in the research. I appreciated their enthusiasm and hard work. They were co-operative and went out of their way to make it successful.
- The pupils who were involved in the research for their enthusiasm and work.

I wish to thank the two "experts" from the university of the Witwatersrand, Dr Sue McCarthy and Ms Meg Doidge, who checked the pre-test, post-test and transferability test with such care. I appreciated the constructive comments that they made about the tests.

I wish to acknowledge the use of some questions for the pre-test and post-test, taken from the research work of Zohar, et al. (1994), and Dreyfus and Jungwirth, (1980). They provided the initial structure for the development of the instruments which were used in the research.

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CHAPTER I

THE CONTEXT OF THE STUDY

1.1 INTRODUCTION

This study involves research into the effectiveness of teaching the skills of critical thinking. From a review of literature on the subject, an approach to the teaching of the skills of critical thinking was developed and a research design planned to test this approach. This report describes the research project which tested this approach and discusses the findings.

1.2 BACKGROUND TO THE RESEARCH

It is the opinion of this researcher that there appears to be a problem with regard to the approach to the teaching of biology in many schools in South Africa. This opinion is based on the experience gained by this researcher, firstly as a member of the examination panel for biology for the senior certificate examinations for the former Transvaal Education Department, and secondly as a headmaster of a large secondary school. A strong emphasis appears to be placed on the learning of facts, with little emphasis on process skills or thinking skills. This occurs despite the requirement of many of the syllabi in the sciences that a skills-based approach be followed. In the early 1970's there was a strong movement in the former Transvaal Education Department towards the approach being followed in the United Kingdom under the Nuffield system, and in the United States under the Biological Sciences Curriculum Study (BSCS) approach. A number of in-service training courses were held for biology and science teachers in this province, encouraging the use of practical work in the classroom and an emphasis on the development of skills. Despite these initiatives a rote learning approach still prevailed in many schools and still does today. Possible reasons for the lack of emphasis of these skills in the approach to teaching and in the continued emphasis on factual content in many schools include the following points.

- There is a strong factual emphasis in most of the matriculation examinations set in South Africa. Sanders and Doidge (1994) contend that there is little doubt that assessment styles dictate the type of teaching and learning that takes place in South African schools. This contention is supported by Raubenheimer (1992) and Schuster (1992). Tamir (1978) refers to the fact that research internationally has shown that examinations influence classroom practice. In Israel it was recognised that examination boards play a crucial role in what is taught in school, and as a result all innovative science programmes were given the mandate to design matriculation examinations for their students.
- The possibility exists that many teachers are uncertain of what skills to teach or how to teach the skills. Beyer and Charlton (1986) indicate that teachers generally focus on the subject matter rather than on the skills they believe they are teaching. Sanders and Doidge (1994) point out that teachers associated with the Independent Examinations Board (IEB), as well as elsewhere in

South Africa, have expressed the need for in-service training to equip them for a move towards the teaching of skills in biology.

More recently, as a committee member of the Association for the Study of Evaluation in Education in Southern Africa (ASEESA), the researcher became involved in organising a workshop entitled "The assessment of thinking skills in the classroom". This included a workshop on the topic for biology teachers which was run by Sanders and Doidge (reported in Sanders and Doidge, 1994). They made the comment that *"neither the majority of the staff involved in planning the ASEESA workshops, nor the teachers who attended the biology workshop, were quite sure what it* [thinking skills] *meant"*. At this workshop the jargon "thinking skills in biology" was explained as *"the skills which biology scholars were expected by their teachers to have in order to successfully complete any task given them in biology which requires them to think"* (Sanders and Doidge, 1994, 5).

If teachers are unsure of the meaning of "thinking skills" it stands to reason that they know even less about teaching methods which could be used with success for teaching thinking skills.

From the above discussion, it is suggested that there are a number of problems inherent in introducing any initiative with regard to the teaching of thinking skills, which could jeopardise the success of the initiative.

- If a majority of teachers do not fully understand what is meant by "thinking skills", and do not know how best to teach them, they are likely to find it difficult to implement the recommendations.
- If there is doubt as to which methods and approach are likely to be successful, teachers may be reluctant to attempt to teach thinking skills.
- If the teaching of thinking skills is to be promoted, it is suggested that various approaches and methods suited to teaching the different aspects of the skills involved should be advocated. Ideally these approaches should be backed by research findings.
- If the final examination does not assess thinking skills it is unlikely that the teachers will emphasise these skills in their teaching.

One of the initiatives set in motion for improving the teaching of skills is that of the IEB. Teachers from schools involved in the IEB have formed a Biology User Group (BUG) which has been working on the development of a curriculum which involves the teaching of skills, including thinking skills (Ayerst and Sanders, 1992). BUG has provided a valuable input into the teaching of skills in Biology by identifying which skills should be taught, organising workshops on how to teach and assess these skills, and preparing teaching and learning materials. It has also been responsible for the development of a new skills-based Senior Biology syllabus which was implemented in 1996.

An aspect of thinking skills which is regarded as important is that of critical thinking. Two important points emerge from the survey of literature on the teaching of critical thinking (see Chapter II).

- The goal of teaching critical thinking is a desirable and valued aim of education.
- Despite its recognised importance, the goal of teaching critical thinking has generally not been achieved.

Though there are many suggestions on how to develop the skill of critical thinking, relatively little research has been done. Investigation into the teaching of critical thinking would thus be of benefit not only to the IEB initiative but to the broader field of education. This study thus involves research into the effectiveness of an approach to the teaching of the skill of critical thinking.

1.3 STATEMENT OF THE PROBLEM

Investigation into the origins of the goal of critical thinking shows that critical thinking has been a desired outcome of education for many centuries. Morgan (1995) argues that it can be traced at least as far back as Socrates (469-399 B.C.). The Socratic approach entails the questioning of definitions and ideas and then rebuilding them from first principles. Michael de Montaigne (1533-1592) stated that *"the best method of leading a boy to make knowledge a personal possession is to turn every lesson into an occasion for the exercise of his own judgement. It is not enough that he should simply repeat what he has been told"* (Boyd and King, 1975, cited by Morgan, 1995, 337). The teaching of critical thinking is still an important goal of educationists in many countries today (Beyer and Charlton, 1986; Young, 1993; Zohar, *et al.*, 1994).

Yet, despite the fact that critical thinking has for so long been regarded as an important aim of education, the level of success that has been achieved in teaching critical thinking remains in question (Beyer and Charlton, 1986; Dunn, 1988; Jungwirth and Dreyfus, 1990). Zohar *et al.* (1994) state that studies that assess critical thinking ability in students have revealed that students often fail in tasks that require critical thinking.

An opinion survey of teachers who attended certain in-service workshops held in the former Transvaal suggests that a problem exists with regard to the teaching of skills in biology classrooms in South Africa (Ayerst and Sanders, 1992). It is thus likely that there is even more of a problem relating to the teaching of critical thinking.

The problem thus, as it relates to this research, is that there appears to be little emphasis on the teaching of the skill of critical thinking in many biology classrooms in South Africa. The problem is further exacerbated by the possibility that many of the teachers do not understand the meaning of "critical thinking" or know how the skill of critical thinking should be taught.

1.4 THE PURPOSE OF THE RESEARCH

The purpose of this research was thus to develop an effective strategy for teaching critical thinking according to the advice in the literature on the topic. In planning this strategy for teaching critical thinking the following two aspects were taken into consideration.

- **What principles of critical thinking should actually be taught?**

  What to teach must be based on a clear understanding of the concept of critical thinking gained from educational theory and research.

- **How can these principles be taught effectively?**

  How to teach critical thinking must be based on

  * the theories of learning relevant to such a programme,
  * the approaches which have yielded success in the past, and must take into account
  * the reasons for the lack of success in teaching critical thinking in the past.

1.5 THE SPECIFIC AIMS OF THE RESEARCH

The research had two aims: firstly, to develop a teaching package which can be used by South African biology teachers to teach critical thinking skills, and secondly, to evaluate the effectiveness of the package in teaching critical thinking.

1.6 RESEARCH QUESTIONS

Question 1. If standard 7 pupils are specifically taught critical thinking skills, does their ability to think critically improve significantly more than a group that is just expected to use the skills without being taught how to use them?

Question 2. If pupils do learn the skills of critical thinking by means of this approach, will they transfer and apply the skills to another subject?

1.7 IMPORTANCE OF THE STUDY

The teaching of the skill of critical thinking is accepted as an important goal of teaching, which, if achieved, will impart *"skills that are useful not just in the science classroom, but in all disciplines, including government, economics, sociology, literature and law"* (Chiras, 1992). It is hoped that the information gained in this study will be of use to South African curriculum developers and teachers who are concerned about the development of critical thinking skills in their biology pupils.

CHAPTER II

THE TEACHING OF CRITICAL THINKING

The following discussion on educational theory and research findings forms the foundation for the development of the teaching strategy for critical thinking investigated in this study. This background information clarifies the following aspects: what is meant by "critical thinking"; the long-standing goal of teaching critical thinking and why critical thinking is regarded as important; and factors affecting the failure or success of the teaching of critical thinking. It also looks at levels of evaluation of critical thinking seen in the literature on this subject.

2.1 DEFINING CRITICAL THINKING

If the goal of teaching critical thinking is to be promoted in schools, a clearer understanding of what is meant by "critical thinking" is necessary in order to successfully formulate an approach to the teaching of critical thinking. Lipman (1988) says that if critical thinking is to be fostered and strengthened at school level, educators need to know its defining features, its characteristic outcomes and the underlying conditions that make it possible. The aim of this research is to develop an approach to the teaching of critical thinking which could be generally used in South African schools, and not limited to being taught in the context of Science. The defining of critical thinking must thus relate to the broader field of critical thinking.

From the definitions of critical thinking given by different authors, the following features emerge:

2.1.1 Critical thinking is characterised by "reflective thinking"

Critical thinking has to do with whether individuals think reflectively, rather than simply accepting statements and carrying out procedures without a significant understanding and evaluation (Hudgens and Edelman, 1986; Lipman, 1988; Greeno, 1989; Chiras, 1992; Chaffee, 1992). Tyser and Cerbin (1991) refer to this aspect of the skill of critical thinking as the "logical line of reasoning". Ennis (1985 45) as says that *"critical thinking is reflective and reasonable thinking that is focused on deciding what to believe or do."*

Regardless of the discipline involved, this aspect of critical thinking is remarkably similar. For the biological scientist, this process of reflective thinking would be applied to research findings and theories, and to the experimental procedures used in research. Chiras (1992, 464) suggests for the biological scientist, critical thinking is *"a process by which one subjects research findings and theories to examination"*. In history and in political science this approach to thinking is used in order to distinguish

facts from judgements. For the man-in-the-street it enables the assessment of the accuracy of the information presented from various sources, such as the media. According to Tyser and Cerbin (1991) the skill allows the individual to determine, on the evidence provided, whether a claim made in relation to an issue should be conditionally accepted, or not accepted.

2.1.2 Critical thinking is facilitated by the use of criteria, rules and principles

If critical thinking involves "reflective thinking" it should be understood that this reflective thinking is not a random, directionless process, but an intellectually disciplined process which employs certain rules or principles. Morgan (1995) refers to a definition of critical thinking gained from information provided at the Thirteenth International Conference on Critical Thinking held at Sonoma State University in August 1993 as:

> *"a unique kind of purposeful thinking in which the thinker systematically and habitually imposes criteria and intellectual standards upon the thinking, taking charge of the construction of thinking, guiding the construction of the thinking according to the standards, assessing the effectiveness of the thinking according to the purpose, the criteria and the standards."*
>
> (Morgan, 1995, p338).

Lipman (1988) argues that "reasonable, reflective thinking" is too vague a definition. He contends that critical thinking is skilful, responsible thinking that relies upon criteria (the rules, principles, or general requirements utilised in critical thinking).

Other authors support the need for principles or rules for critical thinking, and identify certain rules or principles which should be applied in thinking critically (Chiras, 1992; Chaffee, 1992; Adams, *et al.*, 1996). Chiras (1992) lists eleven "principles of critical thinking" which should be taught to students as part of the *"process by which one subjects research findings and theories to examination"* (Chiras, 1992, 464). He suggests that if they are to become critical thinkers students should apply the following principles in evaluating any matter under consideration.

Gather complete information on a subject under scrutiny. He suggests that faulty thinking and erroneous conclusions often stem from inadequate or incomplete factual knowledge about the claims being judged.

Understand and define all terms. Chiras explains how an incorrect or incomplete understanding of the meaning of a term can lead to erroneous conclusions or incorrect judgements about the claim.

Question the methods by which facts are derived. Chiras points out some of the pitfalls with regard to experimental procedure which could lead to incorrect judgements about the validity of the claims made about the results and conclusions. Critical thinkers should examine the methods by which facts are derived to identify weaknesses which would bring the accuracy of the scientists' claims into question.

Question the conclusions drawn from facts. He points out that when evaluating any scientific study, issue or argument, it is important to determine if the facts really support the conclusions.

Look for hidden assumptions and biases. Chiras draws attention to the fact that people often present only data that support their point of view while ignoring data that oppose it, thus distorting the truth.

Question the source of the facts. This principle of critical thinking is inter-related with some of the previous principles listed. It requires that the "source of the facts" be scrutinised regarding each of these principles, because the proponent of the facts may often have a hidden agenda, leading to a distortion of the truth.

Don't expect all the answers. Chiras contends that there are times when it is advisable to reserve an opinion until more information is available. As an example Chiras cites the debate on global warming. Many prominent scientists believe that the temperature of the earth is warming as a result of excess carbon dioxide and other gases from human activities which have accumulated in the atmosphere. Other scientists believe that there are still too many uncertainties to know for sure, and that opinion on global warming should be reserved.

Examine the big picture. Chiras suggests that critical thinkers should assess the implications of a problem which extend beyond the immediate situation. For example, researchers at Monsanto announced that they had found a way to alter the chromosomes of wheat to make the plant resistant to a fungus that causes extensive crop damage. Normal control of the pest involves crop rotation with crops that do not support the fungus. They claimed that with the new wheat, wheat crops could be grown from year to year without requiring the normal crop rotation. Looking at the big picture, however, shows that the advantages of crop rotation, such as nitrogen replenishment by legume crops, would be lost, and might outweigh the benefits of the new strain of wheat.

Examine multiple cause and effect. Chiras states that *"critical thinking demands a broader view of cause and effect. It calls on us to consider all of the contributing factors and their relative contributions." (Chiras, 1992, 468)* For example, some scientists may argue that environmental problems arise from overpopulation, while others may blame environmental problems on technology and its by-products which cause pollution. However many other factors, such as inadequate laws controlling industry, poor education, and poor attitudes towards nature, could be included as causes of the problem.

Watch for thought stoppers. Chiras warns against words or phrases that elicit an emotional or gut-level acceptance of an argument, not an intellectual one. Phrases such as "But everyone knows that!" or " But that's an accepted fact" tend to bring about an emotional acceptance without thinking critically about the issue.

Understand your own biases and values. This suggests that to be a critical thinker one should scrutinise one's own ideas and values, which may be biased, as they may influence one's reasoning.

Zohar *et al.* (1994) also recognise the need for a set of principles for critical thinking. In the Biology Critical Thinking (BCT) project, which was conducted in four schools in Israel, carefully designed activities for developing specific critical thinking skills were incorporated in the biology curriculum. The

678 Seventh Grade students (340 boys and 338 girls) involved in the study, all working from the same biology textbook, were divided into two groups. Only the one group, the experimental group, was involved in the BCT activities. The "skills" or principles incorporated in the activities used in the BCT project were selected because of their frequent use in both everyday life and in the study of biology. It should be noted that the principles listed by Chiras above and the seven skills selected for the BCT project given below overlap to a large degree.

Using the textbook *Water Balance in Living Organisms,* topics on experiments, data analysis, or problem solving were selected to teach the students to :

- Recognice logical fallacies, such as drawing conclusions where the facts were gathered from too small or unrepresentative samples. (Compare this with points three and four of Chiras, which suggest that one should question both the methods by which facts are gathered as well as the conclusions drawn.)
- Distinguish between the findings of an experiment and the conclusions made on the basis of the findings. (Compare Chiras, point four.)
- Identify explicit and tacit assumptions not supported by facts or evidence.
- Avoid tautologies, the needless repetition of words or phrases.
- Isolate variables and identify the relative influence of each on the situation. (Refer to Chiras, point nine.)
- Question hypotheses (Hypothetical reasoning expressed as "if...then...") to determine the possible validity of each hypothesis.
- Identify relevant information for answering a question or solving a problem. (See Chiras, point one.)

Other authors have identified the common faults made by people who do not think critically. Invariably these faults result from the fact that certain principles of critical thinking have not been applied, thus emphasising the importance of these principles in critical thinking. For example, Dreyfus and Jungwirth (1980) identified eight such faults in critical thinking (given below) which they felt had relevance to science education. They referred to these as "logical fallacies". It should be noted that these "logical fallacies" relate mainly to the mistakes made when drawing conclusions from information available, because they have not "questioned the conclusions drawn" as suggested by Chiras.

- Assuming that events which follow others are caused by the first event (*post hoc* reasoning).
- Drawing conclusions on the basis of an insufficient number of instances (i.e. where the sample is too small). Questioning the method used in gaining the information would prevent this fault.
- Drawing conclusions on the basis of a non-representative instance (i.e. when the sample is not representative of the population).
- Assuming that something which is true in some circumstances is true in general.

- Imputing causal significance to correlations.
- Drawing inferences about individuals from the general expectations or characteristics of the particular population.
- Drawing conclusions on the basis of very small and fortuitous differences.
- Reasoning in a circle, i.e. using two similar propositions to prove each other.

The principles of critical thinking should be applied in identifying logical fallacies, or as Chiras (1992, 464) suggests, to look for *"consistencies and inconsistencies in logic, alternative interpretations, and subtle but pervasive biases that may have led to erroneous conclusions"*.
The first, third, and fifth of the "logical fallacies" listed above could be avoided by applying the principle of "questioning the conclusion drawn from the information available", or by looking critically at the "methods used in obtaining the information" put forward by Chiras.

There is thus strong support for the belief that critical thinking employs certain rules and criteria as part of the process of "reflective thinking".

2.1.3 The characteristic outcomes of critical thinking are judgements

If critical thinking is "reflective thinking" in which principles or rules are applied to examine or evaluate particular claims, theories or findings, then it stands to reason that there must be an outcome or conclusion to this process of examination. To understand the concept of critical thinking one must also understand what the characteristic outcomes of critical thinking are likely to be. Sternberg (cited by Lipman, 1988) describes the outcomes of critical thinking as the solving of problems, the making of decisions, and the learning of new concepts. Ennis (1987, 10), cited by Lipman (1988), refers to the outcomes of critical thinking as *"deciding what to believe or do"*. Lipman argues that these definitions are inadequate because the "outcomes" referred to (solutions or decisions) are too narrow. He contends that the outcomes of critical thinking are "good judgements". Judgements may be said to be "good judgements" if they are based on the criteria (principles or rules) of critical thinking.

2.1.4 Critical thinking is self-correcting

By learning to apply the principles of critical thinking to the claims or statements made by others, one becomes aware of the pitfalls of logic and is less likely to make the same mistakes in one's own thinking. Lipman (1988) maintains that because each participant can internalise the methodology of critical thinking each is able to become self-correcting in his or her own thinking. Thus critical thinkers will be less likely to be guilty of illogical thinking and other common mistakes in reasoning (Chiras, 1992). Facione (1990) refers to this as "self-regulation" which he explains as "self-consciously to monitor one's cognitive activities".

2.1.5. Critical thinking is sensitive to context

Thinking critically about any issue or problem must account for all factors peculiar to the specific situation which may influence the application of normal criteria or the validity of the judgement or decision taken on the particular issue.

According to Lipman (1988) thinking that is sensitive to context takes into account

- exceptional or irregular circumstances and conditions,
- special limitations, contingencies, or constraints,
- overall configurations (e.g. a remark taken out of context may seem in error, but not so in the context in which the remark was made),
- the possibility that the evidence is atypical, and
- the possibility that some meanings do not translate from one context to another (e.g. terms for which there are no precise equivalents in other languages).

2.2 THE GOAL OF CRITICAL THINKING.

The development of critical thinking has long been the goal of educationists, as indicated by a 1910 Association of Science and Mathematics Teachers' report.

> *The Central Association of Science and Mathematics Teachers issued a report suggesting more emphasis on critical thinking rather than memorisation, and more attention to problem-solving and applicability.*
>
> (Galloway, 1910, quoted by Mayer, 1986, 483).

This is still a matter of concern in many countries today. The National Science Board Commission on Pre-college Education in America in the mid 1980's recommended the development of student *"capacities for problem solving and critical thinking"* as major goals of science instruction (McCormack, 1984; Beyer and Charlton, 1986, 207). Other authors also refer to the fact that the development of critical thinking has been regarded for many years as one of the major aims of education. (Resnick, (1987) cited by Zohar *et al.*, 1994; Hudgens and Edelman, 1986; Sternberg and Baron, 1985). McMurray *et. al.*, (1991) comment that educators have come to realise that teaching critical thinking is an essential school function, particularly so for the biology teacher, as citizenship increasingly involves complex biological relationships which the life science teacher has the opportunity to deal with in the classroom. Norris (1985) says that *"critical thinking is not just another educational option. Rather it is an indispensable part of education"*.

Lipman (1988) refers to a gradual shift in the goals of education from *learning* to *thinking*. Educationists want students to think for themselves and not merely learn what other people have said. But critical thinking focuses not only on the importance of being able to think but also on the value of being able to make "good judgements" regarding issues and problems (Lipman, 1988).

The teaching of thinking skills is promoted in schools in many countries throughout the world (Young, 1993). She points out, for example, that

- in certain countries the pupils are specifically taught thinking skills. In Venezuela pupils are expected to spend two hours per week on thinking skills. In Malaysia and in Pakistan thinking skills are specifically taught to the pupils as part of the curriculum.
- in Singapore special courses are run for teachers to train them in the teaching of thinking skills.

The importance of the development of skills is also recognised in South African education where, for example, the need for skills development is clearly stated in the aims of most biology syllabi, and in the syllabi of other science subjects.

The National Department of Education in South Africa has embarked on a new Education Initiative which has been referred to as "Curriculum 2005". Professor S. Bengu, Minister of National Education in South Africa, states in the foreword to an Information Brochure on the new curriculum (National Department of Education, 1997), that the curriculum will bring about a shift from one which was essentially content-based to one which is based on learning outcomes. He says that *"its guiding vision is that of a thinking, competent future citizen"*. The brochure refers to the eight "Critical Cross-field Outcomes (essential outcomes)" of the learning process put forward by the South African Qualifications Authority, and lists "the ability to identify and solve problems by using creative and critical thinking" as one of these essential outcomes of education. He stresses the need for support for the teachers in preparing them for the demands of the new curriculum, and suggests that special in-service training should be implemented to assist the teachers in teaching the skills required by the curriculum. Thus the goal of critical thinking will be relevant to the new outcomes-based education envisaged for South Africa.

At the first International Conference on thinking skills, held at the Malta University and attended by some 250 international delegates, it was generally accepted by the delegates that teaching children and adults how to think does work, and is an increasingly vital aspect of development (Young, 1993).

It is evident from a survey of literature that the development of the skill of critical thinking is regarded as an important aspect of education which should be promoted in schools.

2.3 THE VALUE OF DEVELOPING THE SKILL OF CRITICAL THINKING

Educationists have recognised the value of developing the skill of critical thinking, not only for the direct benefits it will bring to the classroom situation, but also for its influence in the field of science and its value to the man-in-the-street. The skill of critical thinking enables the individual to evaluate the problems and issues arising in society more effectively.

2.3.1. In the classroom:

Teaching the skill of critical thinking has been shown not only to improve the ability of the student to think critically, but has also brought additional benefits such as an improved understanding of the subject concepts being taught, more pupil involvement and enjoyment, and improved self-esteem (Brandt, 1988; Young, 1993; Zohar, *et al.*, 1994; Wojciechowski and Todd Deal, 1996; Chubinski, 1996).

Costa says that where teachers do teach for thinking skills an improvement has been seen in the results in standardised test scores (Brandt, 1988). Young (1993) states that research conducted by Professor John Edwards, on the teaching of thinking skills to a class of final primary year pupils in an Australian school, produced astonishing results. Results for this one class on the standardised Australian national tests in *five* subjects were between 17 and 31 percentage points higher than the expected norm and significantly higher than the school's mean results as well. Moreover, when this group wrote the national tests at the age of 16, their results were significantly higher than the rest of their group at the school who had not been involved in the critical thinking programme. She adds that two other benefits from learning thinking skills are a higher level of comprehension and an improved self-esteem. Chubinski (1996) says that using creative strategies to teach critical thinking enhances student interest, creates anticipation for subsequent learning, and increases retention. Swartz (1986) says that teachers who have worked to infuse critical thinking in their own teaching have found that it brings out their best abilities, as well as those of their students.

In their study on the BCT project, Zohar *et al.* (1994) found that the experimental groups scored much higher on critical thinking tests, but also scored significantly higher on the biological topics. (The pre-test mean scores of the two groups were practically the same, indicating that the two groups did not differ in their initial performance in the critical thinking skills used in the project.) They concluded that an approach to the teaching of biological topics which involves the application of critical thinking principles serves to improve students' understanding of the biological concepts they are studying. They contend that "thinking critically" implies higher-order thinking, and that evidence gained from their

work on the BCT project showed that when critical thinking was applied to specific biological topics, it resulted in

- less rote-learning and more meaningful learning,
- improved understanding and better retention of facts.

Thus the teaching of critical thinking could also bring about an improvement in the learning of the subject involved and a better understanding of the concepts of that subject. This contention is supported by Self et. al., (1989).

Students must learn to evaluate data critically, as well as to question the experimental designs which gave rise to the data. Pechenik and Tashiro (1992) indicate that "facts" are interpretations of data, which may well change with time. They state that

> *"Students can become thoughtful consumers of scientific information only if they learn to evaluate data critically, along with the experimental designs that gave rise to those data.*
>
> (Pechenik and Tashiro, 1992, 432).

Tyser and Cerbin (1991) maintain that students will encounter many science-related issues in popular news media, including news articles in newspapers and magazines, which will pique their concern and interest. Students need to develop the confidence to critically evaluate such claims made about science and technology issues. Bitner (1991) suggests that science educators should teach science for the development of creative and critical thinking processes.

2.3.2 In science:

Critical thinking is fundamental to the process of science. Whether directly involved in the study and application of science, or merely as a consumer of science in a technological society, individuals are constantly confronted by claims relating to science which will require evaluation before acceptance. Developing the skill of critical thinking will provide an essential tool for evaluating these claims or dealing with these issues.

Moore (1992) believes that critical thinking underlies the process of science. He emphasises that there are no sacred truths in science, no forbidden questions, and that science values criticism and thrives on debate. Tyser and Cerbin (1991) indicate that the confidence to critically evaluate the claims made about science and technological issues is a necessary ingredient for becoming scientifically literate. Sanders and Doidge (1994) point out that not all scientists are objective, and they may not all be honest. It is thus just as important to critically evaluate the findings of scientists. Tyser and Cerbin (1991) advocate a

"conditional acceptance" of scientific claims based on the evidence available at the time of assessment of the claim.

2.3.3 In the broader sphere:

As only a relatively small proportion of society becomes directly involved in the pursuit of science, a very important aspect of teaching critical thinking is the benefits that it will provide for the ordinary citizen. Applying the principles of critical thinking will provide advantage to the man in the street in two areas in particular.

- Ordinary citizens will benefit by gaining the ability to evaluate the claims and issues which confront them from many different sources, including the media and the scientific world (McMurray, et. al., 1991; Chiras, 1992; Moore, 1992; Young, 1993). Moore (1992) points out the dangers to the ordinary citizen of accepting uncritically every report or claim made in the media. He stresses the importance of teaching students the skills of critical thinking so that as citizens they will question the evidence for such reports, and be able to judge the validity of the claims made by advertisers. Tyser and Cerbin (1991) draw attention to the importance of being able to evaluate critically the scientific and technological claims made in the media. This ability will enable citizens to confront with confidence the science-related issues in the media which pique their interest and concern, and to develop logically persuasive arguments using evidence and inference.
- The ordinary citizen will benefit by gaining the ability to use the principles of critical thinking in their own endeavours. Chiras (1992) argues that education should provide more than facts and a few insights. He contends that by teaching critical thinking, teachers will impart skills that are useful, not only in the science classroom, but also in other areas, including government, economics, sociology, literature and law. Lipman (1988) says that one of the most important advantages of teaching critical thinking is that members of the community not only become conscious of their own thinking but begin looking at and correcting each other's methods and procedures. Critical thinking is essential to the free, rational and autonomous mind and fundamental to a rational and democratic society (Facione, 1990; Paul, 1984). Moore (1992) regards the skill of critical thinking as a necessity for living.

2.4 LEVELS OF SUCCESS ACHIEVED IN THE TEACHING OF CRITICAL THINKING.

Though the teaching of critical thinking skills is achievable, as has been shown by Zohar *et al.* (1994) in the BCT project previously referred to under Section 2.3.1., as well as others such as those mentioned under Section 3.1.1. (Whimbey, 1984; Statkiewicz and Allen, 1983; Tyser and Cerbin, 1991) and despite the fact that the aim of teaching critical thinking has been given prominence in many countries, over a long period of time, the level of success in teaching critical thinking in most schools remains in question. There is evidence, and concern, that the development of the skill of critical thinking is

generally not being achieved. Tanner (1984) refers to the poor development of thinking skills exhibited by most secondary school graduates, which has resulted in professional educators, state education agencies, and numerous national commissions urging increased attention to the teaching of thinking skills at all levels of education in the United States. Yet Chaffee (1992) says that despite the fact that teachers may aspire to teach critical thinking as an educational ideal, critical thinking is rarely taught explicitly and systematically at any level of education.

The initial problem arises at school level, where, despite the fairly commonly stated goal in many syllabi, of developing thinking skills, the level of development of thinking skills amongst pupils is low. A less-than-satisfactory level of proficiency in thinking is exhibited by most secondary school graduates in America (Beyer and Charlton, 1986; Norris, 1985). Pappelis *et. al.* (1980) referred to the problem of a deficiency in these skills amongst the students enrolled for the preparatory programme for medical education. The lack of success in teaching skills at school level results in a problem for tertiary education. Dunn (1988) suggests that many of the Mississippi colleges and universities are faced with the problem of trying to correct their students' academic deficiencies. Students lacking problem-solving skills, as well as other skills, have difficulty performing college work. Remedial courses are thus needed to meet the needs of these students.

It would appear that similar problems exist in South African education. The aims listed in various syllabi encourage the teaching of critical thinking, yet information gathered from an opinion survey of teachers attending workshops held in the former Transvaal indicated that, due to the content-laden syllabi and the fact-orientated exams, these teachers experienced problems with regard to the teaching of skills, inquiry methods and practical work (Ayerst and Sanders, 1992). The new curriculum for South African Education., referred to as "Curriculum 2005", is intended to bring about a shift from the previous curriculum which was content-based to one which is based on outcomes, and emphasises "critical thinking, reasoning and reflection".

2.5 FACTORS WHICH HINDER THE TEACHING OF CRITICAL THINKING IN SCHOOLS.

It would appear from the previous discussion that the level of success in teaching critical thinking is poor. An understanding of the underlying causes of this lack of success in teaching critical thinking is essential if a planned programme for teaching critical thinking is to be successful.

It is important, however, to distinguish between

- the lack of success in **teaching** critical thinking, and
- the lack of **development** of the skills of critical thinking in learners.

The first implies that serious attempts have been made to teach critical thinking, which have failed, while the second implies that the skill has not been developed for various possible reasons, including the possibility that no attempt has been made to teach the skill. This distinction is important, as a failure in the teaching technique suggests that the particular technique used should not be incorporated in a teaching programme, while extraneous factors which cause failure may need to be counteracted to prevent the failure of a planned programme of teaching.

The following factors have been identified in the literature on critical thinking as contributing to the lack of success in the development of critical thinking skills in learners. These factors should be analysed to determine which of the situations mentioned above would apply.

2.5.1 Teacher-related factors

- Teachers require students to apply critical thinking skills but seldom actually teach them the skills, or providing the strategies for higher order thinking (Falkof and Moss, 1984; Beyer and Charlton, 1986; Zohar, *et al.*, 1994). Beyer and Charlton (1986) contend that one of the most important reasons why many high school graduates in the USA are deficient in thinking skills is that teachers fail to teach these skills in their courses. These authors go on to say that *"too often what we assume to be teaching of these skills consists instead only of making students attempt to use these skills"* (Beyer and Charlton, 1986, 207). Costa, editor of the resource book *"Developing Minds"*, asserts that the results will be disappointing when we teach content alone in the hope students will also learn to think. He indicates that there is a lot of evidence available showing this doesn't work (Brandt, 1988). Zohar *et al.* (1994) refer to the claim by Shulman and Tamir (1973) that students who had studied the new inquiry-oriented science curriculum of the 1960's performed as poorly in critical thinking skills as their traditional counterparts, suggesting that this may have been due to the fact that the students were expected to apply the skills without explicit efforts to teach them these skills.
- Teachers are uncertain of which skills to teach or how they should be taught. Whimbey (1984) refers to the *"confusion about which skills to teach, and when"* which teachers experience with regard to the teaching of thinking skills. He points to a possible need to pause until research has clearly identified the primary skills of thinking which should be taught. Paul (1984) suggests that teachers should be encouraged to take at least one university level course in critical thinking.
- Teachers are uncertain of whether the teaching of thinking skills actually works. Tyser and Cerbin (1991) suggest that a factor which may contribute to the lack of teaching of critical thinking is that teachers are reluctant to adopt new techniques because empirical evidence is lacking about the effectiveness of these techniques.
- Teachers present facts and definitions rather than emphasising skills development. Much of the declining scientific literacy, according to Moore (1992) has arisen from the fact that teachers present "facts and definitions" rather than stressing critical thinking. Schools have not made the development of reasoning and critical thinking a priority (Jungwirth and Dreyfus, 1990). Yager

(1982) states that teachers tend to emphasise the textbook information, especially the terminology and definitions, and laboratory work tends to be a demonstration of the information already presented in the textbook.

There appears to be a lack of either a co-ordinated programme or of a suitable methodology for teaching critical thinking in South Africa. The teacher-related factors mentioned above tend to suggest that the general lack of development of the skill of critical thinking, which was discussed previously, lies in the fact that where this has occurred no methodology has actually been implemented, rather than that the methodology used for teaching critical thinking has not been successful. Although the teaching of critical thinking is included as an aim of many of the science syllabi, the syllabi seldom provide a programme or a methodology for actually teaching critical thinking. Thus the teaching of critical thinking becomes merely another noble-sounding aim which is soon forgotten by the teacher. For example, this lack of support for the teaching of critical thinking is seen in the poor training provided for teachers in the teaching of critical thinking. It is exacerbated by the emphasis of factual content alone in the external examinations, as was the practice in certain of the previous Education Departments of South Africa. This lack of emphasis on teaching critical thinking is also reflected in some of the following factors.

2.5.2 Syllabus-related factors

It is evident that many syllabi, particularly in the sciences, place the emphasis on extensive factual content, and teachers find it difficult to complete the required work in the time available. Techniques which facilitate factual transfer are thus readily adopted to ensure completion of the syllabus and the teaching of thinking skills is neglected.

Chiras attributes the problem in part to the massive increase in factual information in the past 20 years which has resulted in less time for teaching skills and more time spent on facts. Young (1993, 17) refers to the situation in Australian schools in which there is a *"great overstuffed curriculum"* which the students must be pushed through. Ayerst and Sanders (1992, 9) report on the feelings of teachers, gathered from a series of workshops held for teachers from the former Transvaal in South Africa. The teachers feel that *"because so much factual content has to be taught teachers are forced to use methods which facilitate the transfer of facts to pupils."*

Tyser and Cerbin (1991) indicate that there is doubt that the development thinking skills can be integrated into a course without sacrificing its content. Zohar *et al.* (1994) report on Mayer's (1987) findings which indicate that college teachers who incorporated critical thinking into their teaching reported a 30% to 40% decrease in the number of topics they were able to cover during the course because of time constraints. However, this perceived obstacle to the teaching of critical thinking may be offset by the benefits gained from including the teaching of critical thinking into the biology curriculum. Zohar *et al.* (1994) point out, from the results obtained from the "Biology Critical Thinking Project"

(BCT) in which they were involved, that students gained a better mastery of the biological topic being studied when critical thinking skills were incorporated in the teaching. They indicate that these findings are also supported by other studies such as those carried out by Moll and Allen (1982), Crow and Haws (1985). Self *et al.* (1989) also support this contention. Bereiter (1984) suggests the teaching of critical thinking will not be successful if it is taught as "enrichment", or as subject matter, but that the teaching of thinking skills should be an integral part of other already-accepted instructional objectives, and permeate the instructional programme, for the teaching to be successful.

2.5.3 Examination-related factors

Arzi and Novak (1986) argue that dramatic effects in meaningful learning cannot be expected as long as students' education is dominated by assessment methods which allow for surface and rote learning. Sanders and Doidge (1994) indicate that research internationally has shown that external examinations do have an influence on classroom practice. Based on Doidge's experience as an external examiner of senior primary biology in Department of Education and Training colleges of education, as well as on the opinion of various science educators in South Africa, gathered by Sanders, these authors contend that assessment styles dictate the type of teaching and learning that occurs in the classroom in many South African schools. Biology teachers in the former Transvaal have indicated that the format of the final matriculation examination is a major stumbling block to changing the way they teach (Ayerst and Sanders, 1992).

Two aspects in particular relating to the nature of the examinations influence the pattern of teaching by teachers and the approach to learning by the students. Firstly the strong emphasis of examinations on factual content, and secondly, the nature of the actual questions used in the examinations, appear to present a serious stumbling-block to an approach to teaching which fosters critical thinking.

- The factual emphasis of the examinations

  Brandt (1988) presents the opinion that the current testing practices in the USA are hindering further development of the teaching of thinking skills in schools as they affect teachers' and parents' perceptions of what is important. Teachers question the need to teach thinking skills when they, and their students, are being evaluated on 'low-level knowledge' and factual content. A similar problem exists in South African schools. A survey was taken of the views of teachers of a new draft syllabus for Biology. The survey involved a series of five repeat workshops held during 1989 and 1990. Sessions of the workshop were held at the Johannesburg College of Education, the University of the Witwatersrand and the FUNDA Science Centre in Soweto, in the former Transvaal in South Africa. The survey thus involved a large number of teachers on a non-racial basis, each attending one workshop session. Ayerst and Sanders (1992) report that the teachers in the survey saw little point in teaching the various skills required if these skills were not examined.

The teachers in this survey felt that their time would be better spent on teaching those aspects that would produce the best results in the factually-orientated examinations.

- The type of examination questions used

  Multiple-choice tests and true-false tests, unless very carefully designed, require students to do little more than recognise an answer. Moore (1992) suggests that carefully designed essay tests would force the students to apply principles of critical thinking.

  From the experience gained by this researcher as a headmaster of a large secondary school in the Transvaal Education Department, as well as a member of the Examination Panel for Biology and a Chief Marker of Biology in this department, it would appear that the emphasis placed on final matriculation results in South African schools is a strong influence on what is taught and how it is taught. For example, a high level of publicity is given to the matriculation results by the media, and many South African universities apply a points system based on the achievement of certain grades in the matriculation examinations to determine acceptance at these institutions. As a result teachers tend to teach that which will be directly examined, and many parents demand that an approach which prepares the pupils for a factually orientated examination is followed.

2.6 APPROACHES TO EVALUATING THE LEVELS OF CRITICAL THINKING ACHIEVED BY STUDENTS

Much of th general criticism which occurs in the literature regarding a lack of critical thinking skills amongst students relates to the fact that critical thinking skills have not been taught in the classroom, rather than that attempts have been made to teach critical thinking which have proved unsuccessful. Various methods have been used to determine the effectiveness of programmes aimed at improving thinking skills. In some cases the evaluation has been fairly superficial, while in ot ers it has been carefully designed and controlled.

Statkiewicz and Allen (1983) carried out a study on a group of 112 students enrolled for a biology course at the West Virginia University in the USA. The study, which will be discussed in more detail under Section 3.1.1., involved the use of problems designed to develop critical thinking. Three or four of these problems, relevant to the material studied at the session, were given to the student after each class meeting. Evaluation of the level of critical thinking made use of a fairly simple method, though inappropriate, because the research design used no control group and no controlled pre- and post-test. They based the evaluation of their "practice exercises" to develop critical thinking on the degree of improvement in the scores achieved for the practice problem exercises from the start of the programme at the beginning of the semester to the conclusion of the programme at the end of the semester.

They determined the correlation between the practice problem scores (grades based solely on lines of reasoning) and examination scores (grades based solely on correct answers). The purpose was to evaluate whether or not there was an improvement in all levels of proficiency by the students as a result of doing the exercises. The students were divided into groups according to the grade an individual received at the end of the semester on the examination scores. The mean scores achieved on the practice problems by each group were determined for each time block of the semester and the levels of improvement in each group were compared. Though giving some indication of the effectiveness of the programme, the method of evaluation lacked a control and accuracy. The results could have been attributed to factors other than those related to the practice exercises given. For example, the influence of the level of work in the class was not controlled, and there was no statistical control of the influence of initial abilities.

A more acceptable approach to evaluating the teaching of critical thinking was used by Tyser and Cerbin (1991). Firstly, they used an experimental and a control group in the investigation. The students taking the freshman-level introductory biology course run by Tyser and Cerbin at the University of Wisconsin in the USA, were divided into two sections. The experimental group (n=33) was taught by Tyser, and the control group (n=27) was taught by a colleague. Secondly, they administered a pre-test and post-test. The pre-test determined the initial level of critical thinking at the start of the project and the post-test the level of critical thinking at the end of the project. The same test was used for both the pre- and post-tests, which may have been a weakness in that it was based on a science news article which would possibly be remembered by the more capable students thus giving them an advantage in the post-test. No mention is made of a pilot study for the pre- and post-test, which could be seen as a weakness. Thirdly, the evaluation was based on whether the post-test answer was "less persuasively" or "more persuasively" written than the pre-test. This may be regarded as a fairly superficial evaluation as there was no analysis of specific critical thinking principles. The "improvement" in the post-test results of the experimental group was shown to be significant.

A third example illustrates a far more carefully controlled and administered research project. The Biology Critical Thinking (BCT) Project was carried out in Israel by Zohar *et al.*, (1994). It involved a larger sample - 678 7th-grade students divided into experimental (n = 367) and control (n = 311) groups. This means the results can be generalised with greater confidence. A pre-test and a post-test were administered, as in the previous example, but with some improvements.

- Two parallel forms of a "General Critical Thinking" test (GCT) were developed for this purpose (Zohar, *et al.* 1994). This provided the advantage that the pre- and post-tests were equivalent giving a more accurate evaluation of the results of the BCT project and avoiding the possible recognition of the questions by the brighter students as in the previous example. However, it is difficult to determine whether parallel tests are indeed equivalent.

- The questions were designed to test all of the principles of critical thinking which were taught in the project. A grid analysis of the principles of critical thinking used in the questions was carried out to ensure that each principle was tested at least twice.
- The tests were piloted as well as checked by three "experts" to ensure that they were equivalent in what they tested and in the level of difficulty. One test was used as the pre-test and the other as the post-test.

Results were carefully analysed to determine specifically which of the principles of critical thinking taught in the programme had been successfully applied by the students.

2.7 CONCLUDING REMARKS

This chapter has provided background information on critical thinking and has explained the importance of teaching critical thinking in the classroom. It has also discussed various factors which may have led to the lack of development of critical thinking in schools in general. The development of a strategy for teaching critical thinking, taking into account this information, will be discussed in the following chapters.

CHAPTER III

DEVELOPING A TEACHING STRATEGY

The planning of a strategy for teaching critical thinking needs to take into account

* the theoretical *approach* to be followed in teaching critical thinking,
* *what* actually needs to be taught when applying the selected approach, and
* *the practical implementation of the aching approach.*

The background and theory on the teaching of critical thinking which was discussed in the previous chapter should provide the framework for deciding what should be taught. How this should be taught and which approach would be suitable for teaching it were developed from information gained from literature on the teaching of critical thinking as well as from learning theory.

3.1 APPROACHES USED IN TEACHING CRITICAL THINKING

As argued under Section 2.3, teaching critical thinking should provide a means by which the students can analyse problems and issues they will confront in their daily lives as well as in the science or biology classroom. To successfully learn the skill of critical thinking the student must gain an understanding of the fundamental features of critical thinking, as discussed on pages 5 to 10, and be able to apply these features to the problems and issues they encounter. The approach used needs to

* promote "reflective thinking" by the individual (refer to Chapter II page 5);
* facilitate the employment of certain criteria, rules and principles which promote critical thinking (Refer to Chapter II page 6);
* lead to "good judgements" as the outcome of the process of critical thinking. (Refer to Chapter II page 9).

Thus in developing a teaching strategy, the approach used should lead to way of thinking which habitually involves the three fundamental features of critical thinking mentioned above i.e. it needs to develop the mental processes or steps which will result in reflective thinking which employs criteria, rules and principles, and which leads to good judgements.

The approaches presented in the literature on critical thinking may be grouped into two categories. The first concentrates on the line of reasoning involved in evaluating claims or issues and presenting a logical justification for accepting or rejecting the claims made. The second emphasises the criteria, rules or principles which should be applied when thinking critically about an issue.

3.1.1 Teaching a "line-of-reasoning" for accepting or rejecting claims

The line-of-reasoning models for teaching critical thinking involve "thinking reflectively" on any issue as well as making a "judgement" on each issue. The student is encouraged to consider all

factors relating to the issue and then decide whether to accept or reject the claims made on the issue. The following methods have been used to teach the mental processes involved in this "line-of-reasoning" approach.

Whimbey (1984) suggests a modification of teaching methods which shifts the emphasis to the "mental processing" procedures, or thought processes, used by most high-aptitude students. Provisions must be made for the teacher to observe the "mental processes" and provide feedback on the processing which is carried out by the student. This should involve a process of "thinking aloud" which would show the teacher the type of mental operations being used by the student. With help from the teacher, or from someone trained to elicit vocalised thinking from the student, the student learns to carry out logical operations more thoroughly and accurately. Whimbey refers to this procedure as "precise processing". The student could then apply these skills in solving new problems. Whimbey reports that the method was used by Charmichael and Ryan (1979) of the Department of Chemistry, Xavier University, New Orleans in the USA, in an introductory chemistry course. These authors indicate that scores on a standardised test of introductory chemistry administered at the end of the semester have improved by a whole standard deviation since the focus on "precise processing" method was introduced.

Statkiewicz and Allen (1983) investigated an approach to teaching critical thinking which involved 112 students enrolled for the General Biology course at the West Virginia University in the USA. The study involved a series of out-of-class exercises given after each class meeting. The problems given in the exercises related to the class material being studied. These problems were in a multiple-choice format which required a full justification for accepting or rejecting each choice. Acceptable justifications required that concepts and information from class study be applied, and a well-developed and clearly expressed line of reasoning be established, leading to acceptance or rejection of each choice. A significant improvement in practice problem performance was observed. The groups of students who normally achieved higher academic grades showed the most improvement while the group who normally achieved the lowest grades showed least improvement.

Tyser and Cerbin (1991) presented a "line-of-reasoning" model for teaching critical thinking which was used in their Introductory Biology courses at the University of Wisconsin, USA. The investigation into the effectiveness of the method involved an experimental group of 33 students and a control group of 27 students. Both groups wrote a pre-test and a post-test (The identical test was used for both pre- and post-test). Their exercises, which they called "Science News Exercises", provide a model for evaluating information in popular-media science articles. The model involves a series of steps which the students must apply in the exercises in order to compose a concise, logically persuasive line of reasoning or argument about why a claim should be either conditionally accepted or not accepted. The steps involve

* identifying evidence in the article,

* evaluating the validity of the claims made, and
* writing a logically persuasive line of reasoning of two to three sentences stating why the claims should be either conditionally accepted or not accepted.

For each exercise, the student is given a short science news article and a list of questions. These questions may include one or two hypothetical claims posed by the instructor. The students are asked to carry out the steps of the model which they have been taught. A comparison between experimental and control groups' post-test results showed that the performance of the experimental group had improved significantly over the control group, in both the objective questions as well as the lines of reasoning.

3.1.2 Providing a set of "principles of critical thinking" which should be applied in confronting any issue

This approach also requires an analysis of a problem or issue to determine whether to accept or reject it, as in the "line-of-reasoning" model above, but provides detail of the principles which should be applied in the process. Chiras (1992), and Zohar *et al.*, (1994) suggest specific principles (Refer to Section 2.1.2. pages 6 and 7, and 8 respectively.) which should be applied in "thinking critically" whereas Dreyfuss and Jungwirth (1980) point out the common faults made by people who do not think critically.

3.2 DECIDING HOW TO TEACH THE SKILL OF CRITICAL THINKING

How to teach critical thinking must be based on

* the theories of learning relevant to such a programme,
* the approaches which have yielded success in the past, and must be taken into account,
* the reasons for the lack of success in teaching critical thinking in the past.

3.2.1 Theories of learning and the teaching of critical thinking

A thorough understanding of how learning takes place puts one in a better position to make decisions about what to teach and how best to teach it (McClelland, 1982; Sanders, 1988).

Two major theories of learning, those of the psychologist Jean Piaget, and of the American psychologist David Ausubel, have had a significant impact on education. These theories, together with the contributions of others in science education, bear consideration in planning a strategy for the teaching of critical thinking. In the following discussion various points relating to learning theory which have relevance for teaching critical thinking will be explored.

- **Selecting a suitable stage of development of the learners for teaching critical thinking.**

It may be argued that a programme for teaching critical thinking skills should be introduced as early as possible so that the skills of critical thinking may be developed over an extended period as the students progress through the school. Falkof and Moss (1984) report on a programme for developing thinking skills which was co-ordinated by a group of teachers for the district of Highland Park, Illinois. The teachers identified the sequential stages necessary for developing the skill which they had selected, that of *making inferences*. The initial stages were introduced at an early grade level, and progressed to more sophisticated levels of the skill at later grade levels. The development of this "continuum model" of skills enabled the teachers to see how the strategies they used at one level contributed to the development of the more sophisticated thinking skills at higher grade levels. Shayer and Adey (1992b) investigated the long-term effects of the teaching of thinking skills. A follow-up on an experimental intervention on the teaching of thinking skills to 12 and 13 year-old students was carried out. The initial intervention involved 234 students (control: n=120; experiment: n=114) from six British schools. The testing of the long-term retention of the skills was based on the British national examinations, taken at the age of 16. They showed that large and permanent effects on the students' achievement resulted from the intervention in the earlier years. In addition, their results suggested that the effects were not domain specific.

An important factor which should be taken into consideration in teaching critical thinking is that critical thinking involves higher-order thinking (Zohar *et al.* 1994). Lipman (1988) refers to various higher-order cognitive skills which are used when thinking critically.

> *"When we think critically, we are required to orchestrate a wide variety of cognitive skills, grouped into families such as reasoning skills, concept-formation skills, inquiry skills, and translation skills."* (Lipman, 1988, 43)

Morgan (1995) suggests that without deeper processing, there can be no critical thinking. A programme to teach critical thinking should thus be aimed at a level at which the pupils are capable of dealing with abstract reasoning and higher-order thinking. However, there is some debate with regard to how this level can be determined. Two of the main schools of thought regarding the stage of development of the learner are based on the theories of Piaget on the one hand, and of Ausubel on the other.

A feature of Piaget's theory of learning is his notion of stages of cognitive development of a child. Piaget proposed that a child passes through four clearly defined stages of cognitive development. These stages coincide with certain age ranges in the development of the child. According to Piaget, abstract reasoning is only possible once the child has reached the final developmental stage (the "formal operation" stage) of this progression, which he suggested occurs from about 11 years of age (Sigel, 1984; Summers, 1982). Bitner (1991) states that the need for formal operational reasoning and critical thinking abilities in achievement in upper level science and mathematics has been documented, but that no studies of formal operational reasoning as a predictor of critical thinking

ability were uncovered in her review of literature. She carried out an investigation on the topic using a sample of 101 students from grades 9 to 12 in a school district in rural Arkansas. Validated tests for measuring formal operational reasoning (Group Assessment of Logical Thinking test - GALT) and critical thinking (Watson-Glaser Critical Thinking Appraisal - WGCTA) were administered to the students. Bitner (1991) found that the five formal operational reasoning modes in the GALT were statistically significant predictors of critical thinking abilities as measured by the WGCTA. If it is accepted that critical thinking involves higher order learning, which according to Piaget, is only possible once the child has reached the "formal operational stage", then the development of a teaching strategy for critical thinking should be planned for an age group which has reached the "formal operation" level suggested by Piaget.

However, there is support for the belief that cognitive development is not based on the physiological ages suggested by Piaget, but on the presence or absence of specific concepts in the cognitive framework of the child relevant to what is to be learnt. Summers (1982, 364) quotes Novak as follows:

> *"The data...support, in our view, a model of cognitive development that is not "stage dependent" but rather dependent on the framework of specific concepts, and integration between these concepts, acquired during the active lifespan of the individual."*

Summers points out that research work on learning in science has in recent years made increasingly more use of a theoretical framework derived from the work of Ausubel (Summers, 1982). This view suggests that the learner is an active participant in the construction of his or her own personalised knowledge. This construction of knowledge involves an interaction between the learner's existing knowledge and the new knowledge. Thus, according to this theory, the learning is influenced, not by the age of the child as suggested by Piaget, but by what the learner already knows. Hewson (1980, 397) refers to the statement by Ausubel which emphasises this belief:

> *"the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly"*

In planning a strategy for teaching critical thinking, the material used and the subject matter involved thus needs to be selected in relation to the level of experience and knowledge of the sample population selected for the research.

Alternative models in psychology, such as that of Kelly (Pope and Gilbert, 1983) are also relevant to science education. The personal construct theory of Kelly, which he described as "Constructive Alternativism", proposes that each person constructs a personal representational model of the world which allows sense to be made of it. These models are composed of a series of interrelated *personal constructs* which are used by a person to interpret present experience in relation to their understanding of past experience, and to theorise about future events. Sigel (1984) suggests that learning takes place as the constructions of knowledge are organised into conceptual representations, a process which involves the resolution of discrepancies between what is expected and what actually occurs in the environment. Pope and Gilbert (1983) suggest that this constructivist view of

knowledge, applied in the educational context, supports those teachers who seek to incorporate the viewpoints of students within the teacher-learner relationship.

In planning a strategy for teaching critical thinking, the *personal constructs* of the pupils involved need to be taken into account when selecting material for the lessons. A possible solution may be to select examples in the lessons which are simple and do not rely on extensive prior knowledge.

An important point which arises from the discussion on Piaget's "stages of cognitive development" and the constructivist views which take into account the existing knowledge of the learner, which is relevant to the teaching of critical thinking, is that the learning of certain concepts, according to these theories of learning, will only be successful if the learner has reached a suitable stage of development to cope with these concepts. This "suitable stage", according to the previous discussion, would more probably be in relation to the presence of specific concepts in the cognitive framework of the learner, as suggested by Ausubel's theory of learning, than in relation to the age of the child as suggested by Piaget's theories. However, in designing the lessons on critical thinking to be used in this research, the sample was chosen from pupils at an age where they are generally capable of higher-order thinking, according to Piaget's theory of learning, as well as being at a suitable stage of cognitive development. The material was selected in relation to the knowledge and experience which would be expected of learners of the particular age and socio-economic standing of the research sample, thus meeting the demands of Ausubel's theory.

- **Learning must be meaningful**

The focus of much of the current research in science education has shifted from the *teacher* to the *learner* (Sanders, 1988). Current theory on learning has tended to place a lot of emphasis on *meaningful* learning. The key concept of Ausubel's theory is that of *meaningful learning* (Summers 1982, McClelland 1982, Sanders 1988). Ausubel suggests that for learning to be meaningful the new idea or concept to be learnt must be consciously related to the prior knowledge of the learner. When new knowledge cannot be linked in to the existing cognitive structure, rote learning or memorisation results (Sanders, 1988). Both McClelland (1982) and Sanders (1988) suggest that, according to Ausubel's theory, two conditions need to be met in order for meaningful learning to take place:

* The material itself must be potentially meaningful to the learner. That is, the learner must possess the relevant knowledge or concepts to which the meaning in the new material can be linked.
* The learner must know how to learn meaningfully *and must intend to do so.*

Strategies for teaching critical thinking should take into account these two aspects. The first may be accommodated by either teaching the necessary background knowledge prior to the relevant critical thinking concept, or by selecting the material used to teach the critical thinking principle in relation to prior knowledge the pupils are likely to possess.

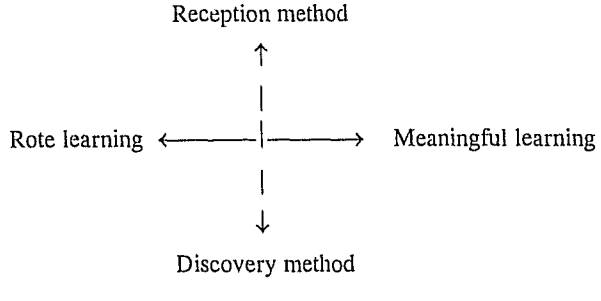
The second aspect may be facilitated by using a meta-cognitive approach where the students are taught self-awareness and other techniques to use to improve their ability to learn meaningfully (Sanders, 1988; Costa, 1984). They must, however, also be motivated so they *intend to learn meaningfully*. Pope and Gilbert (1983) quote Postman and Weingartner (1971) as suggesting that unless the learners perceive a problem to be a problem, and what is to be learned worth learning, they will not become active, disciplined and committed in their studies. A possible means of motivating the student to learn meaningfully may be point out and emphasise the importance of the skill of critical thinking both in terms of science education as well as in everyday living. The importance of critical thinking could be included as an introduction to the programme of teaching critical thinking, involving a suitable explanation and discussion of these aspects, with a re-emphasis of specific points of importance during the programme.

- **Selecting a teaching method which will promote meaningful learning**

In developing a strategy for teaching critical thinking attention must be paid to the process of meaningful learning, and the teaching methods which facilitate it. Summers (1982) refers to the confusion which existed between the concept of meaningful learning and the teaching methods thought to promote meaningful learning, particularly with the major curriculum development projects of the 1960's. The "rote-meaningful" dimension of learning was equated with the "reception-discovery" dimension of teaching.

Learning approach:	Rote learning	Meaningful learning
	<----------	---------->
Teaching method:	Reception methods	Discovery methods

However, these two dimensions should be regarded as independent and placed on different axes (McClelland 1982, Summers 1984, Sanders 1988).



This scheme illustrates that meaningful learning can result from a whole range of possible learning experiences, from reception methods through to discovery methods. The approach for teaching critical thinking may thus be based on teaching methods ranging from reception to discovery, selecting a suitable application for each particular principle being taught.

3.2.2 Principles and techniques used in teaching the skills of critical thinking

Various principles or techniques which have been used in teaching the skills of critical thinking, as well as other skills, have been identified in the literature on critical thinking and are discussed below. These principles and techniques, with due consideration of the theories of learning discussed above, form the basis for the teaching package for critical thinking used in this research. It is the purpose of this research to determine whether these techniques and principles if applied in a programme designed for teaching critical thinking will increase the level of success in teaching critical thinking.

- **The skills of critical thinking must be deliberately taught**

It has been suggested (refer to Section 2.5.1) that a possible cause for the lack of success in teaching critical thinking, particularly in the inquiry-oriented science curricula of the 1960's, is that students have been expected to apply the skills of critical thinking without actually being taught how to use the skills (Beyer and Charlton, 1986; Zohar, *et al.*, 1994). It appears that critical thinking skills do not develop unless explicit and deliberate efforts are invested in developing them.

In order to "deliberately teach" the skill of critical thinking various methods may be used to focus the attention of the learner on the task of learning the particular skills.

* **The learning of the skill of critical thinking should be a clearly stated objective**

Literature suggests that the objectives for the overall programme, as well as the objectives of each specific lesson, should be clearly stated in the process of teaching critical thinking. Angelo (1993) claims that when learners know what their educational goals are and how these goals can best be achieved, the learners usually become more efficient and effective, especially if their goals coincide with those of the teacher. He recommends that early in a programme the goals of both the students and the teacher should be discussed in the class.

The particular skill to be learned in each lesson should be a clearly stated objective of that lesson. Beyer and Charlton (1986, 208) suggest that one of the basic features necessary for learning a skill to any high degree of proficiency and for maintaining it longest is that *"the specific skill to be learned is an explicit, publicly announced lesson objective"* for the particular lesson.

Johnstone and Wham (1982) agree that a "deliberate and explicit" approach should be used when teaching a skill. They suggest that if the "signal" of the relevant information being learnt is not apparent to the learner, it may be enhanced by giving a clear statement of the objective of the exercise.

* **Students should understand the importance and value of learning the skill of critical thinking**

Learning requires focused attention and an awareness of the importance of what is to be learned (Angelo, 1993). Zohar, *et al.* (1994) state that the Biology Critical Thinking project indicated that if the students believed in the importance of learning critical thinking skills it enhanced the learning of the skills. These findings by Zohar, *et al.* (1994) support the recommendations from learning theory discussed previously under Section 3.2.1 on page 27. Accepting the importance of the task increases motivation which enhances meaningful learning.

* **The key procedures and principles that constitute the skill should be clearly articulated.**

Various strategies may be used to achieve this. It may take the form of a discussion of what the students have done or of what they are thinking as they engage in the skill (Beyer and Charlton, 1986; Jackson, 1986). Or the students may be asked to explain to others what they have just learnt, or comment on each others' interpretations and explanations. This helps them to learn it much more effectively and improves the development of critical thinking (Greeno, 1989; Angelo, 1993). Whimbey (1984) employs a "thinking aloud" technique which serves the same purpose, which also allows the instructor to provide guidance on the mental operations being used.

- **When teaching a skill only the information relevant to the skill should be presented**

When teaching a skill, the initial lesson should focus on the skill rather than the content of the discipline (Jackson, 1986). Learners should not be burdened with extraneous information which needs to be understood or learned while at the same time trying to master the principles of the particular skill being learned. Johnstone and Wham (1982, 71) state that *"learning is severely hampered in a high information situation in which the working memory is overloaded with incoming data"*. They refer to the extraneous information as "noise" and explain that if the "noise" level of incoming data is too high the "signal" of the relevant information being learnt is not apparent to the learner. They suggest that the "noise" may be suppressed by stating clearly what is preliminary, peripheral and

preparatory, i.e. by indicating clearly which information is relevant to the exercise and which is extraneous.

Thus, in order to accommodate this principle in a strategy for teaching critical thinking, the exercises used in teaching the principles of critical thinking should be planned in such a way that the only new information to be learned relates to the skill being taught. Any specific prior concepts or information needed by the pupils to facilitate meaningful learning should already have been taught, or should be taught in a separate lesson prior to teaching the skill. This serves two purposes:

* It avoids an overload of information which hampers learning, as discussed above.
* It reduces the problem which, according to learning theory, may arise if the learner lacks the relevant prior knowledge to which to link the new knowledge.

- **Students need to be actively involved in the learning process**

From a constructivist view of learning theory, learning takes place not only through the taking in of new information but also involves the organisation and restructuring of the conceptions or frameworks which the learners already have in relation to the new information gained (Driver and Bell, 1986). According to this theory people construct meanings of what they see or hear by generating links between the new phenomena experienced and their existing knowledge. This construction of meaning, according to Driver and Bell (1986) is a continuous and active process in which learners are actively involved in hypothesising, checking and possibly changing existing ideas as they interact with the new learning material. Pope and Gilbert (1983) suggest that the student may be active in the physical sense, but unless the person can see links between the activity and their personal concerns, the learning derived from the experience will be limited.

Angelo (1993) states that active learning is more effective than passive learning. He indicates that research has shown that students do learn more, and better, by becoming actively involved in the learning process. However he also states that activity, in and of itself, doesn't result in higher learning.

> *"Active learning occurs when students invest physical and mental energies in activities that help them make what they are learning meaningful, and ... when they are aware of that meaning-making".* Angelo (1993, 5).

Sanders (1988) points out that this active involvement in the learning process should not be interpreted only as manual, manipulative activities, but also implies the active reflection by the learner on the material to be learned. She also refers to Piaget's claim that there was no learning without action, and that meaningful learning occurs only when a person reflects. Angelo (1993, 5) quotes Stoddard who says *"We learn to do neither by thinking nor by doing; we learn to do by thinking about what we are doing".*

A range of strategies have been used by researchers to ensure mental engagement with the learning task.

* Statkiewicz and Allen (1983) provided "out-of-class" exercises in which the student activity involved the answering of multiple-choice questions giving complete justifications for the answers given which applied the "line-of-reasoning" concepts taught. They emphasise the importance of student involvement and active participation in the learning process. They point out the advantages provided by these exercises which ensure the involvement of the individual and provide for feedback from the instructor on that involvement. Self *et. al.* (1984) refer to the report by Tennyson and Buttrey (1980) on the phenomenal success achieved by using a computer assisted instructional system which provided continuous feedback on their achievement and learning. Barras-Baker (1993) recommends the use of computers to improve thinking skills through the use certain computer-based instructional strategies, software packages, and performance feedback.
* Tyser and Cerbin (1991) in their "line-of-reasoning" model follow an approach which actively involves the students in the process of learning. Students are asked to apply the steps of the line-of-reasoning model to science news articles thus actively applying the skills they have learnt in their science classes as they do the exercises. Livingston (1989) encouraged reading in the classroom, but encouraged the students to challenge any "pet beliefs" in what they were reading. They were told to question everything, and challenge student's assumptions. The exercises employed by Statkiewicz and Allen (1983), and by Tyser and Cerbin (1991), mentioned above, both encourage this active reflection on the skill being learned, thus promoting meaningful learning.
* Ambron (1987) has used a variety of writing techniques, including the writing of a journal, free-writing, and microthemes (very short essays), to actively involve the students and make learning more meaningful as well as to develop critical thinking. Though little statistical information is available to support the approach, Ambron refers to a case study by Newell in 1984 which showed increased mastery of content and the development of critical thinking skills using an approach which involved these writing techniques. Decoster (1995) also made use of the technique of writing essays on topics which required the pupils to question the information given and apply reasoning skills in their responses. Lozanskas and Barell (1992) refer to a technique which they used to stimulate critical thinking. This involved getting the students to keep a "thinking journal", with their notes about the subject matter on the left, and their reflections and questions on the right. The questions were used for class discussion.
* Greeno (1989) discusses exercises in which students were engaged in reflection on the meanings of terms and mathematical methods and were encouraged to comment on each other's explanations and interpretations. He raises the possibility that critical thinking is more a social phenomenon than it is a characteristic of individuals, and suggests that an effective way to engender critical thinking is to design social environments in which reflection and evaluation of

ideas are encouraged, rewarded, and expected as part of the normal interactive activity of the group.

* Gilbert (1992) refers to the value of teachers formulating questions which will stimulate the students to think at advanced cognitive levels, and actively involve them in the lesson. Various factors relating to the method of questioning were shown to influence the effectiveness of the technique. Riley (1986) carried out an investigation to determine whether the cognitive questioning level of the teacher, and the "wait-time" (the pause that follows a teacher's question), would influence pupil achievement. Scripted lessons were prepared in which the questions were categorised using Bloom's Taxonomy. The lessons were classified according to the questions used as either comprehension, knowledge, or a 50/50 combination of these two types. The wait-times were assigned as one, three and five seconds. Each of thirty teachers was randomly assigned to five randomly selected pupils. Each teacher was then randomly assigned to a treatment. Results showed that the 50% knowledge/comprehension group significantly out-performed the other two groups, while the long wait-time group out-performed the other two.
* Gilbert (1992) suggests that students should also be given the opportunity to ask questions, and to evaluate questions regarding the procedures, in order to promote critical thinking. Allison and Shrigley (1986) argue that children may be taught to ask operational questions (questions that the children may answer from first-hand evidence that they may generate themselves) and suggest that by asking operational questions, they are better able to understand the subject matter of the lesson.
* The discussion of controversial topics may also serve to gain the active participation of the students in the lesson. Nolan and Nolan (1997) suggest that the use of environmental conflict aids the development of critical thinking as it opens the minds of the students to the viewpoints of others, and builds the foundation upon which they can make decisions. Mead and Scharmann (1994) recommend the use of "structured controversy" to motivate the students, suggesting that it promotes critical thinking and improves overall achievement.

For the purposes of this research, the principle that students should be actively involved in the learning process, was regarded as an important principle to be applied in the development of the teaching package. The teachers involved in the research were asked to create a classroom environment in which critical thinking was emphasised and fostered, thus encouraging the development of critical thinking.

- **Repetition and practice enhance the learning of skills of critical thinking**

The literature suggests that the teaching of a skill is more effective if it is followed up with opportunities to put the skill into practice. A programme of instruction which provides further opportunities to use each skill learnt is likely to be more successful than one which offers no opportunity for practice.

Statkiewicz and Allen (1983) showed that there was a definite relationship between the amount of practice and success in the development of critical thinking. Those groups involved in their investigation (described on page 23 under Section 3.1.1) which submitted a high percentage of practice problems showed a significant improvement in critical thinking, while the group which submitted a low percentage of problems showed little improvement.

Beyer and Charlton (1986) indicate that a skill is not learnt as a result of a single exposure, but that students need frequent but intermittent practice in using the skill. Simon (1980) suggests that skills are best learned in training sessions held at regular intervals under the guidance of a tutor. Students should not be taught skills by instruction alone. Tyser and Cerbin (1991) concur, and achieved this by including six or seven exercises in their courses to provide the repetition needed for establishing the strategy of their approach to critical thinking. These exercises are administered at approximately bi-weekly intervals during the semester, thus providing an ongoing repetition of the skills. Zohar *et al.* (1994) applied the principle of repetition by ensuring that each of the seven skills of critical thinking being taught in the BCT project was repeated seven to nine times. They emphasise the importance of exposure to multiple examples.

3.2.3 Teaching the skills of critical thinking within a subject-area context

One of the approaches common to many of the attempts to foster the development of critical thinking is to incorporate the programme for teaching the skills of critical thinking into a knowledge-rich subject environment. The programme for teaching the thinking skills is infused within regular disciplinary courses, thus providing a knowledge-rich environment. It is suggested that this approach contributes not only to the development of thinking skills, but may also lead to a better understanding of the discipline under study, as it decreases rote learning and promotes higher-order thinking (Zohar *et al.*, 1994). An added advantage of the infusion approach is that unless the learning of the skill is embedded in the subject matter being studied the students do not see it as relevant to their work and do not make the effort to learn the skill being taught. From the experience of this researcher gained as Headmaster of a large school, pupils, as well as their parents, often lodged complaints when they felt that time was being spent on learning experiences not related to the final examinations or the subject syllabus.

However, there are two arguments against this approach. Firstly, it may appear to contradict the contention by Johnstone and Wham (1982) that a "high information" situation hinders the ability to learn the particular skill being taught. This problem can be overcome, providing the advantages of both approaches (the infusion approach and the approach of teaching of the skills separately) if each skill is first taught separately as a clearly stated lesson objective, and then the particular skill which has been taught is applied to subject matter which has to be learnt. According to Costa (cited by Brandt, 1988), to teach the skills of thinking in isolation is just as unproductive as to teach content

alone. He recommends that content should be selected for its relationship to thought processes, and the subject material selected should have the learning of thinking skills as its central focus, i.e. the subject material should be suited to the teaching of thinking skills. Beyer and Charlton (1986) refer to research which indicates that students will benefit the most from skill teaching when the skills lessons are provided at a time when the students will be required to apply the skills which have been taught to the content material of the subject course. The learning of the subject matter will then also be more meaningful.

The second argument against the teaching of thinking skills linked to a subject is the contention that if thinking skills are taught within a specific subject domain these skills will not be transferred to other subject domains (Zohar *et al.*, 1994). Perkins and Salomon (1989, p19) comment that

> *"the case for generalizable, context-independent skills and strategies that can be trained in one context and transferred to other domains has proven to be more a matter of wishful thinking than hard empirical evidence".*

They comment that findings that support transfer, on closer examination, allow other explanations altogether. Brandt (1988) quotes Hirsch (1987) as saying that evidence is very strong that skills do not transfer from one content area to another. Chaffee (1992) says that a course in critical thinking will have limited impact on the students' modes of thought unless these same abilities are reinforced in other courses they take. However, others contend that under the correct learning conditions there will be a transfer of critical thinking skills to other content domains (Statkiewicz and Allen, 1983; Perkins and Saloman, 1989; Zohar, *et al.*, 1994). These conditions include

- exposure to multiple examples in different content areas,
- supplementing the examples with rules and generalisations, particularly when the latter are formulated by the learners themselves.

Perkins and Salomon (1989) also state that recent research has shown that transfer *is* obtained when general principles of reasoning are taught together with self-monitoring practices and applications in varied contexts. They indicate that while people fail to apply purely logical, abstract, or syntactical rules to new problems, they clearly do employ analogous, inferential rules to such problems. Wedman, *et al.*, (1996) state that expert problem-solvers, when confronted with a novel problem, will sometimes transfer the knowledge from a previously solved problem. This is referred to as analogical problem solving.

3.3 SUMMARY 0F PRINCIPLES AND TECHNIQUES SUGGESTED FOR TEACHING CRITICAL THINKING

The principles and techniques used in teaching critical thinking, which have been discussed in this chapter, have been summarised in Table 1 on page 36.

Table 1 : Summary of the principles and techniques suggested in the literature for teaching critical thinking

ADVICE FROM LITERATURE	REFERENCES	REASONS FOR INCLUSION THE IN TEACHING PACKAGE
1. The skills of critical thinking must be deliberately taught.	Beyer and Charlton, (1986). Zohar *et al.*, (1994).	It appears that critical thinking skills do not develop unless explicit and deliberate efforts are invested in developing them.
a. The learning of the skill should be a clearly stated objective	Angelo, (1993). Beyer and Charlton, (1986). Johnstone and Wham, (1982).	When learners know what their educational goals are, and how they can best be achieved, learning becomes more efficient and effective.
b. Students should understand the importance and value of learning the skill	Angelo, (1993). Zohar *et al.*, (1994).	Accepting the importance of learning the skill increases motivation which enhances meaningful learning.
c. The key procedures and principles that constitute the skill should be clearly articulated	Beyer and Charlton, (1986). Greeno, (1989). Angelo, (1993).	It helps the students to learn the skills more effectively and improves critical thinking.
2. When teaching the skill only the information relevant to the skill should be presented	Johnstone and Wham, (1982).	Students should not be burdened with extraneous information while trying to master the principles of the skill being learned.
3. Students need to be actively involved in the learning process	Pope and Gilbert, (1983). Driver and Bell, (1986). Sanders, (1988).	Research has shown that students learn more effectively if they are actively involved, mentally and physically, in the process of learning.
4. Repetition and practice enhance the learning of the skill	Statkiewicz and Allen, (1983).Beyer and Charlton, (1986). Zohar *et al.*, (1994).	Research has shown that there is a significant improvement in critical thinking with an increased amount of practice.
5. Teach the skill of critical thinking within a subject-area context	Zohar *et al.*, (1994).	It is suggested in the literature that it provides a relevant context for the learning of the skill and thus decreases rote learning and increases higher order thinking.

3.4 CONCLUDING REMARKS

In order to successfully teach the skills of thinking, Segal and Chipman (1984) argue that one must know both what to teach and what methods and materials to use. They point out, too, that strategies may need to differ for different types of students. For example, less competent learners will require more complete instruction, whereas more competent learners may acquire additional learning strategies simply by hearing about them. From this review of the literature on the teaching of critical thinking, a number of important principles and approaches for teaching critical thinking have been identified. The reasons for the lack of development of critical thinking in schools have also been high-lighted. This information has served as the basis for designing the approach to the present investigation into the teaching of critical thinking. These aspects are discussed further in the methods chapter of the present research. It should be emphasised, however, that much of the information gained from the literature on the topic is not research-based, but has resulted from suggestions by those involved in teaching critical thinking. The application of these suggestions thus provides an interesting opportunity to test these principles.

CHAPTER IV

METHODS AND MATERIALS

The purpose of this research, as discussed on page 4, was to address the problem that the teaching of critical thinking has generally not been effectively achieved at school level. In order to address this problem it was decided to plan and test a strategy for teaching critical thinking. It was felt that this could be done most effectively by preparing a teaching package which incorporated the selected approach to the teaching of critical thinking within the normal syllabus. In planning the methods and the materials to be used for the teaching package for critical thinking the information gained from the review of literature provided in chapters two and three was analysed and a strategy devised which was suitable for the time-period available and for the particular sample group. Important factors for the research were the selection of the pupil level at which to conduct the research and finding a suitable school at which to carry out the research.

4.1 THE SAMPLE

The research was conducted at a school affiliated to the Independent Examinations Board (IEB), which is involved in curriculum development and the setting of external examinations for its affiliated schools as an alternative to the state-controlled provincial education departments. The teaching package was developed for the Std 7 level for a number of reasons.

As mentioned previously (page 2), the Biology User Group affiliated to the IEB is involved in promoting a skills-based approach to the teaching of biology. Teaching thinking skills in biology would thus be supported by their initiative within the IEB group of schools.

* Because the IEB initiative involved an emphasis on skills, the examinations set by the IEB would test these skills. This would provide the added incentive for the teachers concerned with the research to support the approach to teaching critical thinking. (Refer to the argument on page 18, point 2.5.3, which discusses the influence of the type of examination on teaching practice in the classroom.)
* The Std 7 level seemed particularly suitable for the research for the following reasons:
    - This was one focal point of the IEB initiative on skills teaching, and also involved an external examination set by the IEB for the end of the Standard Seven year.
    - The Standard Seven year is the final year of compulsory schooling in South Africa. Teaching the skill of critical thinking at this level would thus not exclude those who choose to leave school at this exit point in the educational system.
    - These pupils should have reached the stage of development where they are capable of abstract reasoning, the "formal operation" stage, according to Piaget (Summers, 1982).

The sample consisted of all the Std. 7 pupils (58 in total) from a girls' school associated with the Independent Examinations Board (IEB). The pilot study was conducted at a second private multi-racial school, using a Std. 7 class of 22 pupils. The pupils in the pilot study and the experimental sample were in the thirteen- to fifteen-year age group. Further details are furnished in Section 4.5 and 4.6.1 on pages 49 and 50.

4.2 THE RESEARCH DESIGN

A quantitative approach was used in conducting this research. The untreated control group design with pre-test and post-test (Cohen and Manion, 1980.) was followed and is illustrated in Figure 1 (below).

	Pre-test	Treatment	Post-test.	Transfer Test
Experiment	O_1	X	O_2	O_5
Control	O_3	_	O_4	O_6

O_1 and O_3 represent the pre-test for testing the initial level of application of critical thinking skills for the experimental and control groups respectively.
O_2 and O_4 represent the post-test for testing the final level of application of critical thinking skills for the experimental and control groups respectively.
O_5 and O_6 represent the transferability test testing the transfer of critical thinking skills to another subject domain for the experimental and control groups respectively
The treatment represents the teaching package which was used in teaching the skills of critical thinking to the experimental group.
"Experiment" refers to the group of pupils from the sample who were exposed to the "treatment" , and "con[illegible]he control group selected from the same school, who were not exposed to the "treatment".
The [illegible]e represents a non-random selection of subjects.

Figure 1 : Diagrammatic representation of the research design

This is a quasi-experimental design as there was some doubt as to the random assignment of pupils to the experimental and control groups. At the start of the year the list of pupils in the standard was arranged alphabetically by the school and then the pupils were assigned to the three classes by placing the first pupil on the list in class one, the second in class two, the third in class three, the fourth in class one, and so on for the whole list. However, during the course of the year there were a number of changes in the classes which may have affected the random assignment of the groups. It was thus necessary to regard the groups as non-randomly assigned groups.

4.3 THE DEVELOPMENT OF THE TEACHING PACKAGE

4.3.1 Approaches used in teaching critical thinking

For the purposes of this research an approach based on teaching a set of "principles of critical thinking" which should be applied by the students to analyse problems and issues which confront them in their

daily lives was used, rather than to teach the "line-of-reasoning" model advocated in some of the literature (See the discussion under Sections 3.1.1. and 3.1.2.)

4.3.2 The principles of critical thinking to be applied in this study

As argued on page 5, thinking critically involves reflecting on the problems and issues confronting one in one's daily life. This "reflection" is facilitated by the use of criteria, rules and principles which guide the mental process involved. The contention is that by teaching the students to use these principles in analysing problems one would be teaching the students to think critically (Chiras, 1992; Zohar, *et al.*, 1994).

The criteria, rules and principles discussed under Section 2.1.2 were considered in deciding which principles to include in the teaching package. However, due to the constraints of time as well as the limitations of the syllabus, it was necessary to limit the number of these principles to be taught. It was also essential to take into consideration the particular pupils involved in the research when selecting the principles of critical thinking to be applied in the study. Care was taken to ensure that the principles selected for the teaching programme were suitable for this level of the pupil, and that the skills selected could be taught in the amount of time available for teaching this group of pupils.

The aspects of critical thinking to be used were identified by the following process:
As many aspects of critical thinking as possible were identified during the literature review and discussed under Section 2.1.2.

* Similar skills were grouped into categories. Eventually seven categories were identified which could be used in the research.
* On defining these more fully, it was found that there was a degree of overlap between some of the skills. It was felt that Standard Seven pupils might find it difficult to make the distinction between these, so two similar skills in two cases were merged, reducing the number of skills to five. It was postulated that if these five basic principles were applied, whether in the classroom or in everyday situations, they would promote a sound basis for critical thinking. According to Chiras (1992) good critical thinkers understand the importance of each of these principles and are able to apply them in everyday situations.

The following five principles of critical thinking (Chiras, 1992) were selected.
When considering the truth or validity of any facts or statements a good critical thinker should always:

1. *gather complete information* on the topic under discussion before reaching a decision.
2. *understand and define all terms* relating to the topic under discussion to ensure that judgements and evaluations are based on a correct understanding of the information,

3. *question the methods by which the information is derived.* Incorrect methods may lead to inaccurate information,
4. *question the conclusions which have been drawn from the information.* Faulty logic may lead to incorrect conclusions,
5. *look for hidden assumptions and biases* which may distort the information presented.

4.3.3 Selection of a suitable section of the syllabus

The first task in developing the teaching package was the identification of a section of the syllabus which would provide material suitable for developing the exercises and activities required for teaching the skills of critical thinking, but also cause as little disruption as possible for the school. The section on "Health" was found to meet these requirements for a number of reasons.

* This part of the syllabus contained a variety of materials suitable for providing exercises for developing the skills of critical thinking.
* The school was scheduled to write an external examination for the Independent Examinations Board (IEB). This section, however, was not included in the work to be examined, and would only be taught after the examination. Thus the control group would not be placed at a disadvantage by not having developed these skills, nor would the school lose time which could have been spent in preparing for this examination.
* The stage of the year at which this section was to be taught provided sufficient time for the researcher to develop the teaching package.

Having identified the five principles of critical thinking to be applied, and selected a suitable portion of the syllabus for the research, the next task involved the development of the teaching package.

4.3.4 The teaching package

The teaching package (Appendix A) was divided into four sections which will be discussed in detail.

- *An introduction for the package*

In a discussion undertaken by the researcher with 5 teachers from 2 different schools it was found that these teachers did not understand the meaning of the term "critical thinking" as it was to be applied in this research. It was thus evident that a fairly comprehensive explanation needed to be provided for the teachers.

An introduction setting out the purpose of the teaching package, an explanation of the concept of critical thinking being used in the package, the reasons why critical thinking is regarded as important, and the approach to be followed in presenting the package, was developed for the teachers. The aim of this introductory section was to emphasise the purpose of the research and to provide background

knowledge and an understanding of what aspects should be emphasised in presenting the work. A copy of this section appears in Appendix A, pages 74 to 81. It was also the intention to get the teachers who were involved in the research to understand the importance and value of critical thinking to their pupils, and to get the teachers involved in, and enthusiastic about, teaching in the way recommended in the teaching package.

- *An introductory lesson for the pupils*

The first lesson was planned as an introduction to the concept of critical thinking (see pages 82 and 83 in Appendix A). The teacher was asked to explain to the pupils that the next section of work they were going to study, the section on health, would involve two aspects:

* the teaching of the normal subject matter, and
* the teaching of the skill of critical thinking.

An explanation of the concept of critical thinking and its importance to the pupils was included in this section to assist the teacher in presenting the topic.

The purpose of this brief introductory lesson was to make the pupils aware of the importance and benefits of developing the skills of critical thinking, and to make them understand that critical thinking is a valuable skill for biologists and scientists, but particularly for the ordinary citizen. It was felt that if pupils understood its importance they would be more motivated to master the skills.

- **Lessons for teaching the principles of critical thinking**

Information derived from the literature on critical thinking as set out in the previous chapter determined the procedures to be followed when teaching the skill of critical thinking. As five principles of critical thinking were selected for this package five specific lessons were planned, each introducing a separate principle. These were short lessons, approximately 10 to 15 minutes each, and formed the "treatment" applied in this research. The "treatment", or lessons from the teaching package, was based on the following aspects:

* Each of the five principles of critical thinking mentioned above was taught as a unit on its own, where the focus of the lesson was to teach that principle only, and not to add any new factual content in the examples used in illustrating the principle. The principle being taught was a clearly stated lesson objective (see discussion on page 29).
* An example was found for each lesson which was used to demonstrate or illustrate the particular principle to be taught. The following approach was used in structuring each lesson.
  - A situation was presented in the form of an activity (mental or physical) in which the pupils could participate. Chiras (1992) indicates that critical thinking is an active process which requires student participation. The more students are involved in the learning process the more they will get out of it.
  - The example or situation used to illustrate the principle either did not require the learning of new factual content, or was already familiar to the pupils. The reason for this was to avoid having the pupils learn new subject information as well as trying to master a skill at the same

time. Thus the "noise" of extraneous information, which would hamper the learning process, is reduced. (Refer to the argument by Johnstone and Wham (1982) presented under Section 3.2.2 page 30.)

- After the activity was completed the pupils were asked to identify and discuss the key procedures that constitute the skill. Once these key procedures had been identified and understood by the pupils, the pupils were asked to put them in writing. This would serve as a consolidation of the points made, as well as a reference for future use. It ensured that the pupils thought about what was involved, mental processing being an essential ingredient of successful learning. (See the argument under Section 3.2.2 on page 30 which suggests that the principles that constitute the skill should be clearly articulated).

In summary, for each lesson on the teaching of a principle of critical thinking, the teacher was provided with the relevant lesson material and was asked:

* to indicate clearly that the objective of the lesson was to learn the particular skill named. (Beyer and Charlton, 1986).
* to give the pupils the relevant activities to do to demonstrate the principle. (Chiras, 1992).
* to discuss the key procedures and principles that emerged from the activities and which constituted the skill. (Beyer and Charlton, 1986)
* to state clearly, and put in writing, the particular principle with its key procedures and techniques. (Beyer and Charlton, 1986).
* to teach the skill separately from other subject matter so that the learning of the skill would not hampered by an overload of incoming data. (Johnstone and Wham, 1982).

Explicit instructions on conducting each lesson were drawn up for the teachers, to ensure that the skill was developed and emphasised. A suitable hand-out for each activity was prepared for the pupils, and overhead transparencies on important aspects of the lesson were provided to assist the teacher in presenting the work methodically and with an appropriate emphasis. A summary of the salient points for each skill was provided for the teachers to hand out to the pupils after the lesson.

- *Applying the principles to the biology lessons*

A topic on health from the biology syllabus was then identified for each of the five principles and a lesson which would apply a specific principle of critical thinking was then developed for each of these topics. Each lesson on a critical thinking principle was matched to the corresponding biology lesson. The lessons were designed so that the short critical thinking lesson (approximately ten minutes) could be followed immediately by the corresponding biology lesson in a single period. Each period allocated for teaching the skills of critical thinking thus consisted of two parts:

* firstly, a short exercise which introduced the particular principle, and
* secondly, the teaching of normal subject matter during which the pupils were given the opportunity to apply the principle to the biology subject material thus providing practice in

applying the principle. The teacher was asked to emphasise the application of the relevant principle in this lesson.

Further opportunities for using the skill were provided at intervals during the teaching of the section of the syllabus selected for this research. As Beyer and Charlton (1986) point out, skills are not learned as a result of a single exposure. Frequent and intermittent practice is necessary for the students to gain a lasting benefit from exercises used to develop skills.

As it was important that the natural sequence of the syllabus was retained, the sequence in which the critical thinking skills were presented was determined by the biology lessons to which they were linked. This, however, did not present a problem as there was no predetermined sequence for presenting the thinking skills

For each sub-topic of the syllabus on health the teacher was provided with an outline of the work to be done. For example, the following outline, presented in Figure 2, was provided for the section of work on germs, disease and infection.

SUBJECT TOPIC: GERMS, DISEASE AND INFECTION

CRITICAL THINKING SKILL:

Question the conclusions which have been drawn from the information available before accepting them as true.

SYLLABUS OUTLINE

I. Micro-organisms which cause disease
- *1. Viruses.*
- *2. Bacteria.*
- *3. Fungi.*

II. Spread of disease
- *1. Contagious diseases - spread by direct contact.*
- *2. Droplet infection. Breathing in germs (sneeze or cough).*
- *3. Germs from food.*
- *4. Germs from water.*

III. Immunity
- *1. Antibodies - your bodies chemical weapons*

IV. Artificial immunity

APPLICATION OF CRITICAL THINKING PRINCIPLE:

Colds and immunity

Figure 2 : Outline of a section of the syllabus with the associated thinking skill

A detailed explanation of the lesson on the relevant principle of critical thinking referred to in the outline, as well as the application of this particular principle to the biology subject material, was given

to the teacher. (Refer to page 87 in Appendix A for an example.) All the overhead transparencies and relevant hand-outs needed for these lessons were also prepared and given to the teacher, so that the presentation of the lessons on critical thinking was well co-ordinated.

4.3.5 Final preparation of the teacher's guide and the pupils' hand-outs

The various documents mentioned above were typed, checked and corrected and finally arranged in sequence according to the syllabus, and printed. Following the method used by Sanders and Mech (undated) in the preparation of a teacher's guide on "The Inquiry Approach to Teaching Microscope Skills" the different sections of the teacher's guide mentioned below were printed on different colours of paper to facilitate using the package. The following colour code was used. (Figure 3.)

1.	General information for the teacher	Blue
2.	Lessons on critical thinking	Green
3.	Syllabus outline and application of critical thinking in biology	Yellow
4.	Hand-outs for pupils	White

Figure 3 : Colour code for the sections of the teacher's guide

4.4 THE RESEARCH INSTRUMENTS

McMurray, et al., (1991) say that there are apparently no critical thinking tests available which are specific to biology. Some examples of questions used to measure the ability to apply critical thinking skills were taken from literature. Question 4 from Part A and Question 1 from Part B of the pre-test (see Appendix B) were taken from the tests set by Zohar, et. al., (1994) for the Biolgy Critical Thinking project, and question 3 from Part B of the pre-test was from the work of Dreyfus and Jungwirth, (1980). These questions were modified for the purposes of this research by the added requirement of providing a reason for the answers selected by the pupils. Additional questions were drawn up specifically for this research. Two equivalent versions of a pencil-and-paper test were drawn up to serve as a pre-test and a post-test. These tests were designed on the same format and logical pattern, but used different questions to avoid any learning effect from the first test. An additional test was set for a different subject (geography) to test for transferability of skills. The questions in all three tests were set to test critical thinking skills which were to be used in the teaching package.

4.4.1 Designing the pre-test

The pre-test (see Appendix B) consisted of two parts, part A and part B, each with four questions. In part A situation was described followed by a question, based on the situation, which would test the ability to think critically. Space was provided for the pupil to give an answer as well as an explanation

for the answer given. The purpose for structuring the questions of part A in this way was to show which errors of critical thinking would show up naturally amongst the group of pupils writing the test. In part B commonly occurring errors were provided as the distracters for the questions, and the pupils were asked to indicate whether or not they agreed with the answers provided, giving reasons for their answers. Part A was to be handed out to the pupils separately from part B and answered before they saw part B so that their answers to part A would not be influenced by the distracters or "errors" given in part B, thus affecting the results of the research.

An example of a question from each part illustrates these differences. (Figures 4 and 5.)

Part A

1. *The history teacher of a certain standard seven class was thinking of getting a new textbook for the pupils. She got a copy of each of the two new books which had become available, and asked the pupils to choose one to use for their studies. As they were due to write a test, the pupils decided to let John study the chapter on the work set for the test from book A and Jim the same chapter from book B. John's mark for the test was 90 and Jim's 60. The class concluded that book A was a better textbook, because John had used it to study and had got a better mark.*

   Was the class justified in making this decision? Explain your answer.

   _____

   _____

Figure 4 : An example of the type of question used in part A of the pre-test

Part B

1. *Two schools (X and Y) held a competition in mathematics for standard seven pupils. A pupil from school Y won. The following comments were made by some people after the competition.*

   Indicate whether you agree or disagree with each of these comments and give reasons for your answers.

   a. The maths teachers from school Y are better than those from school X.

      *Reason(s)*_____

      _____

   b. Pupils from school Y are better than pupils from school X.

      Reason(s) _____

      _____

   c. Pupils from school X had not prepared themselves as well as pupils from school Y.

      Reason(s) _____

      _____

Figure 5 : An example of the type of question used in part B of the pre-test

4.4.2 Validity

The pre-and post-tests were designed to generate scores which would indicate the proficiency in critical thinking of the sample group before and after applying the teaching package on critical thinking. From these scores certain inferences would be made regarding the effectiveness of the teaching package for teaching the skill of critical thinking. Test validity is the extent to which the instrument measures what it claims to measure (Schumacher and McMillan, 1993). The accuracy of the inferences made from the test scores on critical thinking would thus depend on the appropriateness of these tests for the purpose of testing critical thinking in this particular situation. It was thus necessary to establish the validity of these tests in relation to the specific purpose of the research and the particular pupil population. Steps taken to control validity involved firstly a control of content validity and secondly, checking the face validity of the tests.

- *Content validity*

Establishing content validity involves gathering content-related evidence to support the validity of the inferences made from the test scores. According to Schumacher and McMillan (1993), content-related evidence is the extent to which the content of the test is judged to be representative of some appropriate universe or domain of content. For the purposes of this research, that domain of content was the set of principles of critical thinking being taught in this teaching package. It was thus necessary to determine whether or not the pre-and post-tests measured the principles of critical thinking involved in this study. An analysis grid (Appendix E) was used to ensure that all the critical thinking principles being taught would be tested in part A as well as in part B. Each question was analysed to determined which aspects of critical thinking would be tested by the question and this was indicated on the grid. This analysis grid was then checked by two "experts" to confirm that the grid analysis was accurate. Both experts are lecturers at the University of the Witwatersrand in the Department of Science Education, and have extensive experience in the field of critical thinking.

- *Face validity*

Face validity is a less systematic appraisal of the relationship between criteria and content, according to Schumacher and McMillan (1993), and requires a judgement of whether or not the items appear to be relevant and suited to the purpose of the research, i.e. do they appear to measure what the test claims to measure?

The two "experts" were asked whether, in their opinion, the questions were suited to the purpose of the research and to the particular sample selected. They were asked to comment on the suitability of the

questions and the standard of language used, for the level of the pupils in the sample, and whether the test would measure the ability to think critically.

Some changes and adjustments to the test as well as to the analysis grid were recommended by the two experts. These recommendations were carried out.

4.4.3 Designing the post-test

The post-test (Appendix C) was designed to match every aspect of the pre-test. A new question was drawn up to match each question in the pre-test. The resulting pairs of questions were then carefully compared to ensure that they were similar in every respect. i.e. That each pair of questions tested the same principles of critical thinking and that the language used and the complexity of the questions was at the same level. The two experts were asked to check that the two tests were, in their opinion, equivalent.

The reasons for not using the same test for the pre-test and post-test were, firstly, that the questions in the pre-test were fairly simple and recognisable, and secondly, that the time interval between pre-test and post-test was only five weeks, a relatively short period. Thus there could have been a "learning effect" from the pre-test which could affect the results of the post-test, thus threatening the validity of these results if the same test was used as pre- and post-test.

The sequence of the questions in the post-test was also changed to further reduce any learning effect from the first test.

4.4.4 Designing the transferability test

A test (Appendix D) was set in a different subject in order to ascertain whether the skills of critical thinking learned from using this package would be transferred to another subject domain. That is, would the pupils apply these skills in another subject when they had not been specifically instructed to do so? Geography was chosen as the subject as it offered subject material which was suitable for setting the type of questions required. The approach to teaching and testing in Geography was sufficiently different from Biology that it would not to be obvious to the pupils that they should apply the principles of critical thinking which they had learnt in Biology. The pupils in the Biology classes involved in the research sample all took Geography as a subject, so the comparison for the whole group was possible.

The format of the test was changed so that pupils would be less likely to associate it with the critical thinking skills taught in biology.

* It was based on work covered in the geography syllabus.

* Two questions were asked. Each question contained a number of sub-questions with spaces provided for the answers.
* The test formed "Section D" of the final geography examination for the end of the year. It was typed in the same font as the rest of the geography paper (which was different from the font of the pre- and post-test given for the teaching package) thus not appearing to be anything other than a part of the Geography paper.

A further grid analysis was done to ensure that all the skills taught in the package were tested. This test, as well as the analysis of skills tested, was given to one of the "experts" who had analysed the pre- and post-tests to verify that the test tested the skills indicated in the analysis.

A discussion with the geography teacher who taught the whole group of Std. 7 pupils confirmed that she had not taught these skills to the Std 7 Geography pupils in her classes. She also confirmed the geographical accuracy of the questions as well as their suitability for the group.

4.5 THE PILOT STUDY

A pilot study was conducted on the tests to identify problems related to administration, time required for testing, and whether the questions were clearly understood by the pupils. The pilot test was carried out in a second private multi-racial school using a Std 7 class of 22 pupils.

* Administering the test took slightly longer than anticipated. A 40-minute period was allocated for the test, but a some pupils took 45 minutes to complete the test. This was, however, well within the time available for the testing at the school, where an hour had been allocated for the test.
* The teacher had been asked to tell the pupils that if they had any difficulty in understanding the wording of any question they should ask for help. The teacher was asked to make a note of all queries, indicating the question number as well as the nature of the problem. The teacher also asked the class after they had completed the examination whether there had been any difficulties. The only problem mentioned came from a Taiwanese pupil who was not yet proficient in English. The wording of the particular question which had been queried was subsequently simplified for the pre-test.

4.6 THE MAIN STUDY

4.6.1 The sample

As previously indicated, the sample consisted of 58 Std 7 pupils in three classes from a private girls' school. The pupils in this school are randomly placed in the classes, not selected according to ability or

in relation to the choice of other subjects (which might thus result in a streaming effect). It is thus likely that the classes are of similar ability levels with regard to critical thinking. By involving only girls in the research a possible gender effect was eliminated, thus reducing the variables which might affect the results.

The three classes involved were taught by two teachers, both well qualified and experienced, and recognised as capable teachers within the school. Both teachers held a B.Sc. degree and a teaching diploma. The first teacher had eight years teaching experience, and had taught all standards from Std. 5 to Std. 10. This teacher taught two classes. It was decided that the two classes taught by this teacher would be allocated as one experimental group and one control group. In this way a difference in the results between experimental and control groups could not be attributed to the possible influence of different teachers teaching the experimental and control groups. The third class formed a second experimental group taught by the second teacher. This teacher had taught for twenty-four years and held a senior position in the school and was responsible for running the school's Biology Department.

4.6.2 Preparing the teachers for using the package

An initial discussion was held with both teachers in order to gain their co-operation in assisting with the research. During this discussion a brief overview was given of the skills of critical thinking and what would be required in carrying out the research.

During the development of the package the Head of Department of Biology at the school was frequently consulted with regard to the material to be included, the suitability of the level at which the work was pitched in relation to the ability of the group, and any changes or modifications to the sequence of the work. The two teachers were most co-operative in accommodating the requirements of the research work.

Prior to the start of the investigation a detailed discussion was held explaining the theoretical aspects, the use of the materials, how the lessons should be taught and generally ensuring that the teachers were familiar with the requirements of the research. During this meeting the date of the pre-test was finalised, and the starting date for using the teaching package was established.

4.6.3 Administering the pre-test

The pre-test was administered to the pupils on Friday 21 October. All the pupils involved (the two experimental groups and the one control group) wrote the pre-test at the same time, under strict examination conditions. They were asked to use the examination numbers allocated for the IEB external examination, not their names, thus creating a more official atmosphere for the test. This helped to

ensure that the pupils made a serious attempt to answer the questions to the best of their ability. It also meant that the pupils' names did not appear on the papers, thus reducing possible bias on the part of the marker. (The scripts were also marked without being separated into experimental and control groups making the groups less identifiable, which also helped to reduce the influence of researcher bias.)

4.6.4 The research programme

The Research programme took place according to the following schedule:

- *Pre-test:* Friday 21 October. Duration 1 hour
- *Introductory lesson:* Friday 28 October.
- *Lessons on health and on critical thinking were taught according to the schedule shown in Table 2 .*
- *Post-test:* Thursday 24 November. Duration: 1 hour.
- *Transferability Test:* Monday 28 November.

Table 2 : Programme for lessons on critical thinking with corresponding biological topic on health

DATE	CRITICAL THINKING SKILL	BIOLOGY SYLLABUS
2 Nov.	*Question the methods by which the information is derived.* Incorrect methods may lead to inaccurate information.	Heart disease.
4 Nov.	*Question the conclusions which have been drawn from the information.* Faulty logic may lead to incorrect conclusions.	Germs, disease and infection.
11 Nov.	*Look for hidden assumptions and biases* which may distort the information presented.	Smoking and ill-health.
16 Nov.	*Gather complete information* on the topic under discussion before reaching a decision.	Drugs and health.
18 Nov.	*Understand and define all terms* relating to the topic under discussion to ensure that evaluations are based on a correct understanding of the information.	Cancer.

4.6.5 Liaison with the teachers

A meeting was held by the researcher with the Head of Department of Biology at the end of each week to check that the work had been covered according to the instructions and to discuss the work for the following week. Both experimental groups were taught at the same time in adjacent classrooms. The two teachers involved were thus able to co-ordinate work to ensure that both followed the same procedures.

4.7 CONCLUDING REMARKS

Both teachers were asked to note any problems with administering the package, any corrections which should be made, and any suggestions for improvement. An evaluation sheet (Appendix F) was provided as a guide to help the teachers in evaluating the package.

CHAPTER V

ANALYSIS AND DISCUSSION OF RESULTS

In this chapter the results obtained from the pre-test, post-test and transferability test are analysed and discussed. As the teaching package used in this research was designed to teach the pupils to think critically, the emphasis in the analysis of the results is on the use of the various principles of critical thinking which this teaching package aimed to promote. The purpose of this analysis is to determine whether the approach followed in this teaching programme has improved the ability of the pupils exposed to it to think critically.

5.1 MARKING OF THE PRE-TEST AND POST-TEST

In order to interpret the data it is essential to organise them. In quantitative research, this organisation is provided prior to the collection of the data by the instrument used (Schumacher and McMillan, 1993). However, in this case, the data collected from the pre-test and post-test did not fully conform to the organisation which the instruments appeared to provided. In stead, some of the organisation of the data emerged from the data analysis in a manner more common in qualitative research. One of the difficulties faced when marking the pre-test and post-test of this investigation was that when they answered the questions the pupils did not use the formal terminology which was used in teaching the principles of critical thinking during the course. For example, a pupil's answer may have been *"You can't say that. You don't know how much time he spent studying"*. This answer implies the use of the principle *"One must gather complete information before drawing a conclusion on the particular issue in question"*, but the pupil does not actually explain this. In formulating their answers, the pupils may have been applying a particular principle of critical thinking, but it may not have been immediately obvious which principle was being applied.

In order to organise the data, a process of coding similar to that used in qualitative research was employed. This method of analysis involved breaking down the data into units of meaning called *topics* (Schumacher and McMillan, 1993) or *concepts* (Strauss and Corbin, 1990), and then grouping the topics into larger clusters to form *categories*. The technique, referred to as "the constant comparative method of analysis" (Strauss and Corbin, 1990), involves the comparing and contrasting of each *topic* and *category* to identify their distinctive attributes. In this analysis, the *topics* were derived from the answers given by the pupils, emerging during the data analysis, while the *categories* were pre-determined by the questions of the pre-test and post-test, based on the principles of critical thinking which were being tested by each question.

To facilitate the analysis a master sheet was prepared in the format shown in Table 3 below. The question numbers with the *topics* for each question, gained from the answers given by the pupils, were arranged across the top of the page. The pupils were listed vertically down the left side of the page according to their examination numbers, without having been separated into experimental and comparison groups. A grid analysis was then carried out by systematically matching each answer given by a pupil to a corresponding topic, and then marking the appropriate block.

Table 3 : Master sheet for the coding of the data from the tests

			Question A. 1								Question A. 2								Question A. 3							
Pupil Number / Coding *Topics*	*Agree with the question statement*	*Disagree with the question statement*	John is cleverer than Jim		John studied harder than Jim		One can't decide from two pupils' marks alone		The test should be repeated swopping books.		Both should write a test from each book		Jim may have a learning disability.		Agree with the question statement	Disagree with the question statement	Last year's team was stronger		This year's team was weaker		Last year's team had better players		The opposition teams were stronger this year		Last year's opposition was weaker		Agree with the question statement	Disagree with the question statement	He's promoting sugar as he's in the sugar industry		*Other sources of energy don't cause tooth decay*		Some of the dieticians reasons are valid		He is biased towards the sugar industry		The article says 'cut back' not 'cut out'	
7210109		1	1			1										1	1										x										
7210118	x															1						1						1			1						
7210154		1		1												1			1			1						1	1								
7210181		1	1					1							x												x										
7210207	x															1					1							1						1			
7210225	x															1						1						1				1					

"x" *represents an incorrect answer*

"1" *represents a correct answer and the correct reason selected for the answer.*

The second stage of the analysis involved classifying each of the *topics* in the correct *category*, i.e. matching each topic to a particular principle of critical thinking which the topic applied in answering the question. Using a second master sheet, the topics given by each pupil were transposed to the appropriate categories. This master sheet thus provided an analysis of the specific principles of critical thinking which had been applied by each pupil for each question.

The writing of all three tests took place under examination conditions, where all the pupils were seated according to their examination numbers. Only examination numbers appeared on the scripts. The

marking was then carried out for the whole group according to these examination numbers, without first separating them into control and experimental groups. By keeping the whole group intact during the marking the danger of any bias during marking was avoided.

5.2 THE PRE-TEST AND POST-TEST RESULTS

Only when both stages (the classification of the answers given by pupils into the *topics,* and the classification of the *topics* in *categories*) of data organisation had been completed, was the overall group subdivided into control and experimental groups for analysis of the results. The results were then analysed to determine whether the teaching package had resulted in an improved use of the skills of critical thinking.

5.2.1 Selection of the statistical procedure for analysis

The decision about which statistical procedure to use was based on the following factors. The first factor to be taken into account in analysing the results was the possibility that the experimental and control groups were not equivalent initially in their level of critical thinking. As explained on page 46, the pupils were allocated to classes at the start of the year, and it was not possible to re-allocate them for the purposes of this research. Even though the initial placement was done on a random basis, it was not a random assignment according to the research procedures. Furthermore, a number of pupils were changed from one class to another during the course of the year, prior to the start of the research programme. The groups could therefore not be regarded as being randomly assigned, thus allowing the possibility that there were initial differences between the experimental and control groups. Without being able to apply random assignment, which equates the treatment and control groups on all variables except the independent variable (Parker, 1990), it was essential to statistically control the data to reduce extraneous variation. Schumacher and McMillan (1993) state that an analysis of covariance (ANCOVA) accounts for possible initial differences between the control group and the experimental group when determining the level of significance of differences in the post-test scores. However, it should be noted that the use of an analysis of covariance will make statistical adjustments for any initial differences between the groups with regard to the covariate, but the possibility exists that there are other uncontrolled variables related to the dependent variable which may affect the dependent variable. A random selection of the sample may have controlled for this aspect more effectively.

The second factor influencing the choice of statistical test related to the possibility that there would not be a great difference between the experimental group and the control group in the post-test scores because the intervention period was relatively short. Schumacher and McMillan (1993) indicate that ANCOVA is also suitable for use where it is necessary to increase the power of the statistical test to find differences between the groups.

There were therefore two reasons why analysis of covariance was appropriate for the analysis of the post-test results of this research as it is particularly relevant where intact groups are used with no randomisation, as in this case, and where the post-test differences are not expected to be large.

However, ANCOVA is a parametric test which requires that the data is normally distributed. A check on the assumption of normality for the data of this research was carried out before finalising the choice of ANCOVA as the statistical technique to be used. A comparison of the variances of the experimental group and the comparison group was carried out to test the null hypothesis that assumes that the variance (s^2) of the two samples is equal ($s^2_1 = s^2_2$). The F-test, which makes use of the F-distribution, was used for this purpose. The first step involved determining an F value for the sample variances for each of the categories of data obtained, using the expression F = *larger sample variance/smaller sample variance* (Hine and Wetherill, 1975; Clarke, 1994). These values of F were then tested for significance using the F-distribution for degrees of freedom 37 and 19 (Experimental group: n = 38; Comparison group: n = 20. Degrees of freedom = n - 1), at the 5% level of significance. The F-distribution value for 37 and 19 degrees of freedom, at the 5% level of significance, is 2,04.

Table 4 shows the relevant figures obtained from the F-test for the overall use of critical thinking skills, as well as for each of the principles of critical thinking.

Table 4 : The values of the F-test to verify the assumption of normality

Overall critical thinking skills	Test	F value
a) The total number of critical thinking skills used	Pre-test Post-test	1.02 2.09
b) The number of principles of critical thinking used	Pre-test Post-test	1.26 1.91
Principles of critical thinking	**Test**	**F value**
"Gather complete information"	Pre-test Post-test	2,46 1,20
"Question the Methods"	Pre-test Post-test	1.88 1,03
"Question the conclusions drawn"	Pre-test Post-test	1,77 1,48
"Look for hidden assumptions and biases"	Pre-test Post-test	2,19 1,41

If the F value obtained for the F-test is less than the F-distribution value for the relevant degrees of freedom, in this case 2,04, then the variance can be considered not to be statistically significant. That is,

homogeneity of variance can be accepted, and normality of distribution can be assumed (Hays, 1994; Clarke, 1994; Hine and Wetherill, 1975).

In 9 out of the 12 categories shown in Table 4, the F-test produced a value less than the F-distribution value of 2,04. In these 9 cases there is thus no evidence of a real difference in the variance of the two samples, and the null hypothesis that there is no difference between the variances of the two samples ($s^2_1 = s^2_2$) can be accepted (Hine and Wetherill, 1975; Clarke, 1994), which suggests normally distributed scores.

When the scores do not meet the assumption of normal distribution, Schumacher and McMillan (1993) suggest the use of a non-parametric analogue to the parametric test, but they point out that parametric tests are robust and more powerful in detecting significant differences and thus recommend their use in situations where not all the assumptions for their use are met. Thus, even though the test scores were not normally distributed for all the categories, ANCOVA was selected as the appropriate test to use for the analysis of the scores.

The analysis of the results was carried out in two stages using ANCOVA as the statistical test. The first stage involved an analysis of the overall results for **the total number of critical thinking skills used**. The second stage involved an analysis of **the use of each individual principle of critical thinking**.

5.2.2 The overall use of critical thinking skills

The five principles of critical thinking which were selected for the teaching package used in this research are listed in Section 4.3.2 on page 41. Some of the principles involved more than one aspect of critical thinking. For example, the principle "*Question the methods used in gaining the information.*" could refer to the need to "*control other variables*" which might influence the results, or to the fact that *"the sample size was too small"* to provide the information required. The pre-test and post-test were structured so that each question could be answered correctly by applying any or all of two, three, or more, of the five principles of critical thinking.

Determining the ability of the pupils to think critically thus involved analysing how they had applied these five principles in answering the questions of the pre-test and post-test. It was argued that the more proficient pupils were in thinking critically, the more of the possible principles of critical thinking applicable to each question they would use. The analysis of the results was based on two categories. The first category was the *"total number of times the pupils applied the principles of critical thinking"* in answering the test questions. A pupil could provide one, two, or more, answers to each question, each

answer using a principle of critical thinking. The sum of these principles of critical thinking used by each pupil in completing the test provided the data for this category. The second category was based on the "total number of different principles of critical thinking which were used". The data for the two categories is shown in Table 5 under the two columns headed the *"number of times the principles were applied"* and the two columns headed *"the number of principles used"*. The following example illustrates the difference between these two categories. If a pupil answered question 1 from part A of the pre-test (see Appendix B) by saying "I disagree that book A was a better book because (a) the sample was too small to provide conclusive proof, and (b) there were other variables which were not controlled", this would have been recorded as "2" for the *"number of times the principles were applied"*, but only once for the *"number of principles used"*, as both (a) and (b) fall under the principle *"Question the methods which were used"*, as explained above. The mean scores of the pre-test and post-test for each group, shown in Table 5, represent a **percentage** based on the number of times critical thinking skills were used by the group divided by the possible number of times they could have been used by the group. It should be pointed out that it was possible to provide more than one answer, using different principles of critical thinking, for each question. As many pupils provided only one answer per question, the mean score percentages for the test appear to be fairly low.

Table 5 : The use of the skills of critical thinking by pupils for the pre-test and post-test

	Comparison Group (n=20)		Experimental Group (n=38)	
	Total number of times the principles were applied.	*Number of principles used*	*Total number of times the principles were applied.*	*Number of principles used*
Mean score (%): Pre-test	20,0	39,5	21,7	45,2
Mean score (%): Post-test	25,4	51,5	35,8	59,5
Standard Deviation : Pre-test	8,4	11,5	8,5	12,8
Standard Deviation : Post-test	10,7	16,6	7,3	8,7

The question which arises is whether the differences of 1,7%, and 5,7%, in the pre-test mean scores between the comparison and experimental groups for the two aspects being analysed (*"Total number of times the principles were applied."* and *"the number of principles of critical thinking used"*), were statistically significant, indicating a difference in the initial level of ability of the two groups to think critically. Analysis of covariance on the total number of critical thinking skills used, yields an F value of 17,6 which indicates a probability of 0,0001 (refer to Table 6). A similar analysis for number of principles of critical thinking used, yields an F value of 0,8 giving a probability of 0,3 (see Table 6). This means that the experimental group showed a statistically significant difference in their initial ability in terms of the number of times critical thinking skills were used in answering the questions, but that there was no significant difference, at the 0,05 level of significance, in initial ability with regard to the

number of principles of critical thinking which were used in answering the questions.

In order to determine whether the teaching approach was successful it was necessary to determine whether the post-test mean score differences were statistically significant taking into account the differences in initial ability.

For the *total number of thinking skills used*, analysis of covariance yields an F value of 20,3 for the group variance on the post-test, which indicates a probability of $p<0.0001$. This means that the difference of 10,4% in the mean scores for the post-test represents a statistically significant improvement in critical thinking by the pupils exposed to the experimental intervention when compared with thelevel of improvement of the comparison group, once the greater initial ability level of the experimental group for this aspect is corrected for.

For the *number of principles of critical thinking applied* in the post-test, analysis of covariance yields an F value of 4,6 which indicates a probability of 0,03. This suggests that the difference of 8% in post-test mean scores between the two groups was not due to chance alone, but that it represents a statistically significant improvement in the level of critical thinking with regard to the number of principles of critical thinking used which could be attributed to the experimental intervention.

Table 6 : Analysis of covariance comparing the use of the principles of critical thinking by the comparison group and the experimental group

	Effect	F Value	Degrees of Freedom	Level of Significance (P)
(a) The total number of critical thinking skills used	Covariate	17,6	1, 55	0,0001
	Group Variance	20,3	1, 55	<0,0001
(b) The number of principles of critical thinking used	Covariate	0,8	1, 55	0,3
	Group Variance	4,6	1, 55	0,03

Covariate : The covariate is the pre-test. The covariate row represents the statistics on the initial differences between experimental and comparison groups.

Group Variance : The group variance row represents the statistics on the post-test differences between experimental and comparison groups.

These results for the overall use of the principles of critical thinking thus suggest that the approach to teaching critical thinking which was used in this teaching package was successful with regard to both the number of times the pupils applied principles of critical thinking, and the number of different principles of critical thinking which were applied. This supports the contention by Beyer and Charlton (1986), and Jackson (1986), that the skill of critical thinking can be taught if deliberate efforts are made to teach it. The various techniques for teaching thinking skills gained from a review of literature (refer to Table 1 on

page 36), and the information gained from the theories of learning, which were incorporated in the teaching strategy, have been effective in improving the level of critical thinking in the pupils to whom it was applied. However, the level of success should be considered in relation to some reservations and problems relating to this research, which are discussed below, as well as those referred to in Chapter VI.

The analysis for the two aspects given above indicates that there was an improved level of critical thinking by the pupils of the experimental group, thus suggesting that the experimental intervention was successful. However, the difference in the level of success for the "number of times critical thinking skills were used" compared with that of the "number of principles which were applied", as indicated by the difference in the levels of significance ($p<0,0001$ and $p=0,03$ respectively) suggested that there may have been a difference in the levels of application by the two groups of the individual principles of critical thinking. Further analysis of the data for use of individual principles was necessary to see if the pupils in the two groups had acquired **each of the principles** of critical thinking equally well, and if not, whether there were reasons for this.

5.2.3 The level of application of each principle of critical thinking

A summary of the mean scores for each principle of critical thinking, and the relevant statistics from an analysis of covariance for the pre-test and for the post-test, are given in Table 7.

For the first principle, *"Gather complete information before drawing a conclusion"*, the experimental group achieved a lower mean score than the comparison group in the pre-test (with a probability of 0,008), but were markedly better in the post-test, having a mean score which was 21,1% higher than that of the comparison group. With a probability of $p<0,0001$ this suggests that, having corrected for the initial difference in ability, there was a statistically significant gain by the experimental group which was not due to chance and thus probably due to the experimental intervention. Analysis of covariance for the results of the principle *"Question the methods by which the information was derived"* indicates that there was also a statistically significant difference in the post-test mean score for this principle, at the 0,05 level of significance, after the initial differences between the groups had been taken into account. However analysis of covariance for the remaining two principles, *"Question the conclusions drawn from the information available" and "Look for hidden assumptions and biases"* revealed that there was no significant difference between the groups on the post-test scores at the 0,05 level of significance. (The fifth principle "understand and define all terms", which was selected for the research programme, was not tested often enough in the pre-test or post-test to provide reliable data and has thus not been included in the statistical analysis.)

Table 7 : A comparison, using an analysis of covariance, of mean scores for each principle of critical thinking for the experimental and comparison groups

Principles of critical thinking	Mean score		F Value	Level of significance
	Comparison group	Experimental group		
Pre-test : (covariate)				
"Gather complete information"	28,6	26,9	7,4	0,008
"Question the methods"	16,4	21,5	4,1	0,05
"Question the conclusions drawn"	16,6	19,6	2,7	0,1
"Look for hidden assumptions and biases"	8,7	13,8	4.0	0,05
Post-test : (group variance)				
"Gather complete information"	20,0	41,1	35,9	$p<0.0001$
"Question the methods"	26,0	38,9	5,3	0.02
"Question the conclusions drawn"	27,1	31,9	1,2	0.27
"Look for hidden assumptions and biases"	31,6	37,7	0,2	0.65

The significant improvement in the use of the first two principles by the experimental group, and the lack of improvement in the use of the second two principles, may have been caused by a variety of different factors. Some of these factors may relate to the methods used in the teaching package, and serve to confirm the validity of the results, while others may detract from the results. Some of the possible causes of the difference in improvement are suggested in the following discussion.

In the case of the first principle, *"Gather complete information before drawing a conclusion"*, the experimental group improved significantly more than the comparison group. The following factors may have contributed to the success in teaching this principle.

- Far more opportunities were provided for application of this principle in the teaching period, as well as in the test, than for the other principles. This suggests support for the contention of Chiras (1992), and of Beyer and Charlton (1986), that the teaching of critical thinking is an active process involving the pupils and that it is improved by repetition and practice.
- It is possible that this principle is a relatively simple concept which may be readily understood by the pupils, and easily applied, whereas some of the other principles may be a little more difficult to understand and apply.

There was a dramatic increase in the mean scores from the pre-test to the post-test for the last principle

"Look for hidden assumptions and biases" by both the experimental and the comparison group. However ANCOVA suggested that the difference in the means was not statistically significant, and could have happened by chance. This suggests that the increase was due to some uncontrolled factor, and not the experimental intervention. On comparing the questions, it was found that the post-test questions were based on far more emotional issues than the pre-test. In Section A of the test, the pre-test question was based on the effects of sugar on tooth decay, while the post-test was based on the ill-effects of the abuse of alcohol. Because of the strong emotions associated with alcohol abuse, and the greater familiarity with the topic from discussions at the school, in the media, and with parents, it is possible that there was a greater tendency for the pupils to pick up the bias than with the relatively innocuous "sugar and tooth decay" issue. A similar situation was found for the questions from Section B of the two tests. The pre-test dealt with a little-known issue of the dangers of chlorine production, whereas the post-test dealt with the well known and much publicised issue of dune mining at St. Lucia Bay. The fact that the two issues which were raised in the post-test were more likely to be familiar to the pupils, and were more emotional issues, may have contributed to the difference between the pre-test and post-test marks. This imbalance only became evident on analysing the results. This particular principle was tested by only one question from section A and one from section B. Thus there was no other question in the post-test to correct for the imbalance in the questions of the pre-test and post-test for this principle of critical thinking. Should these tests be used in further research on critical thinking, it is recommended that the questions from one of the sections be switched around between the pre-test and post-test, or preferably, that the questions on the familiar and emotional topics which were used in the post-test be replaced.

The response to the questions on the controversial topics by the experimental as well as the comparison groups suggest that whatever contact they had had with the topics in the past had made an impression on them, supporting the contention by Mead and Scharmann (1994) for the use of structured controversy as an instructional approach for developing critical thinking. They suggest that it results in higher student motivation and overall achievement. Nolan and Nolan (1997) recommend the use of environmental conflict to promote critical thinking. They say that it opens the minds of the students to the viewpoints of others, and builds the foundation upon which they can make decisions.

The following points may be made from this discussion.

- More care should be taken in balancing the pre-test and post-test questions. Equivalence in the type of question is not sufficient. Factors such as the familiarity of the question topics must be considered as well. Prior knowledge and prior exposure to the topic, may weaken the effectiveness of a question to distinguish between the relative abilities of the experimental and comparison groups.

- It would be advisable to include a reasonable number of opportunities to apply each principle in the test instrument to reduce the influence of uncontrolled variables which may influence the outcome of the research.
- The fact that there may have been some weaknesses in the test instrument which led to inaccurate results does not mean that there was no improvement for these aspects, but only that the method of assessment of this improvement was inadequate. This stresses the importance of a suitable instrument for testing the effectiveness of the intervention. McMurray *et al.* (1991) comment on the lack of suitable testing instruments for critical thinking in biology. The testing instrument as a limitation in this study is discussed in Chapter VI.

5.3 STATISTICAL ANALYSIS OF THE TRANSFERABILITY TEST RESULTS

The "transferability test" was used to determine whether the use of thinking skills within a particular subject domain (biology) would transfer to another subject domain (geography).

The format of the transferability test differed from that of the pre- and post-test for reasons explained under Section 4.4.4 on page 48. The analysis of the results is based only on the number of critical thinking skills used, and not on each specific principle of critical thinking. It was not feasible to look at each principle of critical thinking individually, as the number of opportunities for applying each principle was too small, and differed vastly from that of the pre-test. It should also be noted that the mean score on the transferability test, for both the experimental and comparison group, was lower than that of the pre-test. However, as the pre-test and transferability test were totally different, with different totals, this difference should not be regarded as relevant.

Table 8 : Data from the test for the transferability of thinking skills

	Control Group (n=20)	Experimental Group (n=38)
Mean : Pre-test (biology)	20,0	21,7
Mean : Transferability test (geography)	9,0	20,5
Standard Deviation : Pre-test (biology)	8,4	8,5
Standard Deviation : Transferability test (geography)	9,5	11,5

Mean scores as a percentage, calculated as the actual number of principles of critical thinking used over the possible number.

The mean score for the transferability test of the experimental group was 11.5% higher than that of the control group (see Table 8). An analysis of covariance was used to determine whether this difference was statistically significant (see Table 9). The pre-test, which tested critical thinking in the subject domain of

biology, was used as the covariate. The analysis of covariance, having corrected for the initially pre-test difference between the two groups, yielded an F value of 13,7 for the group variance (geography test). which indicates a probability of 0,0005. This means that in only 5 times in 10000 would a difference in mean scores of this magnitude, be due to chance alone. This suggests that for this particular experimental intervention, the experimental group showed a statistically significant transfer of critical thinking skills from the subject domain of biology to that of geography.

Table 9 : Analysis of covariance for the transferability of thinking skills

Effect	F Value	Degrees of Freedom	Level of Significance (P)
Covariate	4.6	1, 55	0,03
Group Variance	13.7	1, 55	0,0005

This result supports the contention by Zohar *et al.* (1994) that under certain conditions of learning a transfer of skills will take place from one subject domain to another. These conditions include exposure to multiple examples in different content areas within the subject used to teach the skills, and supplementing the examples with rules and generalisations. Bereiter (1984) refers to the "permeation strategy"' in which the principles of critical thinking are promoted in every possible aspect of the instructional programme. The teaching strategy for this research was designed to accommodate both these aspects, though time constraints, as explained in Chapter VI, limited the use of further practice examples. The contention by Johnstone and Wham (1982) that a "high information" situation, such as that provided by a subject domain, would hinder the learning of the skill, was overcome by separating the lessons on thinking skills from the Biology lessons, but then applying the skills learnt in the critical thinking lessons to the biology subject matter. Though the scope of this research is limited, the findings do support the contention that thinking skills will transfer from one subject domain to another, if these conditions of teaching are met. However, further research on a broader scale is recommended to confirm these findings.

5.4 ANALYSIS OF THE LANGUAGE USED IN ANSWERING THE QUESTIONS

It was not the intention to do an intensive analysis of the language used by the pupils in answering the questions, as the questions were not structured for this purpose. Such an analysis would have been beyond the scope of this research. However, during the marking of the scripts, certain answers appeared to reflect more accurately and precisely the principles of critical thinking which had been taught than did others. These answers were noted and when the scripts were separated into control and experimental

groups after the marking, a follow-up determined from which group they had come.

The following three answers, which had been identified during the marking of the post-test scripts, illustrate the type of wording which suggests the influence of the lessons on critical thinking.

7210485 : Question A4 : *"Firstly, I don't have enough information to be able to judge whether or not it actually was the smallpox vaccination that caused the Aids"*

7210109 : Question B1 : "It would have to be determined if this was the only variable introduced..."

7210029 Question B1(c) : "You have to examine all possible reasons before you can come to a conclusion...."

Though these three candidates, and most of the others whose answers were noted during the marking as reflecting the terminology used in the programme, were from the experimental group, it should be emphasised that this was not a definitive search to identify all candidates who may have used this type of language. What it does illustrate is that, even though the intervention period was short, the use of this language provides some evidence that pupils had learnt to think in the manner that the teaching programme had intended to promote. This adds further confirmation that there were positive gains from the study as was shown by the statistical analysis.

A point which emerges from this analysis of the language used, is that there was a need to provide for qualitative assessment by conducting interviews with pupils. This aspect is discussed under the limitations of the study in Chapter VI.

5.5 CONCLUDING REMARKS

The purpose of the analysis in this chapter was to determine whether the approach to teaching critical thinking which was applied by the teaching package had brought about an improvement in critical thinking in the pupils who had been exposed to the programme. The analysis of covariance provided information which indicated that the approach had brought about an improvement in the overall level critical thinking, and of the use of some of the principles of critical thinking. However, it also showed that not all of the individual principles of critical thinking had shown a statistically significant improvement. The analysis also suggested that there was a transfer of the skills learned in one subject domain to another subject domain, which was statistically significant.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to develop an effective strategy for teaching the skill of critical thinking. However, before looking at the conclusions and inferences drawn from this research, it would be wise to examine the limitations of this research which might cast doubt on the validity of these conclusions and inferences.

6.1 LIMITATIONS OF THE STUDY

6.1.1 Selection of the sample

A number of the problems encountered in this research relating to the sample are discussed below, together with the steps taken, where possible, to negate their influence on the research.

- **The non-random selection of the sample**

The inherent problem preventing the selection of a truly random sample when doing research within a school lies in the fact that the school has invariably established its own structures and programmes, and any changes to these would be disruptive to the school. At the late stage of the year at which the research was carried out, it was not possible to re-assign pupils to groups to achieve true randomisation of the experimental and control groups. When working with intact groups, initial differences between the groups relating to the dependent variable may be corrected by using statistical procedures such as an analysis of covariance. However, Schumacher and McMillan (1993) point out that other uncontrolled and unmeasured variables are also related to the dependent variable and hence may affect the dependent variable. In the school situation, uncontrolled variables includes factors such as the use of different teachers directly involved in the study, as well as factors such as attitude and motivational differences between the pupils (Sanders, 1995).

The class groups which formed the sample for this research were already established and changes would have been disruptive to the school's academic programme. However, as pointed out under Section 4.6.1 on page 49, the placement of pupils within classes in the school was done on a random basis with no link to specific subjects which might involve a selection process based on aptitude, as is often the case for mathematics or science subjects. Though the placement of pupils in classes in this school took place on a random basis, it was not a controlled randomisation process according to research requirements, and some timetable changes had been implemented during the year, further affecting the level of

randomisation. When considering the results of the research, the level of randomisation of the groups should be taken into account, and although the analysis of covariance would have corrected for any initial differences between the groups relating to the dependent variable, other uncontrolled variables could have influenced the outcome of the research.

- **Background of the sample population**

The composition of this particular group may not be representative of the general population, limiting possible generalisation of the results. The school from which the sample was drawn is a private school, which operates on a very high fee structure. The pupils attending the school would thus most likely come from the upper income groups with the corresponding privileged upbringing. There is also a strong likelihood that many of the parents come from an educational background which is higher than that of the general population. This aspect would be likely to influence the results in two ways. Firstly, it is conceivable that many of the pupils, both in the control group as well as in the experimental group, would have been exposed to a pattern of critical thinking within their family circles prior to the starting of the research because of the educational background of the parents. Secondly, the general atmosphere in the school, as well as the basic approach of the Independent Examinations Board (which is the examining body to which the school is affiliated) encourages an enquiring and questioning attitude amongst the pupils, rather than one which is geared to rote learning, and to acceptance of facts without questioning. This could possibly have caused the pupils of this sample, from the control as well as the experimental group, to achieve a better result in the pre-test than would be expected of the general population. If both groups entered the research programme with some prior knowledge of the principles of critical thinking, the margin for improvement in critical thinking due to the experimental intervention would be somewhat reduced, thus possibly also reducing the difference in post-test scores between the experimental and control groups.

- **The sample size**

With only 58 pupils participating in the research, the sample was too small to support a generalisation of the results to the larger population of the country, especially when considering the background of the sample population which was discussed above. The larger the sample, or the more samples are used, the greater the probability that the mean score will approximate that of the larger population. It is thus recommended that in further research on this topic, additional, or larger samples be used.

- **Contact between the control group and experimental group**

As the school involved in the research is a small school with a boarding facility, it is difficult to avoid

some contact between the control and experimental groups. It is thus possible that pupils in the control group may have picked up information relating to critical thinking from the pupils in the experimental group, especially if those in the boarding house were brought together for controlled study periods in the evenings. Such an exchange may thus have weakened the results of the research as some of the control group may have been aware of the skills being taught, or may have borrowed notes from the pupils in the experimental group.

6.1.2 The intervention period

One of the recommendations for teaching critical thinking is that the skill, once taught, should be practised at intervals over a period of time. The discussion under Section 3.2.2 on page 31 emphasises the need for repetition and practice of each skill. Researchers such as Simon (1980), Beyer and Charlton (1986), Tyser and Cerbin (1991) and others, regard repetition and practice in the application of the principles of critical thinking as important in acquiring the skill of critical thinking. The teaching package involved in this research thus included a programme incorporating practice and repetition of each of the principles taught. However, because the particular section of work involved in this research was postponed to a late stage of the year, it was only possible to provide a single opportunity for the repetition of each of the principles taught, and these opportunities were probably not far enough removed from the initial teaching of the principle to gain the full benefit possible. There was no opportunity to create further applications prior to writing the post-test, as the final end-of-year examinations were scheduled shortly after completion of the section of work. Both teachers involved in the teaching intervention commented that more time was needed for the teaching as well as for practising the skills (see Appendix F). Because of the limited intervention period the pupils may not have gained the full benefit from this approach to teaching critical thinking. Thus the limited intervention period may be regarded as a limitation in the research as the results of the research may not accurately reflect the effectiveness of the approach being tested.

6.1.3 The method of assessing the level of critical thinking

Though the tests used in this research were effective in showing which principles of critical thinking had been applied, the marking of the tests revealed certain limitations. Firstly, because the pupils were being asked specific questions about a given situation, they were being prompted to think about the situation and most probably felt that they were expected to find a reason to disagree with the statements or findings given in the question. The question arises whether the same level of critical thinking would occur without the prompting effect of the test. Secondly, some of the answers given were acceptable, but rather vaguely stated. It is possible that in some cases the pupils were guessing. Sternberg and Baron (1985) comment that thinking skills can be directly measured by test items such as those in multiple

choice tests, but the dispositions which underlie the thought processes cannot. The test instrument may thus be seen as a limitation in the research due to the influence of the prompting effect of the questions on the answers given, the allowances made for the vaguely stated answers which were given in certain cases, and the lack of assessment of the underlying thought processes. The results gained from the tests may thus not be an accurate reflection of the actual level of critical thinking of the pupils. The method of assessing the level of critical thinking therefore needs to be extended, as is discussed on page 73.

6.1.4 The test for transferability to other subject domains

The test for transferability of the skills learnt through this teaching package to other subject domains was applied as a part of the Geography examination. Unfortunately it was set as the last section of the examination paper. The reason for this was that the Geography paper was a final year-end examination and the Geography teacher wanted the pupils to complete the official Geography examination before attempting the section on the critical thinking test. She was concerned that they might spend too much time on the critical thinking test and not complete the Geography examination. There was, however, no report of a lack of time from the invigilator of the examination. Most pupils completed the examination with time to spare, but some of the scripts had questions to which no answer was given. This may have been due to the pupils being unable to answer, but could also indicate that they were running out of time. With the possibility that a number of the pupils may have been under pressure to complete the examination, having perhaps spent too much time on the non-research sections of the paper before reaching the section on critical thinking, the results obtained are brought into question. Further research is therefore recommended to determine the level of transferability of skills learnt in one subject domain to another subject domain.

6.2 SUMMARY OF FINDINGS

In concluding this research report, the findings of the research are discussed in relation to the two research questions posed at the start of the project.

Question 1 :

> *If Standard 7 pupils are specifically taught critical thinking skills, does their ability to think critically improve significantly more than a group that is just expected to use the skills without being taught how to use them?*

An analysis of the overall use of critical thinking skills showed that the Standard 7 pupils who were specifically taught the skill of critical thinking showed a significant improvement in critical thinking over those pupils who had not been taught the skill. The analysis was based on two aspects, firstly the number

of times that the pupils used principles of critical thinking when answering the questions in the assessment instrument, and secondly, the number of different principles of critical thinking which were used in answering the questions. In the first case, the improvement of the mean score for the experimental group over the control group was shown to be highly significant ($p < 0.0001$), while for the second aspect the level of significance was lower but still significant ($p < 0,05$).

The improvement in the mean scores of the experimental group over the control group in the application of two of the principles taught in the programme was shown to be significant, while the difference in mean scores for the other two principles analysed was not statistically significant. (The fifth principle "understand and define all terms" relating to the issue being considered, did not occur often enough in the tests to provide a reliable statistic and has thus not been included.)

The findings thus show that for this group of pupils the instructional approach used, which involved deliberately teaching the principles of critical thinking, was significantly more successful than an approach where pupils were just expected to use the skills without being taught how to use them. However, one must bear in mind the limitations which were mentioned under Section 6.1. This result should not be generalised without further extensive research in which the pupils are drawn from a more representative range of backgrounds and the limitation of sample size corrected for.

Question 2 :

> *If pupils do learn the skills of critical thinking by means of this approach, will they transfer and apply the skills to another subject?*

The answer to this question was provided by the results of the analysis of the "transferability test" which was set as part of the Geography examination. The results of this analysis show that the pupils in the experimental group were able to apply the principles of critical thinking learnt in the subject domain of Biology to the subject domain of Geography. Despite the fact that both the control group as well as the experimental group had a lower mean score in the transferability test (geography) than in the pre-test, (which was set as a Biology test), the mean score of the experimental group was 11.5% higher than that of the control group for the transferability test. Analysis of covariance indicated that this difference was statistically significant ($p = 0,0005$).

This result indicates that there was a transfer of critical thinking skills from one subject domain to another. However, this transfer of thinking skills should not be generalised to all subject domains for a number of reasons. Firstly for the reasons mentioned under Section 6.1, particularly the small sample size, and the relatively narrow stratum of society from which the sample was drawn. Secondly the transfer was tested in only one subject, and the approach to learning and testing in geography is fairly

similar to that of biology. The tests should be extended to other subjects such as a language, or commercial subject to determine whether the transfer would still take place.

Table 10 provides an overview of the different aspects which have been analysed by means of ANCOVA, indicating those areas in which there has been an improvement in critical thinking by the experimental group, and those areas where there has been no improvement.

Table 10 : Summary of the research findings based on an analysis of covariance

Aspect	Level of significance : Post-test	Findings based on ANCOVA
Overall use of critical thinking skills		
The total number of critical thinking skills used	$p<0,0001$	Improvement of experimental group in post-test mean score highly significant.
The number of principles of critical thinking used	$p<0,05$	Improvement of experimental group significant.
Principles of critical thinking		
"Gather complete information before drawing a conclusion"	$p< 0,0001$	Highly significant improvement by the experimental group for this principle
"Question the methods by which the information was derived"	$p<0,05$	Significant improvement by the experimental group.
"Question the conclusions drawn from the information available"	$p=0,27$	Post-test mean score differences not statistically significant.
"Look for hidden assumptions and biases"	$p=0,65$	Post-test mean score differences not statistically significant.
Transferability test		
Overall level of critical thinking	$p =0,0005$	Improvement by experimental group in the transferability test was statistically highly significant.

6.3 RECOMMENDATIONS FOR FURTHER RESEARCH

The topic of this research project has current relevance in the new approach to education being adopted by the National Department of Education of South Africa. The "Outcomes Based Education" envisaged for the country emphasises the development of skills. This is illustrated by the fact that a number of the "essential outcomes" of the new curriculum promote critical thinking. These include:

- *identify and solve problems by using creative and critical thinking.*
- *collect, analyse, organise and critically evaluate information.*

- *use science and technology effectively and critically, showing responsibility towards the environment and the health of others*

(National Department of Education, 1997, p16).

Thus the information gained from this research could be of use to those who will now be involved in teaching skills. However, it is recommended that further research be carried out to extend the information and to account for the possible limitations of this research. The following points serve as recommendations should further research be carried out on this topic.

- The research programme should be repeated using a far larger sample. This sample should also be drawn from a broader spectrum of society, and, if possible, randomised. This would determine whether the approach could be generalised to the larger population of the country.

- If the research programme was to be repeated, it is suggested that the intervention period should be extended to provide more time for practising and applying the principles which have been taught. The programme should be started as early in the year as possible so as to allow sufficient time to complete the lessons on critical thinking fully. A revision programme which provides for the repetition and practice needed could be incorporated in each new subject topic throughout the year.

- Further investigation should also allow for long-term testing of the retention of the skills which have been developed during the programme. Shayer and Adey (1992a) recommend that one should wait until the end of the programme when the intervention has produced its maximum effect, and then investigate the differences between the experimental and control group over the next three months to a year.

- The method of assessment used in this research programme had certain limitations, as discussed on page 69. A qualitative study could be included as this would provide a more in-depth evaluation of the level of critical thinking. The inclusion of an interview method of assessment, together with the type of instrument used in this research, would have allowed for inconsistencies, and the "dispositions" referred to by Sternberg and Baron (1985), to be clarified. It is recommended that such a method be added to the pre- and post-test in further research of this nature.

- Testing the approach to teaching critical thinking at a range of different ages may be of value in determining the most suitable level for introducing the programme of teaching skills. Alternatively, a strategy for teaching a graded course of thinking skills, which progresses from the lower levels to the higher levels, could be investigated. Falkof and Moss (1984) refer the outcome of a district-wide thinking skills programme in Highland Park, Illinois, (see page 25) where teachers were able to see how the strategies they used at one level contributed to the development of more sophisticated

thinking skills at higher grade levels. Shayer and Adey (1992b) report that their experimental intervention on teaching thinking skills to 12 and 13 year-old students (refer to page 25) showed a large and permanent effect on students' achievement in later years. This information could be of value in the planning of educational strategies relating to the teaching of skills.

- According to Paul (1985), most of our everyday thinking about real-life problems crosses disciplinary domains and involves contradictory lines of reasoning. A possible alternative method of teaching of critical thinking could be to teach the principles of critical thinking across subject domains. Paul (1985, 46) says "*We must not allow our models of critical thinking to be principally drawn from the kind of specialised, compartmentalised thinking that is dominant in the technical disciplines*".

6.4 CONCLUDING REMARKS

Despite the limitations of this study, it has provided sufficient evidence to suggest that the deliberate and planned teaching of critical thinking skills could lead to an improved level of critical thinking in students. This approach may thus help the individual to gain the far reaching benefits that were mentioned under Section 2.3.

It should be emphasised that the scope of this study was limited and thus would not provide conclusive answers to the teaching of critical thinking. The research may, however, provide the basis for further research on a larger scale which could provide more information on teaching the skills of critical thinking.

APPENDIX A

THE TEACHING PACKAGE: "TEACHING THE SKILL OF CRITICAL THINKING IN BIOLOGY"

TEACHER'S GUIDE

TEACHING THE SKILL OF CRITICAL THINKING.

TEACHER'S GUIDE.

The aim of teaching critical thinking.

The aim of teaching critical thinking has been regarded as important in many countries for a long time, yet one frequently hears the complaint that pupils do not think critically. One may well ask why, with so much emphasis on critical thinking, children still do not develop the skill. The comment has been made that "too often what we assume to be teaching of these skills consists instead only of making students attempt to use these skills". Research however has shown that if an effort is made to explicitly teach these skills, success can be achieved.

The curriculum emphasises critical thinking.

The Independent Examinations Board has included the development of thinking skills in the aims of the new syllabus. It also intends to place more emphasis on the testing of skills in the examinations as well. This implies that teaching must be directed at developing these skills. But how does one teach the skill of critical thinking effectively?

Critical thinking can be taught.

The purpose of this teaching package is to provide a method for teaching the skills of critical thinking which will be fun for the pupils and easy for the teachers to do. The approach and techniques to be used can readily be adapted to suit other sections of the syllabus as well.

The importance of critical thinking.

In the classroom:

'Thinking critically' involves higher-order thinking. Research shows that when students think critically about their work they learn in a more meaningful way and rely less on rote learning, which in turn leads to improved understanding and better retention of facts.

Education should provide more than facts and a few insights. By teaching critical thinking, teachers will impart skills that are useful, not only in the science classroom, but also in other disciplines and other spheres of life.

To the man in the street:

Critical thinking will enable people to analyze and confront the many issues of their daily lives more effectively.

People should not accept uncritically all the information they receive. For example, not all media reports are accurate, and the claims of advertisers can be misleading. It is thus important to teach students the skills of critical thinking so that as citizens they will question the validity of what they are told or read. The skill of critical thinking may be regarded as a necessity for living.

In science:

Critical thinking underlies the process of science. Scientists are not all objective, and may not always be honest. It is thus just as important to critically evaluate the findings of scientists and not blindly accept all scientific findings as facts. There are no sacred truths in science, no forbidden questions. A critical approach is important in scientific enquiry. "Facts" are interpretations of data which may well change with time and new information. Students must thus learn to evaluate data critically, as well as to question the source of the information as well as the experimental designs which gave rise to the data.

Teaching critical thinking.

Defining critical thinking.

One author defines critical thinking as:

> *a process by which one subjects research findings and theories to examination, looking for consistencies and inconsistencies in logic, alternative interpretations, and subtle but pervasive biases that may have led to erroneous conclusions* (Chiras, 1992, 464).

This author suggests that there are eleven things a person must be able to do in order to be an effective 'critical thinker'. He refers to these as the eleven principles of critical thinking. Five of these principles have been chosen for this teaching package which can be applied effectively to the topic 'Health' and which form the basis of critical thinking.

Learning the skill of critical thinking.

Research suggests that the skill of critical thinking is best learned if the following factors are applied in the teaching process:

* The principles of critical thinking are taught separately from other subject matter which has to be learned.
* The pupils know that the objective is to learn the particular skill.
* The pupils are actively involved in a 'hands on, minds on' process of applying a particular principle of critical thinking.
* The pupils discuss the techniques and procedures used in applying the principle so as to clarify the steps or add additional steps.
* The rules and procedures are clearly articulated and written down.

Teaching the principles of critical thinking.

As five principles of critical thinking have been selected for this package there will be five lessons each introducing a separate principle.

Each lesson will consist of two parts:

* a short exercise which introduces the particular principle only,
* followed by the teaching of normal subject matter during which the pupils will have the opportunity to apply the principle to the biology subject material thus provide practice in using the principle.

Lessons on critical thinking principles.

Each lesson introducing a principle must involve the following four aspects, though not necessarily in this order.

* The teacher must indicate clearly that the purpose of the lesson is to learn the particular skill.
* The pupils must carry out the planned lesson activity for applying the particular skill.
* The teacher and pupils must discuss the key procedures and techniques that constitute the skill which were used in the activity.
* The particular principle with its key procedures and techniques must be clearly stated and put in writing.

Applying the principles to the biology lessons.

Each principle has been linked to a particular biology lesson. Teach this biology lesson immediately after teaching the principle. The new subject matter will give the pupils the opportunity to apply the particular principle of critical thinking which they have just learned. Emphasise the application of the principle in this lesson.

Further opportunities for using the skills have been identified in later aspects of this section of work. Pupils should also be encouraged to find opportunities to apply the principles learned whenever possible.

The principles of critical thinking to be applied in this study.

The following five principles of critical thinking have been selected as being applicable to the section of work on health as well as covering the more important aspects of critical thinking. Good critical thinkers understand the importance of each of the following and are able to apply them in everyday situations.

1. **Gather complete information on the topic under discussion before reaching a decision.**
2. **Understand and define all terms relating to the topic under discussion to ensure a clear understanding.**
3. **Question the methods by which the information is derived.**
4. **Question the conclusions which have been drawn from the information.**
5. **Look for hidden assumptions and biases which may distort the information presented .**

Integrating teaching critical thinking skills with biology teaching

Coordinating the different aspects

There are three aspects which need to be coordinated.

1. Teaching each critical thinking skill.
2. Teaching the biology subject material required by the syllabus.
3. Applying each critical thinking skill to the biology subject material.

1.

Teaching the critical thinking skills

Introducing the idea of critical thinking

The lesson introducing the concept of critical thinking is intended to set the scene for teaching these lessons. This lesson should be taught first before the section on health is begun.

Critical thinking lessons

Each critical thinking lesson has been matched to a suitable topic in the section on health. These lessons should be taught at the start of each lesson dealing with the relevant section of biology

* A 'box' which names the particular critical thinking skill to be taught has been inserted in the subject outline at the point where the critical thinking lesson should be taught. The details of this portion of the lesson are provided separately.

* Teach the critical thinking skill at this point following the approach suggested in the corresponding lesson.

2.

Teaching the biology subject material

An outline of the subject material to be covered under each of the topics for the section on **health** has been provided.

These aspects should be taught as you would normally teach them.

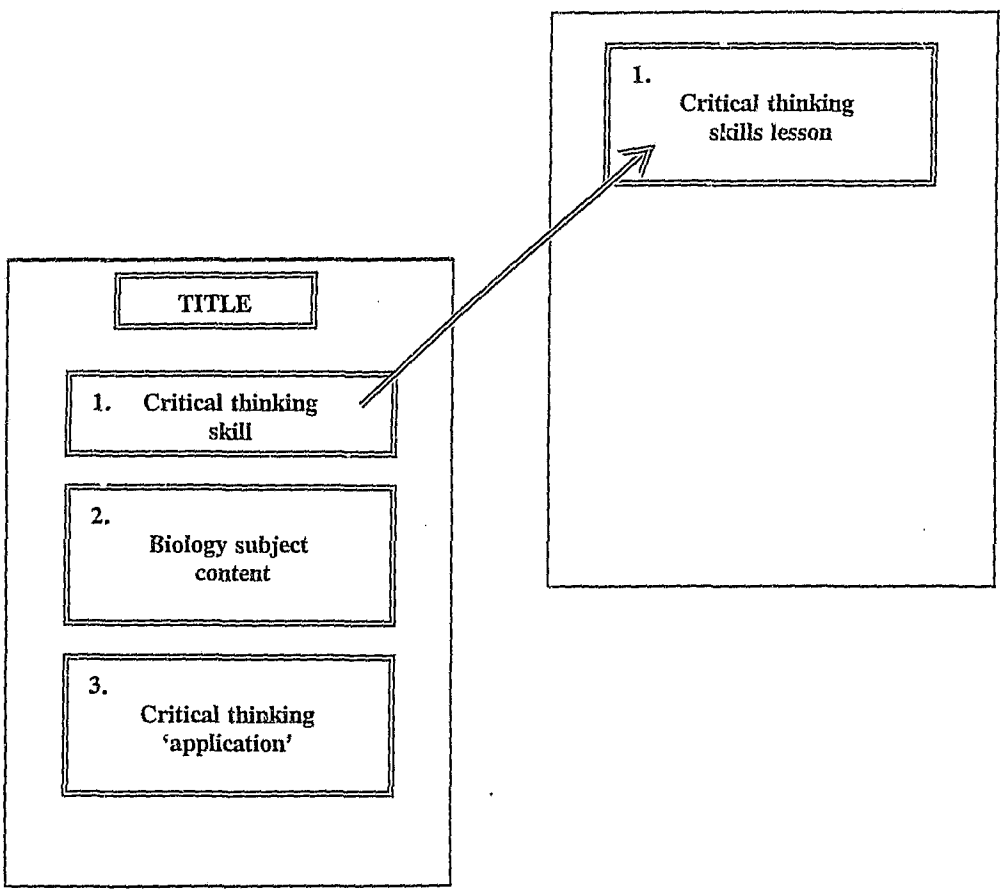
3.

Application of critical thinking skills to biology subject material

* Exercises which apply each critical thinking skill have been selected in relation to particular aspects of the work being taught.

* A 'box' has been inserted at the point where these 'applications' exercises should be introduced, usually towards the end of a lesson.

* The procedures for teaching the particular 'application' exercise are provided separately.



Colour coding for the different sections

The different sections have been printed on different colours of paper to facilitate using the package. The following colour code was used.

1. **General information for the teacher.** ____ **Blue.**
2. **Critical thinking lessons.** ____ **Green.**
3. **Syllabus outline and application of critical thinking in biology.** ____ **Yellow.**
4. **Pupil hand-outs.** ____ **White.**

FLEXIBILITY

The subject material to be taught is under the control of each teacher. The teacher should thus feel free to change the sequence of the biology work if so desired. It will not affect the value of the critical thinking lessons, provided that they are introduced with the relevant topics and the background knowledge for the application of the skills has been covered.

INTRODUCING THE CONCEPT OF CRITICAL THINKING

PURPOSE OF THIS LESSON

The purpose of this brief introduction is to make the pupils aware of the importance and benefits of developing the skills of critical thinking. Pupils need to understand that critical thinking is a valuable skill for biologists and scientists, but particularly for the man-in-the-street. If pupils understand it's importance they will be more cooperative in the lessons.

SUGGESTED TIME

Approximately 10 minutes.

SUGGESTED APPROACH.

1. Explain to the pupils that the next section of work, the section on health, will involve two aspects:
   * the teaching of the normal subject matter, and
   * the teaching of the skill of critical thinking

   Pupils should learn to question the so-called "facts". If information is given, and some conclusion is drawn from it, they should decide if the conclusion is fair and justified.
   These lessons will demonstrate the skills which must be used when any problem or issue is being debated or requires a decision.
2. Ask the pupils what they think is meant by "critical thinking".
   From their discussion lead to a general understanding or explanation of the meaning of critical thinking. The following could serve as an example: (OHP 1. page 11)
   Critical thinking is the process by which one examines the information that one receives from various sources and decides whether to accept it as true or not.

   Possible sources of information:
   * media reports,
   * experimental findings,
   * general discussions.

   Examining the information involves:
   * looking for additional explanations,
   * looking for sound logical reasoning,
   * biases which may have led to false conclusions.

3. The example given on OHP transparencies may be used to illustrate the need to evaluate critically what one reads in the newspapers.
   * Show the transparency labelled 'A'. (p.12)
   * Ask the pupils what their judgement of this school would be, based on this write-up.
   * Ask if they would query any of the information given.
   * Show the transparency labelled 'B'. (p.12)

* Discuss the omission of information which was used to create a false impression of the achievements of the school.

Emphasise to the pupils that the information one gets from various sources may be inaccurate or biased. If they make decisions based on inaccurate information, the decisions are likely to be wrong. e.g. Advertising claims may be biased in favour of the product they are promoting; politicians' claims may leave out information which would harm their cause.

4. Explain that a critical thinking approach will also benefit them in their studies. Emphasise that if pupils think critically about their work they are more likely to:
   * learn in a more meaningful way,
   * rely less on rote-learning,
   * should understand better and
   * will remember the work better.

Defining critical thinking

Critical thinking is the process by which one examines the information that one receives from various sources and decides whether to accept it as true or not.

Possible sources of information:

* **media reports,**
* **experimental findings,**
* **general discussions.**

Examining the information involves:

* **looking for additional explanations,**
* **looking for sound logical reasoning,**
* **biases which may have led to false conclusions.**

A.

Scholarships for next year!

An article appeared in the Star offering two scholarships to 2 top pupils for a certain school for next year. In publicising the school, only in its second year, the following information was included in the article.

> *Not only is it a leader in the academic field, but it has also done well at sports. This is the second year that it has won the inter-high swimming league; the rowing team won 22 medals in the SA rowing championships; the under-15 and under-16 netball teams were league winners.*

What conclusion would you draw about this school's level of sport and it's standing in relation to other schools?

B. Some additional information!

A little more information is provided on the sports achievements of this school.

Swimming: They won the *'E league'* this year.

Rowing: Their rowers competed in the *lower categories* in each age group. A team of 'four' in a 'boat' which gained a third place thus contributed four medals.

Netball: These teams won an *area league*, but not the league championships.

Information may be deliberately omitted to lead the reader to an incorrect conclusion.

SUBJECT TOPIC

GERMS, DISEASE AND INFECTION

CRITICAL THINKING SKILL

Question the conclusions which have been drawn from the information available before accepting them as true.

Page 14.

SYLLABUS OUTLINE

I. Micro-organisms which cause disease
1. Viruses.
2. Bacteria.
3. Fungi.

II. Spread of disease
1. Contagious diseases - spread by direct contact.
2. Droplet infection. Breathing in germs (sneeze or cough).
3. Germs from food.
4. Germs from water.

III. Immunity
1. Antibodies - your bodies chemical weapons

IV. Artificial immunity

APPLICATION OF CRITICAL THINKING PRINCIPLE

Colds and immunity

1. This activity should be introduced after discussing immunity.
2. Discuss the following two questions (OHP page 18.)
   * Will you catch a cold if you get caught in the rain on a chilly day?
   * Why can you get several colds year after year?
3. Hand out the second sheet and ask the pupils to read it and answer the questions.
   (If time is a problem, hand out the sheets (pages 19 and 20) and ask the pupils to do the exercise for homework. Discuss the exercise at the next lesson.)
4. Discuss the answers, relating back to the information given in the lessons.
5. Emphasise the principle of critical thinking applied, showing how it relates to the exercise.

Question the conclusions which have been drawn from the information available before accepting them as true.

QUESTION THE CONCLUSIONS

PURPOSE OF THE LESSON

The purpose of this lesson is to teach pupils that it is important to "**question the conclusions**" which are drawn from any scientific study or in any debate before believing them.

SUGGESTED TIME

5 to 10 minutes.

MATERIALS PROVIDED

1. Sheet entitled "Experiment to test a dog's reaction to music."(page 15). One copy per pupil.
2. Printed sheet of the important points on critical thinking covered in this lesson (page 17). One copy per pupil.
3. OHP to explain that because one event occurs immediately after another does not necessarily mean that the second was caused by the first. (Page 16.)

SUGGESTED APPROACH

1. Divide the class into groups of three or four.
2. Give each pupil a copy of the "experiment" sheet (page 15).
3. Ask them to discuss the questions and decide on answers for each question.
4. Discuss the answers with the class as a whole.
   The pupils should have provided a variety of other possible conclusions.
   e.g. * The dog may always feel sleepy after eating;
   * The dog may just have been tired after the day's activities.
   * The comfort of the room may have made him drowsy.
   Emphasise the point that it was possible to draw other conclusions as well.
5. Discuss the application of this principle in general terms. e.g. When you are involved in:
   * any argument or discussion, or
   * reading newspaper reports or scientific studies, or
   * general conversation,

   look at the information available to see whether you could draw any other conclusions to those given.
6. Emphasise that pupils should not assume that because one event occurs immediately after another, the first caused the second. Use the OHP provided to illustrate this point (page16).
7. Explain that 'generalising' is a fault which occurs frequently in discussions and arguments. i.e. A conclusion which is true in one situation is sometimes incorrectly extended to apply to all cases. e.g. Because a few Kenyan long-distance athletes have done exceptionally well in world athletics it is often assumed that all Kenyans are good athletes.
8. Hand out the summarised points on this principle (page 17) and discuss them briefly.

A standard seven class were given an assignment. They were asked to design and carry out a fair experiment, and then draw up a report to be presented to the class. John carried out and presented the following experiment:

Experiment to test a dog's reaction to music.

I tested my dog to see his reaction to music. So every night after his dinner, for two weeks, I put him in my room and turned on some music. On almost every night he was asleep within 10 minutes. It seems that music makes my dog want to go to sleep.

1. Do you agree with this conclusion? _____

2. List two other possible explanations of why the dog fell asleep.

_____

_____

_____

_____

_____

Homework.

Experiment to investigate whether snakes prefer to eat baby chicks or rats.

Does my snake prefer to eat baby chicks or rats? I answered this question by putting a five-day old chick in the snake's cage. My snake swallowed the chick in 10 minutes. The next night I put a four-inch white rat into the cage. The next morning the rat was still uneaten. My snake prefers to eat chicks rather than rats.

1. Do you agree with this conclusion? _____

2. List two other explanations of why the snake ate the chick. _____

_____

_____

_____

_____

After a period of regular rain a family noticed that some lovely large mushrooms had grown on their lawn. The mother examined them and decided they were of the edible type. So she decided to cook them for the family supper that night.

The father, however, was not convinced that they were not poisonous, so he decided to give some to the dog to see what would happen.



The dog ate the mushroom eagerly and ran off happily. The father concluded that the mushrooms were not poisonous, so the family sat down to eat.

Just then the neighbour's son came running into their house shouting "Your dog is dead! Your dog is dead!"

The mother immediately took away the mushrooms, saying they were poisonous.

The **conclusion** that had been drawn:

The dog had died from eating poisonous mushrooms.

Actual cause of death: The dog had been run over by a car while crossing the road.

Because one event follows another, it does not necessarily mean that the second event was caused by the first.

Question the conclusions which have been drawn from the information given before accepting them as true.

Question the so-called "facts".

If information is given and some conclusion is drawn from it, decide if the conclusion is fair and justified. Such information could come from an argument, a scientific study, newspaper reports, advertising claims, or even in conversation.
To find out whether the information available really supports the conclusions,

* Look for other possible explanations that could be drawn from the same facts. If one alternative is found look for a second and third.
* Identify all variables and question the possible influence of each on the outcome and hence on the conclusion drawn.
* Look for instances where one event which follows another is incorrectly said to be caused by the first.
* Look for cases where the conclusion from a specific instance has been extended to apply to all cases (Generalisations).

If any of these conditions apply to the information you are considering, then that information is questionable. More evidence is needed to support this information.

Question the conclusions which have been drawn from the information given before accepting them as true.

Question the so-called "facts".

If information is given and some conclusion is drawn from it, decide if the conclusion is fair and justified. Such information could come from an argument, a scientific study, newspaper reports, advertising claims, or even in conversation.
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* Look for instances where one event which follows another is incorrectly said to be caused by the first.
* Look for cases where the conclusion from a specific instance has been extended to apply to all cases (Generalisations).

If any of these conditions apply to the information you are considering, then that information is questionable. More evidence is needed to support this information.

Will you catch cold if you get caught in the rain on a chilly day?

Probably not. You cannot catch a cold simply by being caught in the rain. (You may become more susceptible to viruses if your body is weakened by the chill)

How *do* you catch a cold?

Viruses must start to multiply in your nose or throat.

How do the viruses get there?

When someone with a cold coughs or sneezes they spread large numbers of viruses in tiny droplets of mucus into the air. If you are nearby, you can breathe in these viruses.

Will that give you a cold?

If your body is unable to fight them off before they multiply, you get the cold.

Why can you get many colds?

When you get a cold, your body makes antibodies to fight the particular virus that has come into your body.

* You will not get a cold from that kind of virus again.
* However, there are more than 200 different kinds of viruses which can cause colds.
* So if a cold virus that you haven't had enters your body, you will not have antibodies in your blood to fight it.

You may then get another cold!

Will you catch cold if you get caught in the rain on a chilly day?

Probably not. You cannot catch a cold simply by being caught in the rain. To catch a cold viruses must start to multiply in your nose or throat. In order for viruses to get into your nose or throat, there must be viruses present in the air that you inhale. When someone with a cold coughs or sneezes they spread large numbers of viruses in tiny droplets of mucus into the air. If you are nearby, you can breathe in these viruses. If your body is unable to fight them off before they multiply, you get the cold.

Thus the only way a chill from the rain would affect you is to temporarily weaken your body. If there are cold viruses in your throat, or if you breathe in viruses at that stage, then your body may not be able to fight them off, and you might develop a cold.

Why can you get many colds?

When you get a cold, your body makes antibodies to fight the particular virus that has come into your body. You will not get a cold from that kind of virus again. However, there are more than 200 different kinds of viruses which can cause colds. So if a cold virus which you have not had before enters your body, you will not have antibodies in your blood to fight it. You may then get another cold.

Why do people who go to polar regions on expeditions catch colds more easily when they return to a temperate climate?

It often happens that when people return to warmer climates from expeditions to polar regions with its very pure air, they develop very heavy '*headcolds*' which make the nose run and the eyes red.

The following explanation was found in a book.

> *There are very few germs which cause disease in the polar regions because the climate does not favour them. As a result the people who stay for several months in these icy regions gradually lose their immunity to diseases. Their bodies no longer need antibodies to fight germs, so why make them? Thus when they return to the warmer climates their bodies are unable to fight off the germs and they catch colds.*

From what you know about viruses, and from the previous explanation relating to colds, do you think the explanation provided in this book is a satisfactory explanation? _____

If not, give a reason. _____

_____

_____

Can you think of any other possible explanations for why these people catch colds under these circumstances? _____

_____

_____

[For teacher's copy only]

Other possible explanations

* They lose their 'allergic' reactions to dust and pollen which will then make their noses run and their eyes red.

* They can still be affected by new varieties of cold viruses which they had not previously caught.

SUBJECT TOPIC

HEART DISEASE

CRITICAL THINKING SKILL

Question the methods by which the facts are derived

Page 22.

SYLLABUS OUTLINE

1. **How arteries get blocked.**

2. **Blocked coronary arteries.**

3. **Things that can lead to heart disease.**

4. **How you can avoid heart disease.**

APPLICATION OF CRITICAL THINKING PRINCIPLE

"The Swain investigation"

1. Give each pupil a copy of "The Swain investigation" part one (page 27).
2. Ask the pupils to read the piece and then answer the question in the space provided.
3. Have a few of the pupils read their answers to the class.
4. Hand out part two (page 28). Ask the pupils to read it and answer the questions posed at the end.
5. Discuss the answers with the class. Relate this situation to the exercise done with the blocks of wood and nails which demonstrated a 'fair experiment'.
6. Emphasise the critical thinking principle of questioning the methods by which the information is derived, before accepting a statement as true.

QUESTION THE METHODS BY WHICH THE INFORMATION IS DERIVED

PURPOSE OF THE LESSON

The purpose of this lesson is to teach the pupils that it is important to question how the information relating to a topic under discussion was obtained.

SUGGESTED TIME

Approximately 35 minutes.

MATERIALS PROVIDED

1. A set of four blocks of different kinds of wood per group.
   Use cheap wood e.g. Pine; meranti; chipboard; softboard.
   Cut the wood into blocks of about 4cm. square.
2. A packet containing one hammer plus 4 nails per group .
   The 4 nails should be of different sizes, but not too conspicuously different. (2-3cm.)
   Use different sized hammers for each group, e.g. from 4 lb. to very small.
3. OHP for coordinating results (page 24) and non-permanent OHP pen.
4. Instructions for the teacher for directing the activity (page 23).
5. Summary of points to be emphasised. (OHP page 25.) One sheet per pupil (page 26).
6. Old telephone directories on which to hammer in the nails.

SUGGESTED APPROACH

1. Divide the class into groups of four to six pupils.
3. Control and coordinate the activities carefully according to the instruction sheet.
4. Discuss the results with the class according to the instruction sheet.
5. Hand out the summary of important points regarding the skills of critical thinking used in this lesson and discuss them briefly with the pupils.

EXPERIMENTAL DESIGN

TEACHER'S GUIDE

ADVANCE ORGANISATION

1. Prepare sets of four blocks of wood of different types and hardness. Label each type of wood from A to D. Keep the labelling consistent for each type of wood. Suggested size: approximately 4cm. square. suggested types of wood: Pine; Meranti; chipboard; softboard.
2. Obtain a hammers and nails required for the groups and prepare the packets for each group. Nails approximately 2 to 3 cm. long, no too conspicuously different. Use different sized hammers for each group.
3. Obtain old telephone directories on which to place the blocks while hammering in the nails.

PROCEDURE

1. Divide the class into groups of 4 or 5 pupils.

2. The teacher should direct the stages of the exercise. The following is a suggested sequence.
   a. Give each group a set of blocks of wood.
   b. State the aim of the exercise. i.e. To rank the blocks in order of hardness.
   c. Ask the groups to examine the blocks of wood and list the blocks from hardest to softest using the letters on the blocks.
   d. You have been given a hammer and nails. Carry out the following experiment to test your prediction.
      * Hammer a nail completely into the block A.
      * Count the number of times you hit the nail to knock it in.
      * Record this number in the relevant place on the OHP transparency.
      * Repeat this procedure for block B, C, and D. Make sure that every member of the group participates.
3. When all the results have been written up discuss the experiment with the class.
   * Compare the findings of the different groups. (they should be different for the various groups.)
   * Try to get the pupils to discuss the variables which caused the differences in results. Ask them to identify as many as possible. (e.g. Different sized hammers and nails; different people doing the hammering.)
   * Lead on to the need for variables to be controlled in a fair experiment.
4. Establish the idea that because the methods by which the results in this experiment were obtained were questionable, the conclusions drawn would also be questionable.
5. Generalise these findings. If the methods used to obtain information are faulty the information obtained may be inaccurate.
   * Predictions are not always accurate. The so-called "facts" quoted in some newspaper reports are based on predictions and should be questioned.
   * If variables are not controlled in any investigation, the results should be questioned.
6. Thus critical thinkers should question the methods by which information is obtained.

TYPES OF WOOD

GROUP	A	B	C	D
1.				
2.				
3.				
4.				
5.				
6.				
7.				

When evaluating any information -
Question the methods by which the facts are derived.

Conclusions or decisions made on the basis of facts gained by questionable methods may prove to be incorrect. Predictions or intuitions are unreliable as some may be inaccurate.

Examples of sources of information which should be evaluated critically:
* Information from experiments and research.
* Information in media reports, political debates, or advertising claims.
* Information from general conversation.

In considering this type of information:
* be sure that the methods used to obtain the information are fair.
* identify the variables which may influence the accuracy of the information.Decide whether these variables were controlled or their influence taken into account in drawing the conclusions.
* Try to find other evidence to support the conclusion.

When evaluating any information -
Question the methods by which the facts are derived.

Conclusions or decisions made on the basis of facts gained by questionable methods may prove to be incorrect. Predictions or intuitions are unreliable as some may be inaccurate.

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* **Information from experiments and research.**
* **Information in media reports, political debates, or advertising claims.**
* **Information from general conversation.**

In considering this type of information:

* **be sure that the methods used to obtain the information are fair.**
* **identify the variables which may influence the accuracy of the information.Decide whether these variables were controlled or their influence taken into account in drawing the conclusions.**
* **Try to find other evidence to support the conclusion.**

Part one

THE 'SWAIN' INVESTIGATION.

Read the following passage and answer the question which follows.

The 'Swain' investigation.

For many years newspapers and magazines have reported that scientific research shows that oat bran is healthy. Researchers claimed that this was because oat bran in the diet was an effective way of lowering the cholesterol level in the blood. Because a lowering of cholesterol was known to help reduce the risk of a heart attack, oat bran became a popular health food for many people.

However, in 1990 a group of researchers led by Dr Swain carried out another experiment investigating the effect of oat bran in the diet. From the results of their experiment they came to the conclusion that *oat bran had no direct effect on lowering cholesterol levels in the blood.*

The newspapers published a report on Swain's findings.

What effect do you think the newspaper report might have had on the subsequent sale of oat bran? Explain your answer.

Part two.

An investigation into how Swain and his colleagues had carried out their experiment produced the following information.

1. The investigation was carried out on 24 young female dieticians.
   * Their average age was 24 years.
   * They all recorded a low cholesterol level at the beginning of the experiment.
2. Four of the participants (one sixth) dropped out of the experiment. i.e. Their experimental results were included in the initial testing but not in the final testing.
3. What the participants' ate was not recorded or controlled. i.e. they were allowed to eat whatever they wanted, except that some were given oat bran muffins (treatment) while the others were given low fibre wheat muffins (control).

1. Do you think this was a fair experiment? _____

   Give reasons for your answer._____

   _____

   _____

   _____

2. From what you have learnt in class about heart disease do you think the findings of Swain's experiment would be beneficial or harmful to the public in general? _____

   Explain your answer._____

   _____

   _____

   _____

SUBJECT TOPIC

SMOKING AND ILL-HEALTH

CRITICAL THINKING SKILL

Look for hidden assumptions and biases

Page 30

SYLLABUS OUTLINE

I. Poisons in tobacco smoke

2. Nicotine.
2. Tar.
3. Carbon monoxide.
4. Other poisonous gases.

II. Diseases caused by smoking

1. Heart disease.
2. Emphysema.
3. Cancers.
4. Bronchitis.

III. The effect which smoke from smokers has on other people.

APPLICATION OF CRITICAL THINKING PRINCIPLE

The bias of tobacco companies

1. Give each pupil a copy of 'No evidence smoking is a health hazard' (page 34).
2. Ask them to read it and answer the questions.
3. Discuss the answers with the class. Try to emphasise the point that the scientists invited to speak at the seminar would most probably have been those that were not opposed to smoking. Point out that by providing 'scientific support' for smoking The United Tobacco Company would be improving the acceptability of their product to the market.
4. Hand out the second sheet (page 35) and ask them to read it and answer the questions.
5. In the discussion try to get the pupils to see that this report, too, may be biased (to try to prevent people from smoking).
6. Once again emphasise the points made in the critical thinking lesson (page 33) which illustrated the point of looking for hidden bias.

LOOK FOR HIDDEN ASSUMPTIONS AND BIASES

PURPOSE OF THE LESSON

The purpose of this lesson is to show pupils that the accuracy of information can be affected by the personal biases of those that provide the information. Pupils should understand that critical thinkers **"look for hidden assumptions and biases".**

SUGGESTED TIME

Approximately 10 minutes

MATERIALS PROVIDED

1. Sheet 1. Will your decision be 'Yes' or 'No'? (page 31). One copy per pupil.
2. Sheet 2. What will your decision be now? (page 32). One copy per pupil.

SUGGESTED APPROACH

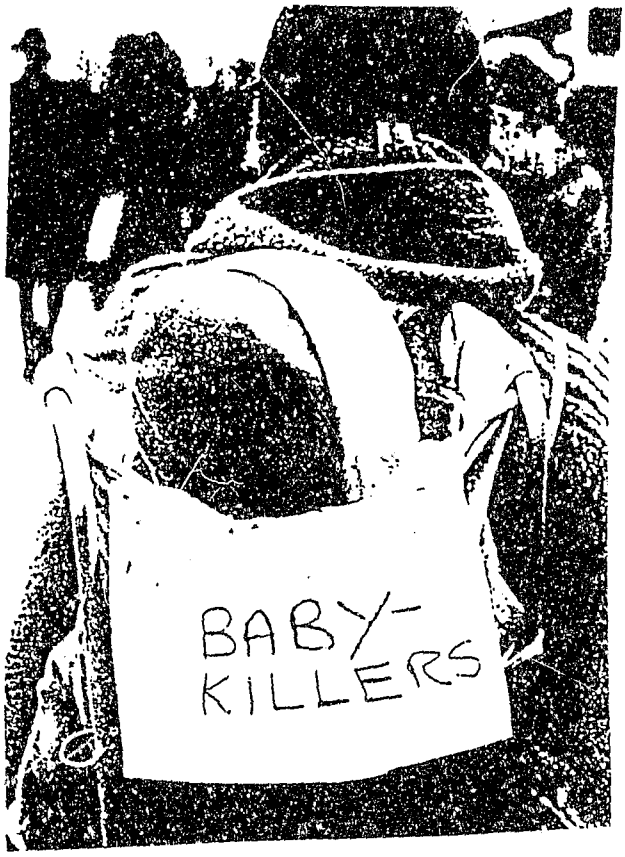
1. This exercise should be done individually.
2. Give each pupil a copy of sheet 1 (page 31).
3. Ask each pupil to read the instructions and, based on the information, decide whether or not abortion should be legalised. The pupils should write their recommendations on the sheet.
4. Hand out sheet 2 (page 32) and ask them to read the instructions and then to complete the exercise and record their decisions.
5. Discuss the exercise with the class. The following important points need to be established.
   a. If people are biased they may purposefully omit information which goes against their belief.
      * Possible questions to ask:
        Did you detect any bias in the two presentations of information? (Answer: Yes)
        Did either of them present any information which supported the opposing point of view? (Answer: No) Why not? Answer: If people are biased they may purposefully omit information which goes against their belief.
   b. Personal bias may have influenced their judgement in deciding on their answers during the exercise.
      * Possible questions to ask:
        Did any of you have strong feelings about this issue? (Answer: 'Yes' or 'No')
        If you did, do you think it influenced you in your decisions? (Answer: 'Yes' or 'No')
        If you felt that you were not biased in this case, do you think that if there was an issue about which you felt very strongly you would still not be influenced in your decisions?
6. Ask them to think of other examples of bias which might distort information. For example, cigarette companies and cosmetics companies mention only the favourable aspects of their products in promoting them.
7. Ask the pupils how bias is evident in the example of the "scholarship" article (page 12) discussed in the introductory lesson, and to what purpose.
8. Emphasise that critical thinkers look for hidden biases and are also aware of their own biases which might influence their judgement. Hand out the summary of the points to be remembered (page 33) from this exercise.

Will your decision be 'Yes' or 'No'?

You are chairman of a committee appointed to investigate the legalising of abortion. To make their decisions fairly, committees usually do a lot of research and reading. After much research the committee presented a report containing newspaper cuttings for your consideration. As the chairman, it is your responsibility to make the final recommendation on whether abortion should be legalised or not. Based on the information collected by the committee, what would your recommendation be?

Recommendation: _____

There are several organisations who are completely against abortion. They demand that all abortions should be stopped:



"Babies are not like bad teeth to be jerked out just because they cause suffering. An unborn baby is a baby nevertheless . . . I have come to believe that those who support abortion on demand do so because in all sincerity they cannot accept that an unborn baby is a human being. Yet surely it is. Its heart beats, it moves, it sleeps, it eats. Uninterfered with, it has a potential life ahead of it . . . *Jill Knight, M.P., in a 1966 House of Commons debate on abortion.*"

"Abortion is an evil. No one has the right to take away life from another human being. From the moment a baby is conceived it has life and must be protected. If we don't protect human babies what hope is there for other forms of life? *Frank, aged 29, accountant*"

What will your decision be now?

One member of the committee felt that the committee's report did not contain all the information on the matter. She presented you (as the chairman) with several other newspaper cuttings. Look at these cuttings and, on the basis of this new information, decide what your recommendation to the committee would be. Indicate this in the space provided.

Recommendation: _____

Did each report individually present a fair portrayal of the problem? _____

If not, in what way was each report biased? _____

_____

_____

ANNA'S STORY: '"I was at home 2 weeks ago when I heard a tractor in the field outside. I saw that it was spraying so I closed all the windows. But I felt really sick. It was a horrible smell that stayed with me for days." Later that day, Anna went to see the farmer who showed her the weedkiller container. It had 245-T and 24-D listed as ingredients on the label.

The chemicals contain the deadly poison dioxin – one drop of which can kill 1200 people. Specialists warned 34-year-old Anna Noon that her baby could be born with severe deformities. Anna has already lost one baby, by a miscarriage. Now she has to have an abortion.'

from *The Mirror* June 13 1985

MARY, aged 17, student: 'I was raped a few weeks ago. That was dreadful enough. Then I discovered I'd become pregnant. I still wake up screaming about the rape. I'm terrified to go out on my own again. I'd just hate this baby. I know I would. It would always be a reminder of what happened to me.'

BARBARA, aged 35, housewife: 'I've already got four children. I was very ill after the last one and my GP told me I really mustn't have any more. I don't know what will happen to the family if I have to have this baby. We all live in just two rooms and one of them is damp. I've got to have an abortion. Otherwise, I'll put it up for adoption. But we can't have it.'

Look for hidden assumptions and biases which may distort the information presented

* Take into account the possible bias of the source of the information. Question what the source of the information stands to gain or lose from the situation, and then examine the information to see if it is biased in this direction.

* Understand your own biases and values which may influence your judgement in considering the particular situation.

Look for hidden assumptions and biases which may distort the information presented

* Take into account the possible bias of the source of the information. Question what the source of the information stands to gain or lose from the situation, and then examine the information to see if it is biased in this direction.

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Look for hidden assumptions and biases which may distort the information presented

* Take into account the possible bias of the source of the information. Question what the source of the information stands to gain or lose from the situation, and then examine the information to see if it is biased in this direction.

* Understand your own biases and values which may influence your judgement in considering the particular situation.

The following extracts were taken from a recent newspaper article.

'No evidence smoking is a health hazard'

Harare. At a two-day seminar hosted by the South African based United Tobacco Company, leading scientists have agreed that there is no conclusive evidence to suggest that smoking is a health hazard. They said that anti-smoking activists are leading a futile crusade against the tobacco industry.

Professor Ian Hindmarch of the University of Surrey said tobacco smoking was "a pleasurable activity which provides smokers with an accessible resource for managing psychological and social events, particularly those which are stressful". He explained further that, "in particular, nicotine reduces the effects of fatigue and boredom and improves mood and psychological function". He said that the effects of nicotine are thus an important part of tobacco use.

What point of view regarding smoking would the United Tobacco Company organisers look for in the scientists they invited to speak at the seminar?

_____

_____

Do you think that the newspaper article gives a fair representation of the facts? Give reasons for your answer._____

_____

_____

The following information was taken from a pamphlet issued by an anti-smoking organisation.



Smokers die younger

The death rate among cigarette smokers at all ages is higher than among non-smokers. South Africans smoke more than 21 000 *million* cigarettes each year, one of the world's highest consumption-per-person rates, and not surprisingly we have the highest incidence of coronary heart disease in the world, [an illness linked with smoking]. Health statistics vividly show that the more you smoke the more likely you are to die prematurely. The reason for the deadliness of cigarettes is the variety of diseases they cause.

Heart attacks and strokes

Heart and blood-vessel diseases are our leading causes of death, and the mortality rate from coronary heart disease among smokers is twice that of people who have never smoked. A survey in a hospital's cardiac unit revealed that more than 90% of those admitted with heart attacks were smokers. Those who continue to smoke after their first heart attack are twice as likely to die in the following year than those patients who stop.

Lung cancer

It is very rare for a non-smoker to have lung cancer. A rising death rate from lung cancer — the most common cancer among white males, the second commonest among coloured males and increasing among black males and white females — is about 1 000 per cent higher for cigarette smokers than for non-smokers. For the 40-a-day smoker, the death rate is at least 20 times higher.

Does this information present an unbiased picture? _____

What is the aim of presenting this information? _____

_____

SUBJECT TOPIC

DRUGS AND HEALTH

CRITICAL THINKING SKILL

Gather complete information

page 37

SYLLABUS OUTLINE

I. Drugs and their effects

1. Heroin.
2. Cocaine.
3. LSD.
4. Cannabis.
5. Solvent and glue sniffing.

II. The risks of taking drugs

1. Addiction.
2. Infections.
3. Overdoses.
4. Mental harm.
5. Changes in behaviour.
6. Accidents.

III. Alcohol

IV. Medicinal use of drugs

1. Beneficial use of drugs.
2. Testing of drugs before allowing public use.
3. Some common medicinal drugs.
   * Pain killers.
   * Tranquillizers.

APPLICATION OF CRITICAL THINKING PRINCIPLE

The scandal of thalidomide

1. Divide the class into groups of four or five pupils.
2. Give each pupil a copy of "the scandal of thalidomide" (p.41).
3. Ask them to read the piece and the questions which follow. They should then discuss it amongst themselves and to write down answers for the two questions.
4. Discuss the answers with the class. Suggested answers:
   1. There was no research done on the effect of the drug if taken during pregnancy.
   2. Test for its effect under all circumstances, or list the conditions under which it can be taken safely.
5. Emphasise that in this example the developers of the drug had not 'gathered complete information' on its effects in its probable field of usage.
6. Emphasise the need to gather all the relevant information on the particular topic under discussion before making a decision.

GATHER COMPLETE INFORMATION

PURPOSE OF THE LESSON

The purpose of this lesson is to show pupils the importance of having all the information which is relevant for making a decision or drawing a conclusion. They must understand that to **"gather complete information"** is an important aspect of critical thinking.

SUGGESTED TIME

Approximately 10 minutes.

MATERIALS PROVIDED

1. Sheet 1. (p.38) "Making a decision on the information available". One copy per pupil.
2. Sheet 2. (p.38) "The other side of the story". One copy per pupil.
3. A list for each pupil of the important points to remember for this skill.

SUGGESTED APPROACH

1. Hand out sheet 1 (p.38. "Making a decision on the information available"). Give one copy to each pupil.
2. Ask them to read the passage and then answer the question at the end individually.
3. Based on the information provided, ask how many feel that Jane should be punished and how many think she should not be punished.
4. Have a few of the pupils give the reasons for their answer, during a report-back
5. Hand out Sheet 2 (p.38. "The other side of the story"). Ask the pupils to read it and answer the question based on the new information available.
6. Find out how many changed their initial decision. Try to draw from the pupils in a discussion that a decision to punish Jane would have been unfair. Get them to see the importance of having all the information in this case.
7. Generalise the principle. Ask pupils to think of other areas where it is necessary to gather complete information in order to make a fair decision. Some possible examples are: Newspaper articles where one person/party is portrayed as the villain; scientific/medical reports; political wrangling. (This could be a homework assignment.)
   (Use the OHP from the introductory lesson on "Scholarships" (p.12) to show the effect of information deliberately omitted.)
8. Give each pupil a copy of the summary of important points regarding this aspect of critical thinking (p.39) and discuss briefly with the class. (OHP - p.40.)

Making a decision on the information available

A standard seven class was divided into groups to work on an important project. Each member of the group was given an individual task for homework. The class had a double period the next day. During the first period of their double they would use the information from their homework tasks to finalise the project and prepare for a test on the project to be written in the second period of the double. The group would receive a mark for the completed project.

Group A decided that Jane should do the most difficult part, an essential part of the project, because she was both clever and reliable. The next morning, however, Jane had not done the work. The group received a very poor mark for the work, and were put at a disadvantage in the test they then had to write. The teacher punished Jane for not doing the work, because she had let her team down.

Do you think it was fair that Jane was punished? _____

The other side of the story

The teacher was worried about Jane's uncharacteristic behaviour, and after the lesson, called Jane aside. Jane burst into tears and told her teacher, whom she liked and trusted, that her father had come home drunk again the previous evening. There had been a huge family argument. Her father had gone wild and hit her mother severely and had also hit her and told her to go to bed. She showed the teacher the welts on her thighs. That was why she had not done the work.

Do you still think it was fair that Jane was punished? _____

Gather complete information on the topic under discussion before reaching a decision.

1. In considering any problem or issue, always make sure that you have all the facts necessary for
   * drawing a conclusion,
   * making a decision, or
   * passing a fair judgement.

   There may be information missing, or deliberately withheld, which could change the decision you would make on the issue.

2. REMEMBER:
   * 'There may be another side to the story'. i.e. Check to see whether there could be an opposing point of view.
   * There may be some facts missing which would throw new light on the problem. Are there any obvious areas where the information seems scanty?
   * Information may have been deliberately withheld to influence the decision made.

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   * There may be some facts missing which would throw new light on the problem. Are there any obvious areas where the information seems scanty?
   * Information may have been deliberately withheld to influence the decision made.

The scandal of thalidomide

This tragic story began in Germany in 1957. A medicine which had been widely tested on rodents, cats, rabbits and human subjects was launched on the market. It was promoted as a powerful tranquillizer which did not produce harmful effects, even when given in many times the necessary dosage. It could even be bought over the counter in Germany. In Britain approval was given in 1958 for its sale on a doctor's prescription.

By chance it was discovered that the new tranquillizer was particularly useful in treating the depressions and nausea that often cause misery during the early stages of pregnancy. Soon it was widely used for this purpose, and even recommended by some doctors.

In November 1961 the horrific news hit the world headlines! The drug, thalidomide, if taken during pregnancy, had a deforming effect on the unborn baby. By this time about ten thousand deformed babies had been born, mostly in Germany. Only about two thousand had survived.

What had gone wrong?

What was the problem with the research on thalidomide that led to this tragedy? _____

_____

_____

_____

Before releasing medicines onto the market, what conditions need to be met by the developers of the drug? _____

_____

_____

SUBJECT TOPIC

CANCER

CRITICAL THINKING SKILL

Understand and define all terms

Page 43

SYLLABUS OUTLINE

I. What is cancer?

II. The main causes of cancer

1. Radiation.
2. Diet.
3. Smoking.

III. Treatment of cancer

1. Surgery.
2. Chemotherapy.
3. Radiotherapy.
4. Lasers.

APPLICATION OF CRITICAL THINKING PRINCIPLE

1. Give each pupil a copy of graph A (p.47). Ask them to study the graph individually and then write down a conclusion drawn from the graph.
2. Have a few of the pupils read their answers to the class.
3. Hand out graph B (p.48) to each pupil and once again ask them to study the graph and give a conclusion in the spaces provided.
4. Ask the pupils if they have changed the initial conclusion drawn. Have them read some of the changes.
5. Discuss the difference in the conclusions for the two graphs. Elicit from the pupils what brought about the change of conclusion. Use the OHP (p.49) provided to discuss the conclusions drawn. i.e. The first graph represented the total of all cancer cases, not distinguishing between the different types of cancer. The conclusion from the first graph would seem to be that there was 'an inexplicable health threat caused by the dramatic increase in the incidence of cancer'. A clearer and more precise defining of the term 'cancer' shows that there is an increase in lung cancer only, probably due to an increase in smoking and pollution, which can be dealt with. (OHP - p.50)
6. Generalise the principle.
   Emphasise the need to understand and define all terms clearly in the context in which they are being used.

UNDERSTAND AND DEFINE ALL TERMS

PURPOSE OF THE LESSON

The purpose of this lesson is to teach the pupils that it is important to "**understand and define all terms**" in relation to the situation in which they are being used.

SUGGESTED TIME

Approximately 10 minutes.

MATERIALS PROVIDED

1. Sheet 1. The effect of mutations (p.44). One copy per pupil.
2. Sheet 2. Are mutations good or bad? (p.45). One copy per pupil.
3. A list of the important points to remember for this skill. One copy per pupil.

SUGGESTED APPROACH

1. Carry out the activity without mentioning the critical thinking principle to be demonstrated.
2. Hand out a copy of sheet 1 (p.44) to each pupil. Ask them to read the extracts and answer the questions at the end of the page.
3. Discuss the answers with the class. Emphasise the point that people tend to think of a 'mutation' as a 'bad' thing.
4. Hand out sheet 2. (p.45) to each pupil.
5. When they have read the page discuss how having a clear understanding of the meaning of the word 'mutation' makes it easier to see that the change need not necessarily be harmful.
7. Generalise the principle.
   * Emphasise the need to understand and define all terms in the context in which they are being used.
   * Refer to the need to apply this principle with regard to media reports from newspapers, television etc.
   * Emphasise that if terms are incorrectly defined people may draw incorrect conclusions.
8. Hand out the summary of the points to be emphasised (p.46) on this aspect of critical thinking (one copy per pupil) and discuss briefly with the class.

The effect of mutations

Read the following extracts and then answer the questions which follow.

1. Several years ago an accident occurred at a nuclear reactor at Chernobyl in Russia which caused the release of a large amount of radio-active material into the air. This was a serious health threat to the people of the area. The following article appeared in The Times, London.

Irradiated survivors could face premature death

Victims of the Chernobyl nuclear disaster in Russia who received huge doses of radiation will be at risk for weeks, months and years to come, nuclear health experts said. Pregnant women could give birth to children suffering from genetic disorders and mutations. The longer-term effects include the development of leukaemia and cancers of the thyroid, lungs and breast.

2. This extract is taken from a book on mutations.

One notorious mutation, known as sickle-cell anaemia, affects the ability of the red blood cells to carry oxygen. This mutation occurs commonly in Central African populations and may sometimes cause death.

1. What do you understand by the word 'mutation'? _____

_____

_____

2. What do you think is the general impression people have when they hear the word 'mutation'?

_____

_____

_____

_____

3. Do mutations provide any benefit to the individual? _____

Explain your answer. _____

_____

_____

Are mutations always harmful?

Read the following passages and then answer the questions below.

1. The gene which causes sickle cell anaemia also makes the individuals who have the gene resistant to malaria. Thus in areas where malaria occurs, the presence of this gene could provide an advantage.

2. In an attempt to improve the wheat crop in India, special wheat seeds were brought in from the USA. These plants grew very well, but the grains were red (which the Indians did not like) and were low in protein. The Indian scientists bombarded the seeds with atomic radiation to cause mutations, and then the seeds were sown. Those that grew were carefully studied to see if any improvements had occurred due to mutations. They found a new variety which grew well in the Indian conditions, had a large amount of protein, and was the correct colour for Indian tastes. Within a few years the Indian wheat crop had more than doubled on the same area of land.

Does your understanding (given in question 1 of the previous page) of the word 'mutation' agree with the meaning of the word 'mutation' as it is used in these two paragraphs? _____

If not, how would you change your definition to include the broader meaning shown in these two paragraphs? _____

_____

_____

Most people tend to think of mutations as a change to the genetic material, which will be harmful to the person concerned. Using this definition of the word when discussing any issue relating to mutations could lead to faulty conclusions.

Understand and define all terms relating to the topic under discussion to ensure a clear understanding.

In order to make a fair decision when considering any issue or problem:

1. Ensure that the meanings and interpretations of all terms are clearly defined in relation to the the situation being considered.
2. Be aware of the incorrect use of terms which may lead to misinterpretation of the information.

Understand and define all terms relating to the topic under discussion to ensure a clear understanding.

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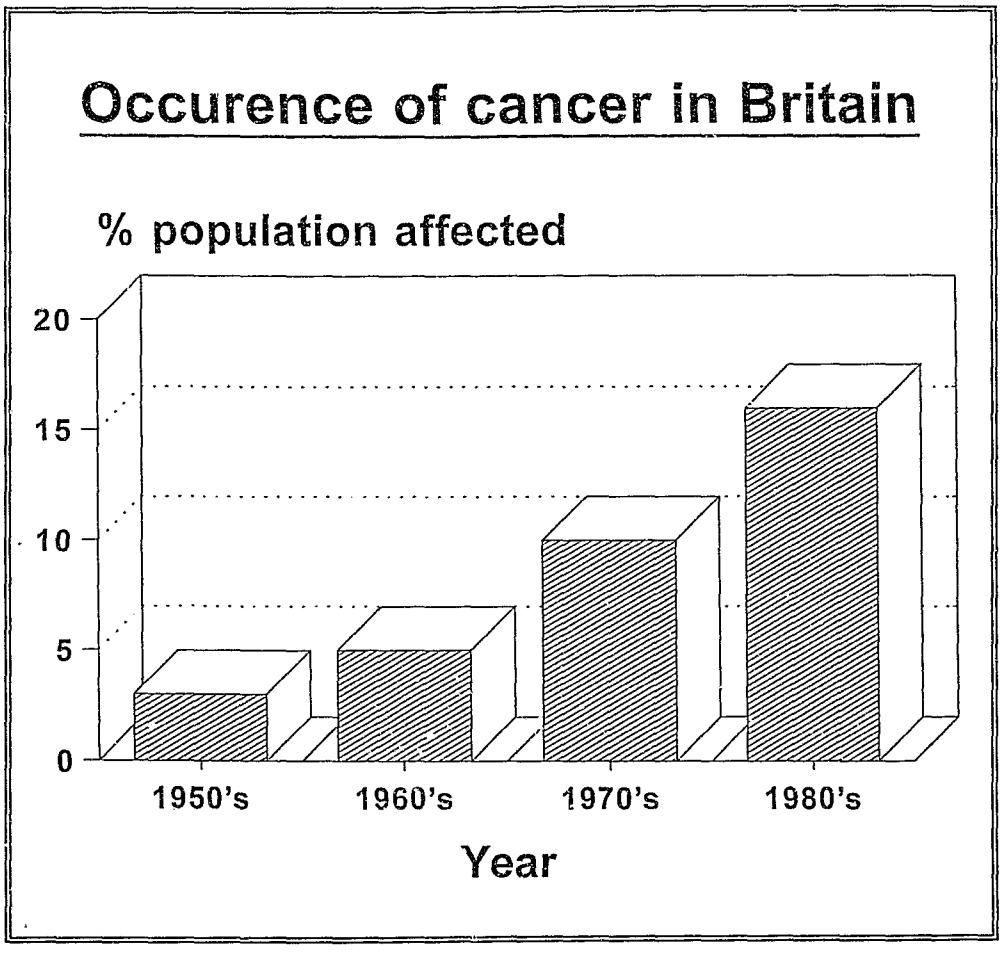
In order to make a fair decision when considering any issue or problem:

1. Ensure that the meanings and interpretations of all terms are clearly defined in relation to the the situation being considered.
2. Be aware of the incorrect use of terms which may lead to misinterpretation of the information.

Graph A

Study the following graph and answer the questions below.



What conclusion would you draw from the information given in this graph? _____

_____

_____

How do you think people in Britain would feel if they were given this information? _____

_____

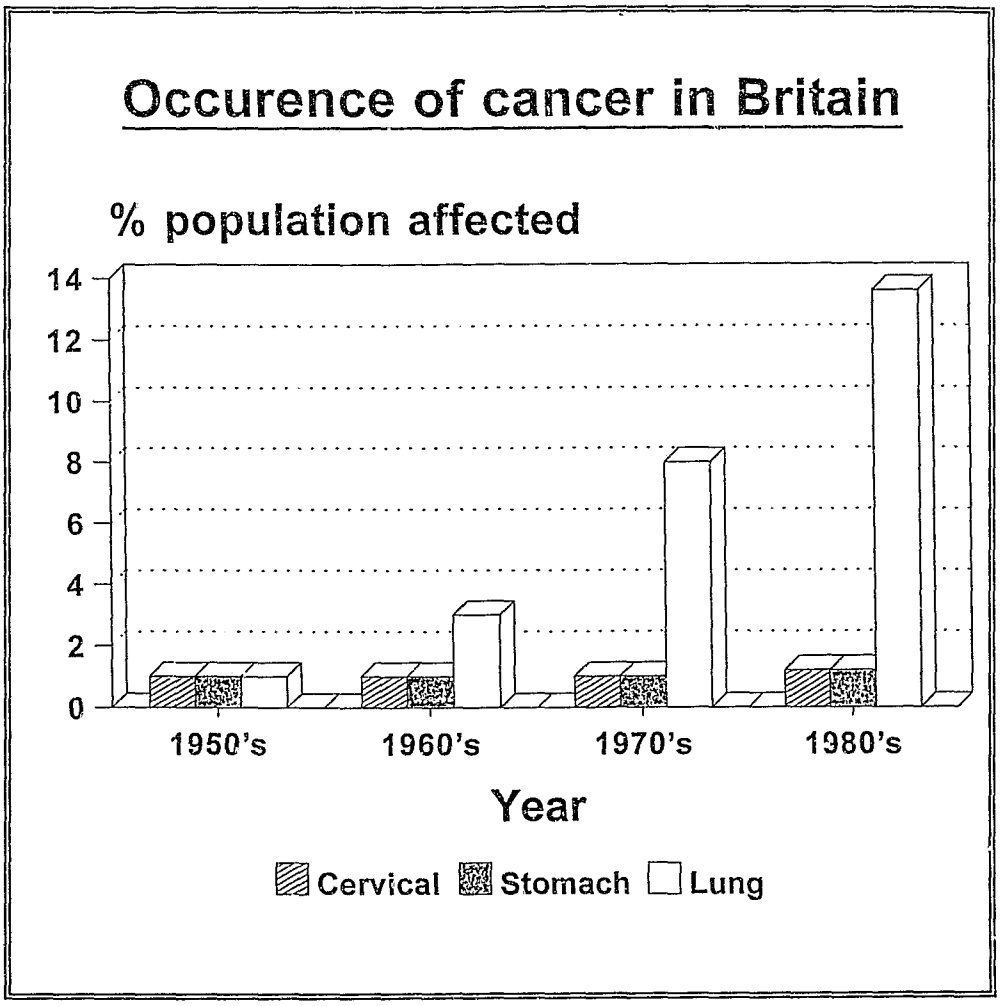
_____

What could be done to overcome the problem? _____

_____

Graph B

Study the following graph and answer the questions below.



What conclusion would you draw from this graph? _____

_____

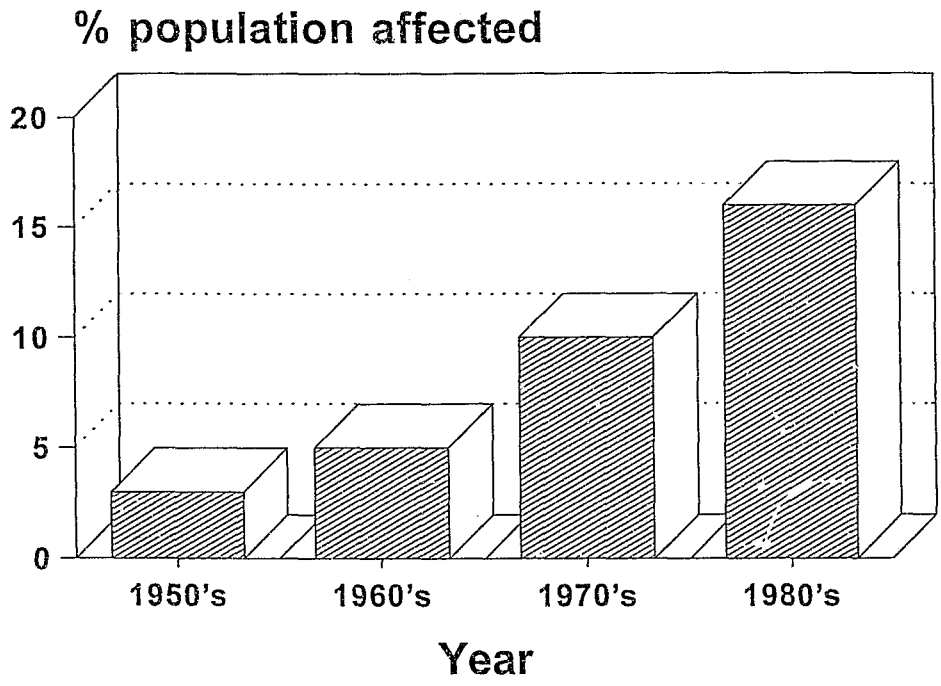
What is the probable cause of the increase of cancer in Britain? _____

_____

What could be done to overcome the problem? _____

_____

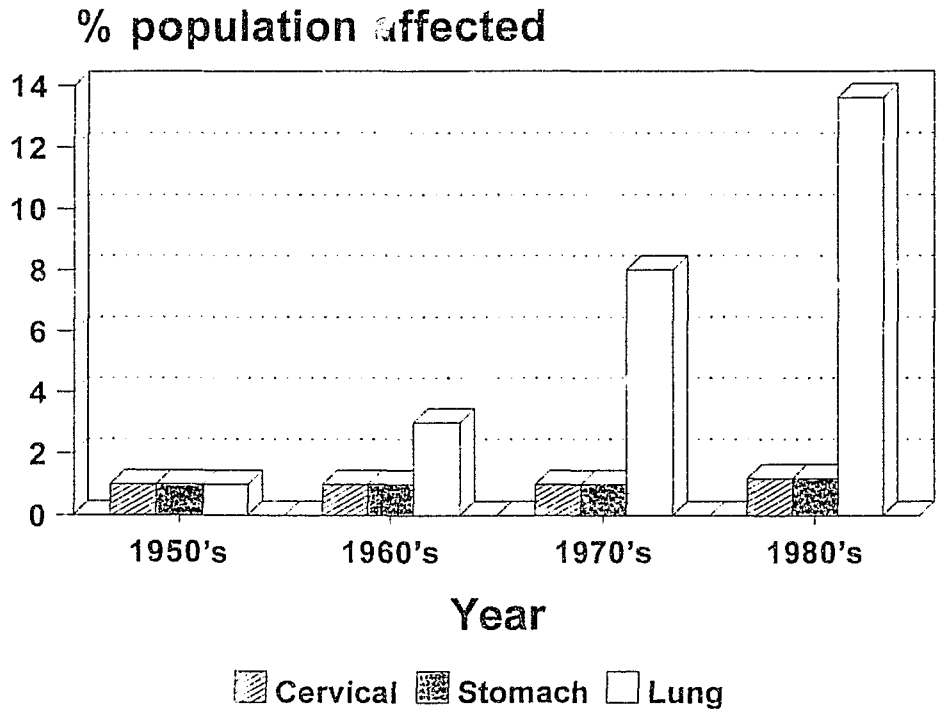
Occurence of cancer in Britain



Conclusion:

Inexplicable general health threat - case hopeless

Occurence of cancer in Britain



Conclusion:

Increasse in smoking and pollution - the problem can be dealt with.

Gather complete information on the topic under discussion before reaching a decission.

1. In considering any problem or issue, always make sure that you have all the facts necessary
   * for drawing a conclusion,
   * making a decision, or
   * passing a fair judgement.

   There may be information missing, or deliberately withheld, which could change the decision you would make on the issue.

2. REMEMBER:
   * 'There may be another side to the story'. i.e. Check to see whether there could be an opposing point of view.
   * There may be some facts missing which would throw new light on the problem. Are there any obvious areas where the information seems scanty?
   * Information may have been deliberately withheld to influence the decision made.

Understand and define all terms relating to the topic under discussion to ensure a clear understanding.

In order to make a fair decision when considering any issue or problem:

1. Ensure that the meanings and interpretations of all terms are clearly defined in relation to the the situation being considered.
2. Be aware of the incorrect use of terms which may lead to misinterpretation of the information.

When evaluating any information -
Question the methods by which the facts are derived.

Conclusions or decisions made on the basis of facts gained by questionable methods may prove to be incorrect. Predictions or intuitions are unreliable as some may be inaccurate.

Examples of sources of information which should be evaluated critically:
* Information from experiments and research.
* Information in media reports, political debates, or advertising claims.
* Information from general conversation.

In considering this type of information:
* be sure that the methods used to obtain the information are fair.
* identify the variables which may influence the accuracy of the information.Decide whether these variables were controlled or their influence taken into account in drawing the conclusions.
* Try to find other evidence to support the conclusion.

Question the conclusions which have been drawn from the information given before accepting them as true.

Question the so-called "facts".

If information is given and some conclusion is drawn from it, decide if the conclusion is fair and justified. Such information could come from an argument, a scientific study, newspaper reports, advertising claims, or even in conversation.
To find out whether the information available really supports the conclusions,

* Look for other possible explanations that could be drawn from the same facts. If one alternative is found look for a second and third.
* Identify all variables and question the possible influence of each on the outcome and hence on the conclusion drawn.
* Look for instances where one event which follows another is incorrectly said to be caused by the first.
* Look for cases where the conclusion from a specific instance has been extended to apply to all cases (Generalisations).

If any of these conditions apply to the information you are considering, then that information is questionable. More evidence is needed to support this information.

Look for hidden assumptions and biases which may distort the information presented

* Take into account the possible bias of the source of the information. Question what the source of the information stands to gain or lose from the situation, and then examine the information to see if it is biased in this direction.

* Understand your own biases and values which may influence your judgement in considering the particular situation.

APPENDIX B

PRE-TEST ON CRITICAL THINKING SKILLS IN BIOLOGY

TEST

EXAMINATION NUMBER | | | | | | | |

INSTRUCTIONS

Read each question carefully, taking into account the information provided, before deciding on your answer.

Part A

1. *The history teacher of a certain standard seven class was thinking of getting a new textbook for the pupils. She got a copy of each of the two new books which had become available, and asked the pupils to choose one to use for their studies. As they were due to write a test, the pupils decided to let John study the chapter on the work set for the test from book A and Jim the same chapter from book B. John's mark for the test was 90 and Jim's 60. The class concluded that book A was a better textbook, because John had used it to study and had got a better mark.*

   Was the class justified in making this decision? Explain your answer.

   _____

   _____

   _____

   _____

2. *A new coach prepared the school's first hockey team for the season's matches. Despite all his efforts, the results at the end of the season showed that the team had lost almost all their matches, whereas the previous year's first team had won most of their matches. A group of pupils saw the principal and, blaming the new coach for the poor results, demanded that the previous year's coach be asked to come back to coach the school's first team the following year.*

   Do you agree with the pupils in blaming the new coach for the poor results? Explain your answer.

   _____

   _____

   _____

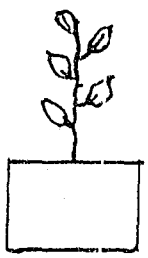
   _____

3. *An article in a newspaper stated that the use of refined sugar had been shown to be one of the most important dietary factors causing tooth decay and that South Africans should try to reduce their daily consumption of sugar. A senior dietician from the South African Sugar Association, responded in a letter to the paper, saying: " Our research indicates that diet is only one of many factors contributing to tooth decay. Heredity factors and poor health care also contribute to the process. Sugar plays an important role in the diet because it is an excellent source of ready energy. I recommend the continued use of sugar in the daily diet".*

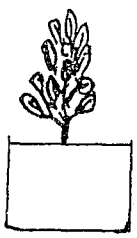
Do you think that the dietician's comments are fair? Give reasons for your answer.

4. * *A standard seven class wanted to see at what temperature plants grew best. So they decided to grow some plants at different temperatures to check experimentally which was best. They agreed that the girls would grow a bean plant at 10°C. and would make sure that the temperature was kept at 10°C. The boys would look after their bean plant, keeping the temperature at 30°C. They were very careful to check that the plants were treated identically (i.e. that they got the same amount of light and water, and were planted in identical pots of soil). The drawings show the results several weeks later. The class concluded that beans grow better at a temperature of 30°C. than at a temperature of 10°C.*

Do you agree with their conclusion? Explain your answer.



10°C

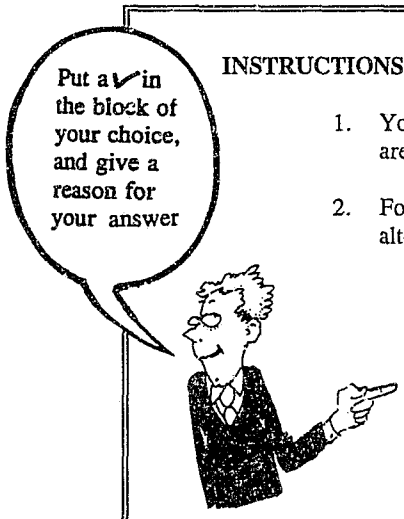


30°C.

* *Adapted from the test for the 'Biology Critical Thinking Project' (Zohar, et. al., 1994).*

PART B

EXAMINATION NUMBER | | | | | | | |



INSTRUCTIONS

1. You do not need specific knowledge to answer these questions but you are urged to think carefully before writing down your answers.

2. For each question a number of possible answers are given. For each alternative answer you will be given the following option:

☐ *I agree* ☐ *I disagree*

Reason _____

_____

_____

3. Put a tick in the block of your choice, and then give a reason for your answer.

1. * Two schools (X and Y) held a competition in mathematics for standard seven pupils. A pupil from school Y won. The following comments were made by some people after the competition.

Indicate whether you agree or disagree with each of these comments and give reasons for your answers.

a. The maths teachers from school Y are better than those from school X.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. Pupils from school Y are better than pupils from school X.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. Pupils from school X had not prepared themselves as well as pupils from school Y.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

* *Adapted from the test for the 'Biology Critical Thinking Project' (Zohar, et. al., 1994).*

2. *A research team wanted to investigate workers' attitudes. Thousands of construction workers were interviewed. The results, published in a local newspaper, showed that most of the interviewed workers were satisfied with their jobs and had a responsible attitude towards their work. People in the street were interviewed to find out what they thought about the article. Some of their conclusions are given below.*

   Indicate whether you agree or disagree with these conclusions and give reasons for your answers.

   a. "Yes. Research shows that construction workers are satisfied with their jobs and are responsible workers."

   ☐ *I agree* ☐ *I disagree*

   Reason(s) _____

   _____

   _____

   _____

   b. "Construction workers can't be satisfied and responsible in their jobs because I know two construction workers who complain about everything and don't accept their family responsibilities."

   ☐ *I agree* ☐ *I disagree*

   Reason(s) _____

   _____

   _____

   _____

   c. "I agree with the research findings that workers are well satisfied and responsible people.

   ☐ *I agree* ☐ *I disagree*

   Reason(s) _____

   _____

   _____

   _____

3. * *A scientist was experimenting with a new variety of tomato plant in the laboratory. One day he accidently spilt a chemical solution on the soil in which the plants were growing. The plants continued to grow, but a few days later purple spots appeared on the leaves. Some of the laboratory assistants discussed the situation and made the following comments.*

Indicate whether you agree or disagree with these comments and give reasons for your answers.

a. The chemical broke down the chlorophyll in the spotted areas, causing the purple colour.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. The chemicals caused the appearance of the spots as there were no spots on the leaves before the chemicals were spilt on the soil.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. It is not possible to say whether the chemicals caused the spots or not. The spots may have been caused by something else.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

* *Adapted from question a question used by Dreyfus and Jungwirth, (1980).*

4. *Environmental groups say the "industrial production of chlorine poses a severe threat to the ecosystem and should be phased out". However, scientists from the Research Division of Euro Chlor, the chlorine industry federation based in Brussels, argue that "there are chlorinated organic compounds in nature, and industry is not creating a new risk by contributing a few more".*

In a debate on the problem, the following points were made. Indicate whether you agree or disagree with each of these points, and explain why.

a. The chlorine products can't be an environmental threat because research scientists from Euro Chlor have indicated that there is no new risk involved.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. The environmentalists base their claims on facts which show that chlorine is a harmful substance. It would probably be a threat to the environment.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. The argument that chlorinated organic products are produced in nature shows that the dangers are unlikely to be a serious threat to the environment.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

APPENDIX C

POST-TEST ON CRITICAL THINKING SKILLS IN BIOLOGY

TEST

EXAMINATION NUMBER

INSTRUCTIONS

Read each question carefully, taking into account the information provided, before deciding on your answer.

Part A

1. *An article in the newspaper strongly condemned the use of any alcoholic drinks, particularly by teenagers. It mentioned the ill-effects resulting from the abuse of alcohol, such as damage to the liver and brain, stomach ulcers, heart disease and the danger of alcoholism. In response to this article, the Public Relations Officer for the Wine and Liquor Merchants Association of South Africa said that the article was an exaggeration. He said that research has shown that beer contains nutritious substances and that a glass of wine with supper helps to reduce blood cholesterol levels.*

   Do you think that the Public Relations Officer's comments were fair? Give reasons for your answer.

   _____

   _____

   _____

   _____

2. *A panel responsible for evaluating and recommending textbooks for schools decided to test the effectiveness of two new textbooks, written by different authors, for the standard seven biology syllabus. School A was given the one book and school B the other book. The schools were asked to use the book given to them as their only textbook for the year. The average mark for biology at the end of the year was compared.*

   School A's average was 75%
   School B's average was 62%

   The panel concluded that the book used by school A was the best and recommended it to all schools.

   Was the panel justified in making this recommendation? Explain your answer.

   _____

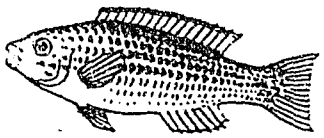
   _____

   _____

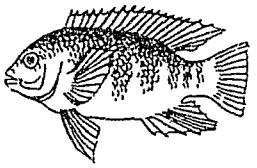
   _____

3. *The standard seven pupils were asked to carry out an experiment in their biology class. They decided to test whether young fish would develop better in water from the river or water from the tap. They bought two baby fish from the pet-shop in town and put the one fish in an aquarium which they had filled with water from the river near the school, and the other fish in an aquarium filled with water from the tap. They were very careful to check that the fish were treated identically (i.e. that they got the same kind and amount of food, and the temperatures were the same.) After several weeks they compared the two fish. The drawings below show the two fish drawn to the same scale. The class concluded that fish develop better in tap water than in river water.*

Do you agree with their conclusion? Give a reason for your answer.



Fish kept in river water

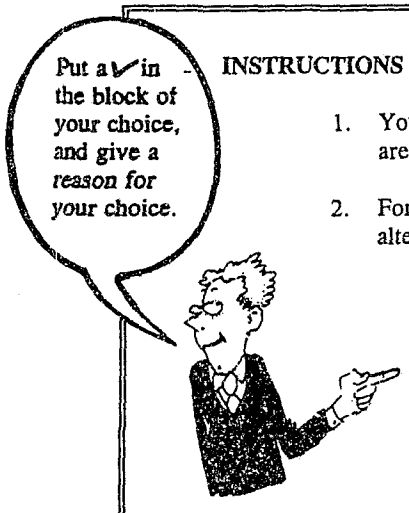


Fish kept in tap water

4. *"Smallpox blamed for Aids explosion" The Times*
The Times reported a claim from a World Health Organisation (WHO) expert that the vaccinating against smallpox had caused the Aids explosion. This claim was based on the fact that the Aids virus was first identified in Central Africa in the late 1970s, soon after the people in the area had been vaccinated for smallpox.

Do you agree with the WHO expert that vaccination for smallpox was responsible for the Aids explosion? Explain your answer.

PART B



INSTRUCTIONS

1. You do not need specific knowledge to answer these questions but you are urged to think carefully before deciding on your answers.
2. For each question a number of possible answers are given. For each alternative answer you will be given the following option:

☐ *I agree* ☐ *I disagree*

Reason _____

_____

_____

3. Put a tick in the block of your choice, and then give a reason for your answer.

1. *A scientist decided to change the brand of food she was using for the rats that she kept in the laboratory. A few days later patches where hair had fallen out began to appear on the rats. Some of the laboratory assistants discussed the problem and made the following comments.*

Indicate whether you agree or disagree with these comments and give reasons for your answers

a. The new food destroyed the roots of the hair, causing the hair to fall out.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. The new food must have caused the hair to fall out as the hair was growing perfectly before the rats were given the new food.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. It is not possible to say whether the new food caused the hair to fall out or not. Something else may have caused the hair to fall out.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

2. Two schools (X and Y) held a cross-country competition. A pupil from school Y won. The following comments were made by supporters after the race.

Indicate whether you agree or disagree with each of these comments and give reasons for your answers.

a. The coaches from school Y are better than the coaches from school X.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. The pupils from school Y are better long-distance runners than those from school X.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. The runners from school Y were more enthusiastic and trained harder than the runners from school X.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

3. *Well-known environmentalists say that the mining of the St. Lucia dunes will damage the environment to an unacceptable extent. Richards Bay Minerals, who will be mining the dunes, arranged extensive research by their own scientists. These scientists concluded that the mining would only have a low impact on the area, and that once the dunes had been rebuilt and indigenous plants and animals re-established the area would recover fully.*

In a debate on the problem the following points were made. Indicate whether you agree or disagree with each of these points and explain why.

a. The mining of the St Lucia dunes is unlikely to have any serious long-term effects on the area as the research scientists from Richards Bay Minerals have indicated that the mining will have a low impact on the environment.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. Environmentalists base their claims on experience of other mining operations which have damaged the environment. They are probably correct in their predictions.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. The fact that the dunes will be replanted with plants that occur naturally in the area when mining is finished means that no serious long-term damage will be done.

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

4. *A team of researchers from the World Health Organisation conducted research into the numbers of people in Africa who suffer from malnutrition. The results published in the newspaper showed that an alarming number of people in Africa suffer from malnutrition because they do not get the full range of nutrients required by the body in their diets. People in the street were interviewed to find out what they thought about the situation. Some of their comments are given below.*

Indicate whether you agree or disagree with these comments and give reasons for your answers.

a. "Research shows that malnutrition occurs amongst many people in Africa because they do not have a balanced diet."

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

b. "There can't be that many people in Africa who are suffering from malnutrition as the only people I know from Africa are overweight and couldn't possibly be suffering from malnutrition."

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

_____

c. "I agree that there are people who eat too little and so will suffer from malnutrition."

☐ *I agree* ☐ *I disagree*

Reason(s) _____

_____

_____

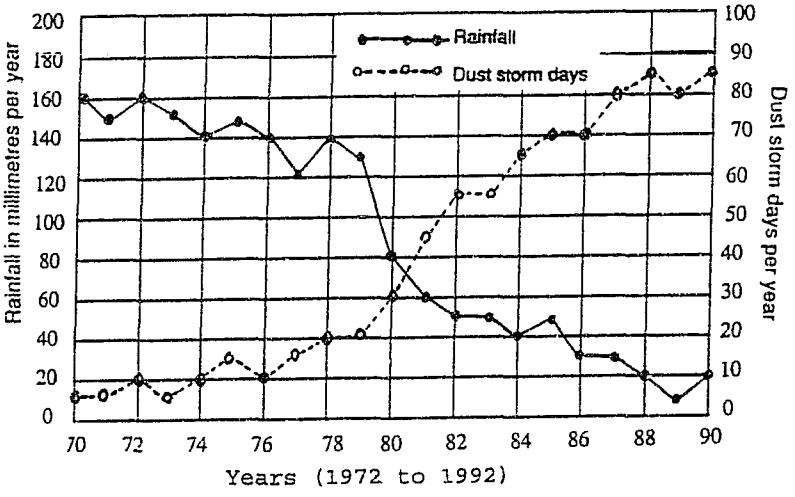
_____

APPENDIX D

TEST IN GEOGRAPHY FOR THE TRANSFER OF CRITICAL THINKING SKILLS

Section D **Name:** _____

1. Desertification is the process where land that was once fertile is being turned into desert. Sixty percent of Africa is either already desert or in danger of becoming desert. Records were kept of the annual rainfall as well as the dust storm days per year for a particular region of Africa for the period from 1960 to 1986. The results are shown on the following graph:



a. A standard seven pupil was asked to comment on desertification from the information shown in the graph. His comment was: "The graph shows that desertification is a people-created disaster resulting from over-cultivation of the soil".

Indicate whether you agree or disagree with his answer by circling your choice below and give a reason/reasons for your choice.

I agree / I disagree

Reason(s) _____

_____

_____

b. The farmers in the area blamed the decrease in rainfall on the disturbance to the atmosphere caused by the volcanic eruption of Mount St Helens in 1980. Indicate whether you think the farmers were correct in making this comment and give a reason for your answer. (circle either 'yes' or 'no'.)

Yes / no *Reason(s)* _____

_____

_____

c. A newspaper headline read: **"Drought-resistant seed will help reclaim land"**. Grass seeds had been treated with a special seed-coating process to protect them against drying out. A sample of 300 seeds were kept in hot dry conditions in the laboratory for several months. The seeds were then planted in containers in the laboratory and watered once. Ninety percent of the seeds germinated. The scientists who carried out the experiment claimed that these seeds could resist dry conditions and could thus be used to reclaim land affected by desertification.

Indicate whether you agree or disagree with this claim and give reasons for your answer. (Circle your choice of answer below.)

I agree / I disagree *Reason(s)* _____

_____

_____

2. A decision had been made to build a nuclear reprocessing plant near Dournreay in the north of Scotland. Dournreay already had a nuclear power station to generate electricity. The nuclear reprocessing plant would reprocess nuclear waste from the whole of Europe. The advantages of placing the plant at Dournreay were that land was cheap, and that materials could be transported in and out of Dournreay easily because it was situated on the coast.

   However, not everyone was happy about the new plant. A number of statements relating to the debate about the proposed new processing plant were recorded in the local newspaper.

   a. The Rosshire Committee against the Dournreay Reprocessing plant said: "The new plant may create new jobs, but many will lose their jobs because a nuclear reprocessing plant would harm farming, fishing and tourism in the area."

      Was this comment justified? Indicate your answer by circling 'yes' or 'no' below and give reasons for your choice in the space provided.

      Yes / No Reasons: _____

      _____

      _____

   b. The Chairman of the Public Enquiry said: "There is evidence to show that childrens' illnesses and deaths are higher in Dournreay than the national average. This is no doubt due to the presence of the nuclear power plant."

      Do you think the Chairman's comment is fair? (Circle your answer and give an explanation for your answer.)

      Yes / No Explanation: _____

      _____

      _____

   c. The U K Atomic Energy authority said: "Nuclear reprocessing is completely safe. The presence of this plant will not cause any threat to health."

      Do you think this is a fair comment? (Circle your answer, and give an explanation for your choice.)

      Yes / no Explanation: _____

      _____

      _____

   d. The "Ban Nuclear Development" organisation said: "All developments relating to nuclear power are harmful to man and should be banned!"

      Is this statement justified? (Circle your answer and give an explanation for your choice.)

      Yes / No Explanation: _____

      _____

      _____

APPENDIX E

ANALYSIS GRID FOR THE CRITICAL THINKING SKILLS TESTED IN THE PRE-TEST

Analysis grid for the critical thinking skills tested in the pre-test and post-test

Pre-test → / Questions→					B1			B2			B3			B4		
Post-test →* / Critical thinking skills used ↓	A1	A2	A3	A4	a	b	c	a	b	c	a	b	c	a	b	c
	A2	A4	A1	A3	B2			B4			B1			B3		
					a	b	c	a	b	c	a	b	c	a	b	c
1. Gather complete information before drawing a conclusion	√	√			√	√	√	√			√	√		√	√	√
2. Understand and define terms				√					√	√						
3. Question the methods used in gaining the inform ion																
a. No control											√					
b. Other variables not controlled	√				√						√	√				
c. Poor sample size	√			√												
4. Question the conclusions drawn																
a. Can't draw conclusions from the information given								√	√	√						
b. Can't generalise	√				√	√	√	√	√	√						
c. Other conclusions are possible		√	√	√							√	√				
d. Correlation not equal to causation		√									√	√				
5. Look for hidden asumptions and biases			√											√	√	√

* *The sequence of the matched questions was changed in the post-test*

APPENDIX F

TEACHER EVALUATION FORMS FOR THE TEACHING PACKAGE ON CRITICAL THINKING

Response: Teacher I

EVALUATION OF PACKAGE

I would greatly appreciate your comments about this package. Any comments or suggestions you make will be used to modify the package to improve its usefulness to pupils and teachers.

TEACHER'S GUIDE

1. **Accuracy**

   Please use a red pen to mark any inaccuracies or suggested changes on the teacher's guide. I will give you a replacement copy once the changes have been made to the package.

2. Have you been given enough guidance? Are the explanations clear enough? Please elaborate under the following headings.

   Guidance given

   The guidance was very clear and well presented. I did get a little confused at the beginning before the pages were numbered, but after they were numbered it was very easy to follow.

   Clarity of explanations

   The explanations were clear and easy to follow. It was particularly useful having questions in italics.

   Language used

   The language was concise and easy to follow.

Please add any other comments you would like to draw to my attention.

Response: Teacher I

PUPILS' ACTIVITY SHEETS AND SUMMARIES OF IMPORTANT POINTS ON CRITICAL THINKING

1. Please indicate on a spare copy of each hand-out, using a red pen, any errors or problems that need to be corrected, or any suggestions for improvement.

2. Please comment on the length of time taken to do each of the suggested lessons on critical thinking, as well as the lessons applying the critical thinking principles to biology.

   Discussion, particularly group work, took longer than the time indicated. Those exercises directly relating to the work were more useful and evoked more discussion, which was valuable.

3. Please comment on the pupils' response to the exercises. Was it positive? Did they appear to enjoy the activities? Were they keen to learn about critical thinking?

   The students seemed a little wary to begin with, but participated well in discussions and enjoyed the activities once they were under way.

4. Please add any other comments you would like to make relating to the pupils' exercises and involvement.

   My feeling is that exercise has been very valuable for the students. They may have benefited from more practice at each principle. Discussion on the pre-test, and where they may have gone wrong, may have given them a better idea of how they could improve their skills of critical thinking.

Response: Teacher II

EVALUATION OF PACKAGE

I would greatly appreciate your comments about this package. Any comments or suggestions you make will be used to modify the package to improve its usefulness to pupils and teachers.

TEACHER'S GUIDE

1. **Accuracy**

   Please use a red pen to mark any inaccuracies or suggested changes on the teacher's guide. I will give you a replacement copy once the changes have been made to the package.

2. Have you been given enough guidance? Are the explanations clear enough? Please elaborate under the following headings.

   Guidance given

   Clear, well set out.

   Clarity of explanations

   Good.

   Language used

   Fine!

Please add any other comments you would like to draw to my attention.

1. The wood and nails exercise - get soft wood, girls can't hammer!
2. Page 12 OHP on Scholarship - too smallto read (by class).
- put A and B on separate pages - enlarge.
3. Page 5: Change order of skills to fit in with the order done(Page numbers).
4. Page 38: Exercise did not really give the desired result. Only 3 out of 20 pupils said "yes" to the first part, and therefore changed their decision when given part two. (They all did change.)

Response: Teacher II

PUPILS' ACTIVITY SHEETS AND SUMMARIES OF IMPORTANT POINTS ON CRITICAL THINKING

1. Please indicate on a spare copy of each hand-out, using a red pen, any errors or problems that need to be corrected, or any suggestions for improvement.

2. Please comment on the length of time taken to do each of the suggested lessons on critical thinking, as well as the lessons applying the critical thinking principles to biology.

   1. Critical thinking - need more time to discuss answers, particularly if they don't all agree.
   2. Syllabus content: more time needed to apply critical thinking skills. We used 3 weeks (4.5 hrs teaching time) - need approximately 6 weeks.

3. Please comment on the pupils' response to the exercises. Was it positive? Did they appear to enjoy the activities? Were they keen to learn about critical thinking?

   Response: - good; pupils enjoyed the activities and discussions. They seemed to be keen to learn the ideas of critical thinking and apply them to other situations (eg. adverts).

4. Please add any other comments you would like to make relating to the pupils' exercises and involvement.

   The hand-out of points at the end of each lesson, should have the page number at the bottom of each - so that all pupils get the number. (Where two hand-outs were printed on one page, only the bottom one would have a page number.)

APPENDIX G

PRE-TEST: ANALYSIS OF THE MARKING TO SHOW WHICH THINKING SKILLS WERE USED IN ANSWERING EACH QUESTION

Control Group

Critical thinking skills / Student Number	Qu. A1				Qu A2			Qu. A3			Qu. A4			Qu B1a			Qu B1b			Qu B1c			Qu B2a			Qu B2b			Qu B2c			Qu B3a				Qu B3b				Qu B3c			Qu B4a			Qu B4b			Qu B4c		
	Gather complete information.	Other variables not controlled.	Poor sample size.	Can't generalise	Gather complete information.	Other conclusions are possible.	Correlation not equal to causation.	Other conclusions are possible.	Look for hidden assumptions and biases.		Understand and define terms.	Poor sample size.	Other conclusions are possible.	Gather complete information.	Other variables not controlled.	Can't generalise	Gather complete information.	Can't generalise		Gather complete information.	Can't generalise		Gather complete information.	Can't draw conclusion from the info.	Can't generalise	Can't draw conclusion from the info.	Can't generalise		Can't draw conclusion from the info.	Can't generalise		Gather complete information.	No control.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.	Gather complete information.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.				Gather complete information.	Look for hidden assumptions and biases.		Gather complete information.	Look for hidden assumptions and biases.		Gather complete information.	Look for hidden assumptions and biases.	
7210056	1	1				1									1		1	1								1																							
7210074	1	1	1		1	1					1				1		1	1		1					1	1				1																		
7210083											1															1							1															
7210092	1	1									1															1																							
7210127	1				1				1		1			1	1			1		1						1																							
7210145	1	1			1			1	1					1						1				1		1																							
7210172		1									1					1	1			1				1		1			1																				
7210190	1																				1		1	1		1			1																				
7210261			1								1							1							1	1			1			1																
7210305		1									1														1	1			1			1																
7210378	1	1																1							1	1			1																			
7210403																1													1																			
7210421	1	1									1				1			1		1					1				1			1																
7210449	1										1				1		1								1				1			1																
7210458				1	1						1			1											1				1																			
7210467		1				1								1						1					1				1																			
7210494		1				1								1	1		1			1					1				1			1																
7210546	1				1						1				1		1			1	1				1				1			1																
7210573	1	1												1			1								1				1			1																
7210582		1												1			1			1			1		1				1			1																
Total	11	12	2	1	5	4	0	1	2	0	11	0	0	7	7	2	4	10		8	3		1	0	8	0	18	0	0	12		6	0	2	1	0	8	0	0	0				3	5		4	0		5	0	

| SUMMARY | | | | | | | | | | | | | | | | | | |

rimental Group

ident number	Qu. A1				Qu A2			Qu. A3		Qu. A4			Qu B1a			Qu B1b		Qu B1c		Qu B2a			Qu B2b		Qu B2c		Qu B3a				Qu B3b		Qu B3c		Qu B4a		Qu B4b		Qu B4c		SUMMARY															
	Gather complete information.	Other variables not controlled.	Poor sample size.	Can't generalise	Gather complete information.	Other conclusions are possible.	Correlation not equal to causation.	Other conclusions are possible.	Look for hidden assumptions and biases.	Understand and define terms.	Poor sample size.	Other conclusions are possible.	Gather complete information.	Other variables not controlled.	Can't generalise	Gather complete information.	Can't generalise	Gather complete information.	Can't generalise	Gather complete information.	Can't draw conclusion from the info.	Can't generalise	Can't draw conclusion from the info.	Can't generalise	Can't draw conclusion from the info.	Can't generalise	Gather complete information.	No control.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.	Gather complete information.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.	Gather complete information.	Look for hidden assumptions and biases.	Gather complete information.	Look for hidden assumptions and biases.	Gather complete information.	Look for hidden assumptions and biases.	1. Gather complete information.	2. Understand and define terms.	3. Question the methods.	a. No control.	b. Other variables not controlled.	c. Poor sample size.	4. Question the conclusions drawn.	a. Can't draw conclusion from the info.	b. Can't generalise	c. Other conclusions are possible.	d. Correlation not equal to causation.	5. Look for hidden assumptions and biases.	Number critical thinking skills used	Possible number critical thinking skills	Number categories CTS used	Number categories possible
70109	1				1					1			1				1																		1						4	1			2										
70118		1				1							1												1				1												2			2			2	1		1	8	41	5	10
70154		1																			1					1																	1		1	1			4	41	4	10
70181									1								1					1			1		1				1			1		1				3			1			4			1	9	41	4	10
70207	1									1			1	1			1		1			1			1			1			1							1		4	1		3			4				12	41	4	10
70225	1	1								1				1			1		1			1			1			1					1							2			2			4			1	9	41	4	10
70243	1	1						1					1												1	1		1		1			1		1					4			2			1	1		1	9	41	5	10
70252	1	1				1			1	1								1		1	1	1						1			1			1						3	1		3			2	1		2	12	41	6	10
70289						1		1					1	1			1		1			1			1									1							3			1		1	4	2			11	41	5	10
70298		1								1			1				1		1	1		1			1			1					1		1	1				3	1		2			5	1		2	14	41	5	10
70323	1		1			1							1	1			1		1			1					1				1									4			1	1		4	1			11	41	5	10
70350	1				1					1			1												1			1									1			4	1		1							6	41	3	10
70387	1	1			1	1				1			1			1	1	1					1			1							1							5	1		1			3	2			12	41	5	10
70412	1	1											1	1		1	1						1			1								1	1	1	1			5			2			4			2	13	41	4	10
70430		1																					1				1				1									2			1			1				4	41	3	10
70537	1	1				1														1			1			1			1					1						2			3			2	1		1	9	41	5	10
70555					1					1			1				1					1				1								1						4	1					3				8	41	3	10
70591					1	1																	1		1			1												1			1			2	2			6	41	4	10
70608	1	1																																						1			1							2	41	2	10
didate																																																							
70065	1	1			1				1				1				1						1		1						1										3			2			1	3			1	10	41	5	10
70047	1	1			1	1				1			1					1						1			1				1				1		1			6	1		1	1			2	2			13	41	6	10
70038					1					1			1				1		1												1					1					5	1						1	1			8	41	4	10
70029	1	1			1	1				1			1					1				1		1	1			1	1		1				1		1			5	1		2			3	3		1	15	41	6	10
70010	1																					1		1	1			1	1						1					2						3	2			7	41	3	10
70136	1	1								1	1						1					1	1				1													2	1		1	1		1	3				9	41	6	10
70163	1																					1		1				1	1											1			1				3				5	41	3	10
70216	1	1			1	1							1	1			1		1			1		1					1		1									5			2			1	3	2		1	14	41	6	10
70234										1			1				1																							1	1						1				3	41	3	10
70270	1	1				1				1			1			1	1	1						1				1												4	1		1	1			2	2		1	12	41	7	10
70314	1					1									1								1																	1							2	1			4	41	3	10
210332	1	1				1			1				1				1				1		1			1				1	1				1					3			2			3	2		2	12	41	5	10
210341	1	1				1								1		1	1		1	1			1			1		1									1				4		1	2		1	1	4		1	14	41	7	10
10369														1			1						1																	1						2	1			4	41	3	10
210396		1				1				1							1		1				1				1													1	1		1	1		1	1	3			8	41	6	10
210485	1	1				1				1		1					1		1				1					1												2	1		2			2	2		1	10	41	6	10
210500	1	1	1										1				1						1																	2			1	1		2				6	41	4	10
210528	1	1											1					1													1	1								3			2			1	1			7	41	4	10
210617	1								1	1			1	1		1		1													1	1			1		1			5	1		2			1			1	2	12	41	6	10
tal	26	23	2	0	10	16	0	2	5	17	1	1	23	8	1	5	18	12	5	4	1	18	2	33	1	21	8	4	9	4	0	5	9	14	1	7	14	10	2	2	0	112	16	4	49	3	7	87	39	1	21	339	1558	172	380
																																									Possible Total →	418	38	38	152	76	114	266	190	114	152				

APPENDIX H

POST-TEST: ANALYSIS OF THE MARKING TO SHOW WHICH THINKING SKILLS WERE USED IN ANSWERING EACH QUESTION

APPENDIX H. Post-test : Analysis of the marking to show which thinking skill were used in answering each question

Control Group

Critical thinking skills / Student Number	Qu. A1		Qu A2		Qu. A3				Q. A4			Q B1a				Q B1b				Q B1c			Q B2a		Q B2b		Q B2c		Q B3a			Q B3b			Q B3c		Q B4a		Q B4b		Q B4c		SUMMARY															
	Other conclusions are possible.	Look for hidden assumptions and biases.	Gather complete information.	Other variables not controlled.	Gather complete information.	Understand and define terms.	Poor sample size.	Other conclusions are possible.	Gather complete information.	Other conclusions are possible.	Correlation not equal to causation.	Gather complete information.	No control.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.	Gather complete information.	Other variables not controlled.	Other conclusions are possible.	Correlation not equal to causation.				Gather complete information.	Can't generalise	Gather complete information.	Can't generalise	Gather complete information.	Can't generalise	Gather complete information.	Can't generalise	Look for hidden assumptions and biases.	Gather complete information.	Can't generalise	Look for hidden assumptions and biases.	Gather complete information.	Can't draw conclusion from the info.		Can't generalise		Can't draw conclusion from the info.		1. Gather complete information.	2. Understand and define terms.	3. Question the methods.	a. No control.	b. Other variables not controlled.	c. Poor sample size.	4. Question the conclusions drawn.	a. Can't draw conclusion from the info.	b. Can't generalise	c. Other conclusions are possible.	d. Correlation not equal to causation.	5. Look for hidden assumptions and biases.	Number critical thinking skills used	Possible number critical thinking skills	Number categories CTS used	Number categories possible
7210056		1		1							1					1							1												1				1						1				2	1		2	1	8	36	6	10
7210074	1		1	1											1		1						1	1	1	1		1																3				2				3	2			10	36	4	10
7210083	1	1																											1																							1		2	3	36	2	10
7210092			1	1						1				1									1		1													1		1				2				2			1	1	2			8	36	5	10
7210127							1		1			1				1							1	1	1	1	1				1							1		1				6			1		1	3			1	12	36	5	10
7210145		1		1					1		1			1					1				1			1	1				1		1					1						3				2				3	2	2	12	36	5	10
7210172		1	1	1							1	1				1			1									1			1							1						3				1			1	1	2	2	10	36	6	10
7210190				1	1						1				1		1		1				1			1		1										1		1				2				2			1	3	1	2		11	36	6	10
7210261	1					1	1		1		1			1				1					1	1		1		1										1		1				3	1			1	1		1	3	2	1		13	36	8	10
7210305				1		1																	1															1		1				1	1			1			1	1				5	36	5	10
7210378		1		1		1																	1	1		1					1		1				1		1				1	1			1			1	4			2	10	36	6	10
7210403	1														1									1		1										1										1			1	2	1			5	36	4	10
7210421		1	1	1	1	1				1	1	1											1	1	1			1			1				1			1		1				5	1			1			2	3	1	1	2	16	36	8	10
7210449		1				1																	1								1													1	1									2	4	36	3	10
7210458						1					1													1												1											1				1	1		1		4	36	4	10
7210467				1											1								1		1																				2				2							4	36	2	10
7210494	1			1							1	1		1			1		1				1				1				1							1						2				3				3	1	2	1	12	36	6	10
7210546				1		1					1						1						1				1					1						1		1				2	1			2			1	2			1	9	36	6	10
7210573		1	1	1						1				1						1			1		1		1				1		1				1		1				3				2	3		1	1	2	14	36	7	10
7210582	1	1			1				1			1			1				1				1		1		1				1		1				1		1				4					1	1	5		2	13	36	5	10
Total	6	9	5	13	3	7	2	0	3	4	9	5	0	5	3	1	2	6	2	5				15	8	5	10	6	5	0	0	10	0	4	0	0	6			13		10				44	7	0	26	2		17	38	17	15	19	183	720	103	200
																																											Possible Total →				220	20		20	60	20		40	120	100	60	60				

X H. Post-test : Analysis of the marking to show which thinking skill were used in answering each question

ıtal Group

| Qu. A1 | | | Qu A2 | | Qu. A3 | | | | Qu. A4 | | | Q B1a | | | | | Q B1b | | | | | Q B1c | | | | Q B2a | | Q B2b | | Q B2c | | Q B3a | | | Q B3b | | | Q B3c | | Q B4a | | Q B4b | | Q B4c | | SUMMARY | | | | | | | | | | | | | | | | | |
|---|---|---

APPENDIX I

ANALYSIS OF THE MARKING OF THE TRANSFERABILITY TEST TO GEOGRAPHY TO SHOW THE THINKING SKILLS USED BY THE PUPILS

CONTROL GROUP

Critical thinking skills / Student Number	Qu. 1a				Qu.1b					Qu.1c						Qu.2a						Qu.2b						Qu.2c						Qu.2d					
	Y	N	1. Gather complete information.	a. Can't draw conclusion from the info.	Y	N	1. Gather complete information.	a. Can't draw conclusion from the info.	d. Correlation not equal to causation.	Y	N	1. Gather complete information.	a. No control.	b. Can't generalise	b. Other variables not controlled.	Y	N	1. Gather complete information.	b. Can't generalise	5. Look for hidden assumptions and biases		Y	N	1. Gather complete information.	5. Look for hidden assumptions and biases		Y	N	1. Gather complete information.	a. Can't draw conclusion from the info.	5. Look for hidden assumptions and biases		Y	N	1. Gather complete information.	b. Can't generalise	5. Look for hidden assumptions and biases	
7210056	x				x					x						x						x						x						x					
7210074		1		1	1						0						0						1	1				1						0					
7210083	1				1					1						1						1							0					1					
7210092	1					0				x						x						x						x						x					
7210127		0				0				x						x						x						x						x					
7210145	1				1					x						x						x						x						x					
7210172	1				1					1							0						0						x						x					
7210190	x					0					1	1				x						x						x						x					
7210251		1	1			0					1	1				1							0																	
7210305		0				0					1			1		x						x						x						x					
7210378	1					0					0					1						1							1			1			1			1	
7210403	1				x						0					1						1						1							1	1			
7210421		1		1		0				1							1	1					1	1					1		1			1			1	
7210449	1					1		1		x						1							1	1					1		1			0				
7210458		0				0					0					1						x							1		1			0				
7210467	1					1		1		1							0						1	1				1						1			1	
7210494	1					1		1			0						1	1					1	1					1		1			1			1	
7210546		1		1	1						1			1		1							1	1					1		1			1			1	
7210573		0				0					1	1					1		1				1	1					1		1			1				
7210582	x				x					x						x						x						x											
Total		4	1	3		3		3	0		5	3	0	2	0		3	2	1	0		7	7	0			7	2	2	3		7	2	4	1					
Possible Total →																																							

SUMMARY												
	1. Gather complete information.	2. Understand and define terms.	3. Question the methods.	a. No control.	b. Other variables not controlled.	c. Poor sample size.	4. Question the conclusions drawn.	a. Can't draw conclusion from the info.	b. Can't generalise	c. Other conclusions are possible.	d. Correlation not equal to causation.	5. Look for hidden assumptions and biases.	Number critical thinking skills used	Possible number critical thinking skills	Number categories CTS used	Number categories possible
7210056													0	20	0	7
7210074	1							1					2	20	2	7
7210083													0	20	0	7
7210092													0	20	0	7
7210127													0	20	0	7
7210145													0	20	0	7
7210172													0	20	0	7
7210190	1												1	20	1	7
7210251	2												2	20	1	7
7210305									1				1	20	1	7
7210378									1			1	2	20	2	7
7210403	1												1	20	1	7
7210421	2							1	1			1	5	20	4	7
7210449	1							2					3	20	2	7
7210458								1					1	20	1	7
7210467	1							1				1	3	20	3	7
7210494	3							1	1				5	20	3	7
7210546	1							1	2			1	5	20	4	7
7210573	3			1					1				5	20	3	7
7210582													0	20	0	7
Total	16			1	0			8	7		0	4	36	400	28	140
Possible Total →	140			20	20			60	60		20	80				

EXPERIMENTAL GROUP

Student Number	Qu. 1a Y	Qu. 1a N	Qu.1b 1. Gather complete information.	Qu.1b a. Can't draw conclusion from the info.	Qu.1b Y	Qu.1b N	Qu.1c 1. Gather complete information.	Qu.1c a. Can't draw conclusion from the info.	Qu.1c d. Correlation not equal to causation.	Qu.1c Y	Qu.1c N	Qu.2a 1. Gather complete information.	Qu.2a a. No control.	Qu.2a b. Can't generalise	Qu.2a b. Other variables not controlled.	Qu.2a Y	Qu.2a N	Qu.2b 1. Gather complete information.	Qu.2b b. Can't generalise	Qu.2b 5. Look for hidden assumptions and biases.	Qu.2b Y	Qu.2b N	Qu.2c 1. Gather complete information.	Qu.2c 5. Look for hidden assumptions and biases.	Qu.2c Y	Qu.2c N	Qu.2d 1. Gather complete information.	Qu.2d a. Can't draw conclusion from the info.	Qu.2d b. Can't generalise	Qu.2d 5. Look for hidden assumptions and biases.	SUMMARY 1. Gather complete information.(7)	2. Understand and define terms.	3. Question the methods.	a. No control.(1)	b. Other variables not controlled. (1)	c. Poor sample size.	4. Question the conclusions drawn.	a. Can't draw conclusion from the info.(3)	b. Can't generalise (3)	c. Other conclusions are possible.	d. Correlation not equal to causation.(1)	5. Look for hidden assumptions and biases.(4)	Number critical thinking skills used	Possible number critical thinking skills	Number categories CTS used	Number categories possible
7210109	1					1		1			0				1					1				x																						
7210118	1					0					0					1	1				0			x								1															
7210154		1		1		0					1	1			1						1	1			1			1			2															
7210181		1		1		0					0				1						0				0			1	1		1														
7210207		1		1		1	1				1			1			1	1			1	1			1	1			1	1		5													
7210225		1		1		1		1			1	1			1						1	1		1				1			2														
7210243		0				0					1	1		1			0				1	1			1		1			1		2													
7210252		0				1		1			1	1		1			1	1			1	1			1		1			1		2													
7210289		0				0									1						1	1			1		1			1														
7210298		1	1			1	1								1						1	1			1		1			1		2													
7210323		0				0					1	1					1	1			1	1			0																			
7210350		0				1	1			x					x					x				x																				
7210387		1	1	1		0					1			1			1		1		1	1			1	1					3														
7210412		0				0					1			1			1	1			1	1			1	1					3														
7210430		0				0					1	1					0				1	1			0			1			2														
7210537		1	1			1	1				1			1			1	1			1	1			1		1				5														
7210555		1	1	1		1	1				1	1		1			1	1				1			1	1					6														
7210591		1		1		0					0				1			1			1	1			1		1				1														
7210608		1		1	1						1			1				1			1	1		1			1				1														
7210065		0				0				1							1	1			1	1			0			x			1														
7210047		0				1	1				1			1			1	1		1	1	1			1	1					3														
7210038		1		1		1	1				1	1			1			1	1			1	1			1	1					4														
7210029		1		1		1		1			1	1					1	1			1	1			1						3														
7210010		1		1		1		1			1			1			1	1			1	1			1	1					4														
7210136		1		1		1		1			0			1			1	1			1	1			1	1					3														
7210163		1		1		0				1				1			1	1			1			1	1			1			1														
7210216	1					0					1			1			0				1	1			0			1			1		2												
7210234		0			x						1	1					0							x				x																	
7210270		0				1		1			0						1	1			1	1			1	1					3														
7210314	x				x					x					x						x				x																				
7210332		0				0					1	1		1			1	1			1	1			1	1					3														
7210341	1					0					0						1		1		1	1			0						1														
7210369		1	1	1		1		1	1	1							1		1		1	1		1			1				2														
7210396		0				1		1			0						1	1			1	1			0						2														
7210485		0				0				1					x					x				x			x																	
7210500	x				x					x							1	1			1			1	1			1			1														
7210528		0				1	1										1	1			1	1			1		1				1														
7210564	1					0				1					1			1	1		1	1			1		1				2														
7210617	x				x					x					x					x				x																				
		16	5	14		17	8	9	1		19	11	0	11	0		19	15	3	1		29	29	0		25	11	6	9		26	6	12	8	84						28	28	1	18	159	760	91	266
																																		266		38	38			114	114	38	152				

Possible Total →

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Author Orsmond C G
Name of thesis The Development And Evaluation Of A Package For Teaching Critical Thinking Skills In Biology Orsmond C G 1998

PUBLISHER:
University of the Witwatersrand, Johannesburg
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