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A Study of Scientific Thinking with Young Adolescents

by
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A thesis submitted for the degree of Doctor of Philosophy (Ph.D)
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To the Memories of my grandfather and grandmother

Mokgosi and Maradela Serumola

They loved me and protected me throughout my childhood as their own child. May their souls rest in peace. Their parental love and care have made me what I am now.

Abstract

This project looks at the ability of young adolescents at lower secondary level to recognise experiments as ways of asking questions in scientific investigations. Many science curricula emphasise the need for pupils to develop skills necessary for experimenting, like planning and designing experiments for investigations, deciding on which variables to manipulate during the experiment, recognising a critical piece of information which could be used to plan and design a critical experiment. A number of questions based on the available literature and theoretical evidence were raised. These questions formed the basis for the study:

(1) Do pupils at lower secondary level appreciate the inclusion of experiments in science learning?

(2) Can these pupils identify a critical piece of information necessary for providing a credible solution to a problem?

(3) Do lower secondary level pupils have the ability to conceptualise or see experiments as ways of asking critical questions in scientific investigations?

(4) Can the development of the experimenting skill in those pupils at lower secondary level who have not yet developed it be accelerated through appropriate teaching?

(5) Can lower secondary pupils from completely different teaching and cultural backgrounds demonstrate similar performances in terms of seeing the experiment as a way of asking critical questions in scientific investigations?

To answer these questions a three stage investigation was used. Each stage was called an experiment. For the entire investigation, a total of 1964 pupils were used from Botswana [junior (lower) secondary schools] and Scotland [lower secondary schools]. A card game called Eloosis, questionnaires/tests, teaching units and interviews were employed at different stages of the investigations. The teaching units and Eloosis were used to help pupils accelerate the development of the ability to recognise critical pieces of information for critical experiments in scientific investigations where possible. The questionnaires/tests were designed to examine evidence of the development of this ability skills. Interviews were meant to solicit more information from pupils regarding the ability of the pupils to conceptualise the place and nature of experimentation in scientific enquiry. However, Scotland pupils and one sample of the Botswana pupils did not participate in the use of teaching units. The data collect from the Scotland pupils was primarily used to establish the wider acceptance of the results obtained from the

Botswana group.

From the results obtained from this study, it was clear that pupils from different educational and cultural settings equally appreciated the inclusion of experimental work in their science activities. However, their perceptions of its place and purpose differed from those of the curriculum planners. The evidence from the data analysis suggested that the ability to see experiments as ways of asking questions in scientific investigations is significantly developmental and cannot be homogeneously accelerated. The result appears to be true for all pupils at this age range regardless of their educational and cultural background. There was also a general lack of the ability to identify a critical piece of information which, in the opinion of this project is related to the ability to recognise critical experiments for working out solutions to scientific problems. However, it was not possible to gain much insight into the extent to which the teaching units and Eloosis, when used over a longer period of time, could impact on the development of the experimental skills. The reason for this lies within the restrictions on time and the willingness of the schools to allow such a prolonged access to their pupils.

It also emerged from the interview results that most pupils, in their responses, confused experimenting with practical work. This finding explains why a significantly higher number of the pupils indicated that what they liked most about their science lessons were experiments.

Acknowledgements

This project could not have been completed without the help and encouragement of many people. This is my opportunity to thank them.

First I would like to thank my supervisor Dr. Norman Reid who has kept me going even when I thought I could no longer do so. His valuable guidance and constant support have kept this project on the correct path.

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Finally I would like to thank my sons Katlego and Pako for having endured my absence during their time of growing into young men. Above all, my sincere gratitude goes to my dear wife, Oarabile (Moanza), for believing in me and providing the spiritual encouragement during the years of my study and for her patience throughout all those years of being separated from me.

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CHAPTER ONE

BACKGROUND INFORMATION TO THE PROJECT

1.1 Development of Education in Botswana

It could be said that 1977 marked a change in the education policies of Botswana. At independence in 1966, Botswana inherited the kind of education system that has been described by some educators as having neglected the development of human resources (Kann, 1992). The evidence to this observation was the critical shortage of skilled manpower (Botswana Government, 1977a).

The need to develop a kind of education that addressed adequately the social, economic, and technological requirements of the country was commissioned by the then president of Botswana, Sir Seretse Khama in 1976, and was reported under the title of 'Education for Kagisano' in 1977. Recommendations from this report aimed at amalgamating the operations of the education authorities and designing a curriculum that suited the manpower development for the country to meet the economic, social and technological demands of the century. This report was followed by the Government White Paper : National Policy on Education whose main part of the policy aimed at providing universal access to nine years education to all Botswana children (Botswana Government, 1977b).

Before 1977, about 35% of primary school leavers proceeded to junior secondary education level (Botswana Government, 1994). This intake of primary school leavers into junior secondary schools was reported to have risen to 95% in 1994. According to the Botswana Development Plan No. 8 (Ministry of Finance and Development Planning, 1997), it is projected that this figure will still be unchanged by the year 2004.

The implementation of the decision to increase the number of junior secondary school intake from 35% to 95% has had a number of consequences which included:

- The need to construct additional junior secondary schools.
- The retraining of unqualified and training new teachers.
- The development of new management strategies.
- Redefining of the purpose of education provided at that level.

Other problems included a pupil population composing of a wider range of abilities and an unstable curriculum. In science education, the major problems that emerged out of this expansion were shortage of trained local science teachers and inadequate facilities like laboratory space and equipment.

To alleviate some of the problems brought about by the expansion, new junior secondary schools were built, two new colleges of secondary education were constructed and the University of Botswana increased its intake of students in the Mathematics and Science Department. In addition, non-science teachers were offered training in science teaching as part of the Zim-Sci project (Prophet, 1988).

1.2 Botswana Education System

The structure of the education system in Botswana has changed since independence in 1966 from 7+3+2 to 7+2+3 in 1988 and most recently back to 7+3+2 in 1996. The first seven years are at primary level, the next two or three years are at junior secondary level and the last two or three years are at senior secondary level. The levels of education after senior secondary are part of the training system at tertiary level. The tertiary education system consists of colleges of education (primary and secondary), administration college, a college of agriculture, technical colleges, and a university. Vocational institutions are meant to train junior secondary school leavers and some senior secondary school leavers in occupational skills necessary for employment.

The current education system, implemented in 1996, is a product of the Government Policy Paper No. 2 of 1994 entitled 'The Revised National Policy on Education' which is based on the recommendations from the report of National Commission on Education, 1993. The report still emphasised universal access to education for all Botswana children. However, the duration of this basic education is now ten years. The reasons for these changes are both political and economical in nature and will be elaborated on later. Figure 1.1 presents the education system currently in place.

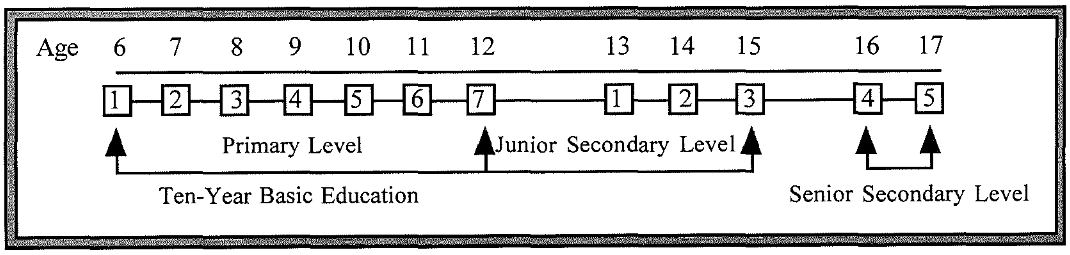


Figure 1.1 The Current Botswana Education System

As part of an on-going process to implement the revised national policy on education, the National Development Plan 8 proposed a future structure of the Botswana Education system which aims at incorporating pre-primary level, vocational training, literacy programmes, adult basic education, distance education and part-time study and tertiary institutions (see figure 1.2).

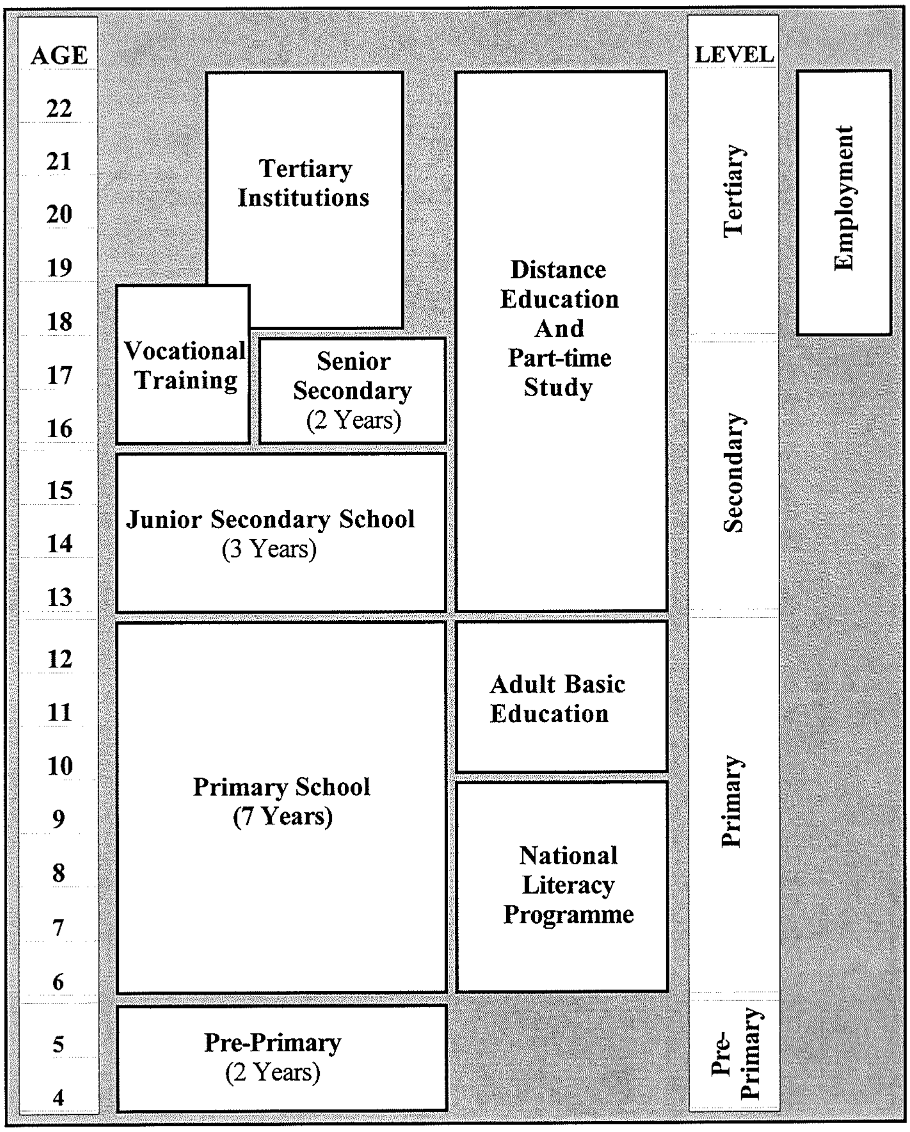


Figure 1.2 Future Structure of the Education and Training System of Botswana

Source: (Botswana Government, National Development Plan No. 8, 1997/98 - 2002/03)

Even though the proposed structure is part of the Revised National Policy on Education of 1994, some aspects of it are still at the planning stages and not yet fully implemented. Pre-primary and some tertiary institutions are still privately managed. For example, their curricula are planned separately and in some cases do not conform to the government system of education. The school starting age is still flexible such that some pupils are older than the age range prescribe for each level.

1.3 Science Teaching in Botswana Junior Secondary Schools

The Place of Science in the Junior Secondary School Curriculum

All junior secondary schools in Botswana, both private and government owned, have been merged into one system called Community Junior Secondary Schools (CJSS), except for those private schools which fall under the English medium category. This situation came into effect in the 1980s as part of the implementation of the 1977 National Policy on Education. A common curriculum is used by all CJSS consisting of six core subject compulsory to all pupils (table 1.1). The number of optional subjects offered by each school depends on the availability of teachers specialising in those areas.

Botswana CJSS Academic and Non-academic Curriculum		
Core Subjects	**Options**	**Non-academic Activities**
English	Design and Technology	Physical Education
Setswana	Art	Sports (various)
Mathematics	Religious Education	Debating Club
Integrated Science	Home Economics	Drama Club
Social Studies		Environmental Club
Agriculture		Others

Table 1.1 The Botswana CJSS Curriculum

Non-academic activities are offered at the schools as out-of school activities and are not graded or assessed. Again the availability of specialised teachers in those activities usually determines their offer by the schools.

On completion of the junior secondary education, admission to the senior secondary schools depend on the pupil's performance grade on the end-of-year three examination written by all pupils in the country and the pupil's performance on project work from practical subjects. Plans are on-going to include the pupils' continuous assessment grade, recorded over the three year period, as part of the final grade for junior secondary education.

Historical Developments in Science Teaching in Botswana

Historically, the integrated science course in Botswana was introduced in 1974 (Makgothi and Lelliott, 1992). Before then, according to Makgothi and Elliott, the science course in place was known as Introductory Science Course divided into the separate science disciplines of biology, chemistry and physics. This course posed a lot of problems to the teachers who found it difficult to teach with inadequate equipment and no textbooks. However, the Integrated Science Course launched in 1974 was a modified version of the Scottish Integrated Science Course. The course comprised fifteen units grouped under three basic science principles: *conservation of energy*, *particulate nature of matter* and *the cell as a basic unit of matter*. Pupils who underwent this course were basically being prepared to proceed into senior secondary level science or the Cambridge Overseas School Certificate Science.

Following the National Policy on Education in 1977, changes were made to the junior secondary school science syllabus. This changes were undertaken to address the impending situations of many junior secondary school leavers requiring skills necessary for dealing with everyday life after only two years of secondary science education and pupils with a wide range of ability. There was, therefore, more emphasis on practical work and the injection of social relevance to the science taught at that level. Worksheets were introduced with activities requiring pupils to follow prescribed instructions and efforts were made to frame the problems in the activities to suit the contextual knowledge of the pupils.

Over the years, it has been realised that pupils were following the instructions without developing an understanding of the processes involved in carrying out scientific investigations. In addition, new developments in science teaching and learning in Europe and some parts of the world influenced these reforms. In a sense, the two years of secondary science teaching were considered inadequate given the wide range of ability of pupils (Botswana Government, 1994). Employers complained of the usability of potential employees with a two-year junior secondary certificate, while parents became increasingly worried about their children leaving school below the employment age. Therefore, the Revised National Policy on Education of 1994 made recommendations to the effect that school system be reverted to the former 7+3+2 system. This meant three years of junior secondary education and a change in the curriculum.

The Integrated Science Course Syllabus Used in Botswana CJSS

At CJSS integrated science is taught by one teacher who assumes knowledge of all the three science disciplines. A new integrated science syllabus was introduced in schools in 1996 as demanded by the new system of 7+3+2. The syllabus is organised into ten broad themes called modules. Coverage of the topics during the three years is spiral to allow for the gradual development of concepts. The rationale behind the Botswana's three-year junior secondary science syllabus embodies among others the notions that

> *"Science by its nature involves experimental activities characterised by enquiry methods of learning. Through learning science, children can understand the rapidly changing environment around them. Children learn about objects and events by asking questions, investigating and experimenting to find appropriate answers"* (Botswana Government, 1996).

Based on this rationale, seven main aims of the three-year junior secondary science programme were generated. These state that at the end of the three years of junior secondary science programme, pupils are expected to have developed:

(1) an understanding of basic principles and concepts of science as they are experience in everyday life.
(2) Positive attitudes towards scientific skills such as curiosity, open-mindedness, creativity, objectivity, integrity and initiative.
(3) an ability to use process skills associated with practice of science for understanding and exploring natural phenomena, problem solving and decision making.
(4) an awareness and appreciation of the interrelationship among science, technology and society in the context of science and everyday life.
(5) an awareness, literacy and an understanding of the significance of computers in the science related careers.
(6) the ability and responsibility to protect the environment and use natural resources on a sustainable basis.
(7) the ability to make informed decisions about further studies and science-based careers and vocations.

It is clear that these aims reflect the expectations of the policy makers and curriculum developers who presumably are under pressure to conform to the worldwide demands on school science teaching. The focus of this project, however, is on the emphasis by the syllabus that pupils should have developed abilities on the use of process skills such as experimenting as reliable aspect of scientific enquiry for providing appropriate answers.

The questions being asked here are: Are pupils at this age range (13-15 years) cognitively ready to learn and use such highly abstract conceptual skills? If the pupils are cognitively ready, what appropriate methods are available for teaching and learning of such skills? If the pupils are not cognitively ready, can their ability to develop such skills be accelerated through some intervention materials?

MODULE 1: THE SCIENTIFIC METHOD AND PRECAUTIONS		
Unit 1.1 - How Scientists Work (10 periods)		
Topics	General Objectives Pupils should be able to:	Specific Objectives Pupils should be able to:
Doing science	1.1.1 acquire basic process skills to carry out investigations using scientific method and develop an interest in science.	1.1.1.1 explain what science is. 1.1.1.2 discuss how science affects our everyday life 1.1.1.3 observe people with science-related careers in their working environments (use of video cassettes and guidance materials recommended) 1.1.1.4 demonstrate the following process skills suitable for simple investigations: observing, comparing, classifying, measuring, interpreting, analysing, inferring, predicting, formulating hypothesis, controlling variables, experimenting (designing and carrying out procedures), problem solving and communicating in daily life situations. 1.1.1.5 infer correctly relations of variables from experimental results presented in tables, graphs, observations. 1.1.1.6 make reasonable conclusions on the basis of available experimental results.

Table 1.2 Topic One of Unit 1.1 of Module 1 from the Junior Secondary Science Syllabus

Module one of the syllabus content entitled 'The Scientific Method and Precautions" is dedicated to the development of process skills of which experimenting is a part (see table 1.2). This module is usually done at the very beginning of junior secondary science teaching with year one pupils. Afterwards, the rest of the modules stress the need to learn science content with very minimal efforts to infuse these skills. There are efforts to include specific objectives which require teachers to engage pupils in scientific investigations and experimenting. However, the pressure to cover enough content material that prepares pupils for the terminal examinations at the end of the three years somehow reduces most of the teaching and learning of science to lecture and memorising of concepts. In general, the new three-year junior secondary science syllabus has a solid and traditional layout which prescribes tasks for teachers and pupils and does very little to inculcate the skills necessary for experimenting.

1.4 Practical Work Activities

In the new three-year junior secondary science syllabus, the use of worksheets has been cancelled. Teachers are encouraged to use a variety of methods which they consider appropriate for the calibre of the pupils they are teaching. These methods include lecture and practical activities such as excursions, project work, laboratory work, investigating everyday events and group discussions. The teachers are not allowed to use a set of prescribed practical activities for their lessons. They have to plan and design all practical activities themselves which meet the wide cognitive ability of their pupils.

In every junior secondary school in Botswana, there are rooms reserved for laboratory work. However, in some schools these rooms are also used as normal teaching rooms and most of the facilities installed are vandalised. Each laboratory room has an adjacent storeroom equipped with basic scientific equipment. The idea of placing the responsibility of planning and designing practical activities solely on teachers is seen by some educators as encouraging teachers, particularly inexperienced teachers, to rely on textbooks for most if not all of their teaching needs. The textbooks used in this course are locally written and contains sample activities to help teachers in their lesson plans.

Recently, the mixed ability concept was introduced as an approach to be undertaken by all teachers. This approach is still in its infant stages of infusion into the school systems. The problems of 'how to and what to' are addressed by organising inservice training sessions throughout the country on mixed ability teaching lead by experts from Scotland and some college lecturers trained in that area. In addition, teacher training colleges have been asked to integrate and infuse mixed ability concept in their methodology courses. The researcher has been involved in this process since the first day of its inception.

Science teachers, in particular, have expressed disappointment in their effort to implement some of the approaches they learned from pre-service and inservice training due to lack of time, the large class sizes and lack of resources to assist in their planning of the activities. On average a class comprises 35 pupils and each class is allotted 5 periods of science teaching. Each period lasts 35 minutes which means that the pupils are exposed to science teaching for 2 hours 55 minutes (10% of the total teaching time in a week) in a 45 period by 35 minutes per week timetable.

1.5 Science Teachers' Training and Development

Pre-service training

The training of science teachers for these schools is mainly done by two colleges of education. A few teachers are trained by the University of Botswana. The training is at the level of diploma in science education over a period of three years. In the colleges, student teachers are expected to study all three science subjects: biology, chemistry and physics, as their major subjects, with a minor in either mathematics or computer education.

All students are also required to study courses in methodology in science, education, information technology, and communication and study skills. The methods course involves approaches used in teaching science in a mixed ability context. The education course introduces students to theories of teaching and learning and education philosophy. The information technology course was designed to help students develop teaching aides using modern equipment like computer, videos, and other interactive software programmes. The communication and study skills course entails class presentation of learning material, the use of language and body gesture during teaching.

At the university, the diploma course, which is no longer offered, used to offer student teachers the chance to study all science disciplines, mathematics during the first year only, a methodology course, education courses and science education courses. However, due to shortage of local teachers at senior secondary schools, most of them were recruited to teach at that level. Plans are in hand to phase out the diploma courses for secondary school teachers in favour of bachelors degree courses. The upgrading of the teachers holding the diploma qualifications is on-going (Botswana Government, National Development Plan 8, 1997). According to the National Development Plan 8, the records of 1996 indicate that about 30% of all science teachers in junior secondary schools were expatriates. This figure has since decreased due to the increased intake of student teachers by the colleges.

In-service training

The Botswana education system has adopted the practice of continuous learning by teaching through inservice training courses and workshops. The ministry of education has divided the country into regions which have the responsibility to organise regional inservice training workshops. Each region has an education centre built to facilitate the running of these workshops by providing organisational assistance, facilities and material production.

There are also national inservice workshops which are usually attended by regional representatives who in turn disseminate the information gained from these workshops to their regional members. University, college and ministry personnel are usually involved either as facilitators or as participants in these workshops. There are rare cases where individual teachers selected from schools are sent for a short course either outside the country or in-country sponsored by government.

It is hoped that through these courses teachers will be assisted to enrich their approaches to teaching and learning and continuously improve on their delivery in the classroom. However, the realities of having to satisfy the demands of the curriculum under the conditions teachers in Botswana find themselves, eventually place the heavy load of achieving academic excellence.

1.6 Purposes of the Study

It is common to hear teachers say that their pupils do carry out experiments during science lessons. Likewise, many school science syllabuses specify the importance of pupil experimental work. However, although these are good intentions by school science teachers and curriculum designers, important questions remain:

- Do pupils at the end of their study programme demonstrate signs of having gained some useful skills necessary for experimentation?
- Given the highly abstract nature of process skills involved in experimenting, are the pupils at the level of junior secondary school able to conceptualise the role of experimentation and how to go about it?
- Historically, experimenting in the schools in a manner similar to how scientists do it has been criticised for limiting the amount of science content to be learned and narrowing the scope of learning science. How do schools then hope to achieve all these things within a specified time frame of learning science?
- Does learning school science necessarily have to prepare one to become a scientist?

These questions will be explored in the next chapters of this thesis. However, for the purpose of this study, the focus is on the second question. The aims of this research were developed around this question. Some educators argue that the teachers' expectations of what pupils should have learned at the end of the teacher planned instructions, in most cases, do not harmonise with the variety of pupils' perceptions that develop as a result of their interaction with the information presented (Johnstone, 1997; Hodson, 1990).

This study started by looking at critical thinking in young adolescents during problem solving. The thinking then was to explore the thinking strategies pupils use when confronted with a scientific problem. However, as ideas developed, it became clear that the necessary thing to do was to investigate the place and nature of these critical thinking skills in this age group. In particular, it was decided to focus on the development of such skills required for experimentation. Experimenting is emphasised by many syllabuses at lower secondary level.

The aim being explored by this study, therefore, is to determine the place and nature of experimentation in the minds of lower secondary school pupils (early adolescents). Although the notion of experimenting is emphasised by school science at this level, it is not clear how its development can be achieved. Some teachers are reported to have merely lectured to the pupils on what experimenting is, as carried out by scientists, and never bothered to devise the means to developing the skill associated with experimenting in pupils. Researchers assert that what are normally considered experimental activities in schools are mainly characterised by pupils following teacher planned instructions to come up with a set of results known to the teacher. The pupils rarely get involved in the planning and designing of the experimental procedures. These assertions are discussed in details in the chapter three.

The main aim of the study was divided into segments which defines the kind of results expected from the study and these are:

(1) To determine the nature of experimentation (i.e. the ability to identify critical piece of information needed for the design of a critical experiment) in the minds of young adolescents (13-15+ years) at junior secondary levels.

(2) To determine whether the use of an experiment as a source of evidence can be developed through the use of guided instructions (i.e. use of teaching units and a game called Eloosis)

(3) To establish the impact of maturity on the development of the

experimental approach and the ability to identify the critical piece of information for a critical experiment when given a problem based on the student's daily experience.

1.7 Possible Approaches

There are a number of approaches that can be used to collect data for the study. These include:

- Interviewing pupils in Botswana about their views concerning experimenting.
- Developing scientific activities which would require pupils to plan and design experiments.
- Develop tests to determine if the pupils could conceptualise the place and nature of experimentation in scientific enquiry.
- Construct questionnaires to obtain further information on experimenting at junior secondary level.
- Develop teaching units to find out if the skills necessary for experimenting could be taught.
- Use of research approved approaches to develop the skills of experimenting.
- Carry out a longitudinal study of pupils at lower secondary level from year 1 to year 3 using teaching approaches that are meant to develop experimental skills.

Out of all these possible approaches available to use in the study, the choice was limited to developing teaching units and tests, use of questionnaires, use of approved approaches and interviews (restricted to a few pupils). Due to the time frame for the project and the logistics of having to travel to Botswana and be allowed all these three years to disrupt normal teaching, it was not possible to opt for the longitudinal study.

It was also not possible to organise an interview session for all the pupils in the sample group since there would not be enough time to interpret and analyse all that massive data. Developing scientific activities requiring pupils to plan and design their experiments was coupled with the use of teaching units as intervention material. The rationale for using questionnaires and interview is discussed below.

1.8 Introduction to Research Plan

This research study is intended to investigate if pupils at lower secondary level are able to conceptualise the place and nature of experimentation in scientific enquiry. The following areas are considered in order to establish a case for the study:

- Chapter two reviews the learning and teaching of science in schools in order to provide a base for the historical development in science teaching and learning.

- Chapter three discusses practical work in school science by exploring old approaches and comparing them with the new approaches. The aim is to establish the need to revisit the development of experimental skills during school science practical activities.

- Chapter four reviews some of the learning theories and models in cognitive development in order to provide a theoretical foundation for the study.

- Chapter five continues to review theoretical learning models particularly those concerning cognitive acceleration and information processing. The reason for their inclusion is to provide a theoretical basis for possible explanation some of problems encountered in establishing pupils' concept of experimenting.

- Chapter six describes the procedures of experiment one and presents the results obtained from the experiment. This part describes the experiment which seeks to establish the base line for the study. The outcome of the data collected during this part of the study is used to determined the direction of the next part of the study.

- Chapter seven describes the procedures of experiment two and presents the results obtained from the experiment. The outcome of the analysis of the results from this experiment is also used to determine the need for a further investigation.

- Chapter eight describes the procedures for the third experiment meant to explore the effect of experiment two in a different setting. The aim was to establish the generalisability of the results obtained in experiment two.

- ◇ Finally, chapter nine presents a general summary of the outcomes of the study. In addition, conclusions based on evidence from the three experiments are drawn together with the limitations of the study and future work to be done.

CHAPTER TWO

LEARNING AND TEACHING IN SCIENCE

2.1 Introduction

> *"What kind of scientific knowledge, skills or understanding do they* (pupils) *think they need for dealing with everyday life ? What aspects of science do they find interesting and how much do they value the education they receive? And what do they think the content of the science curriculum should be?"* (Osborne and Collins 2000, p.23).

These questions are raised in their study conducted in England between January 1998 and December 1999. The concern is on the kind of input the views from recipients of science education (i.e. pupils and their parents) will have on the attempts to improve the quality of science education. The authors contend that this has been given little or no attention in the past.

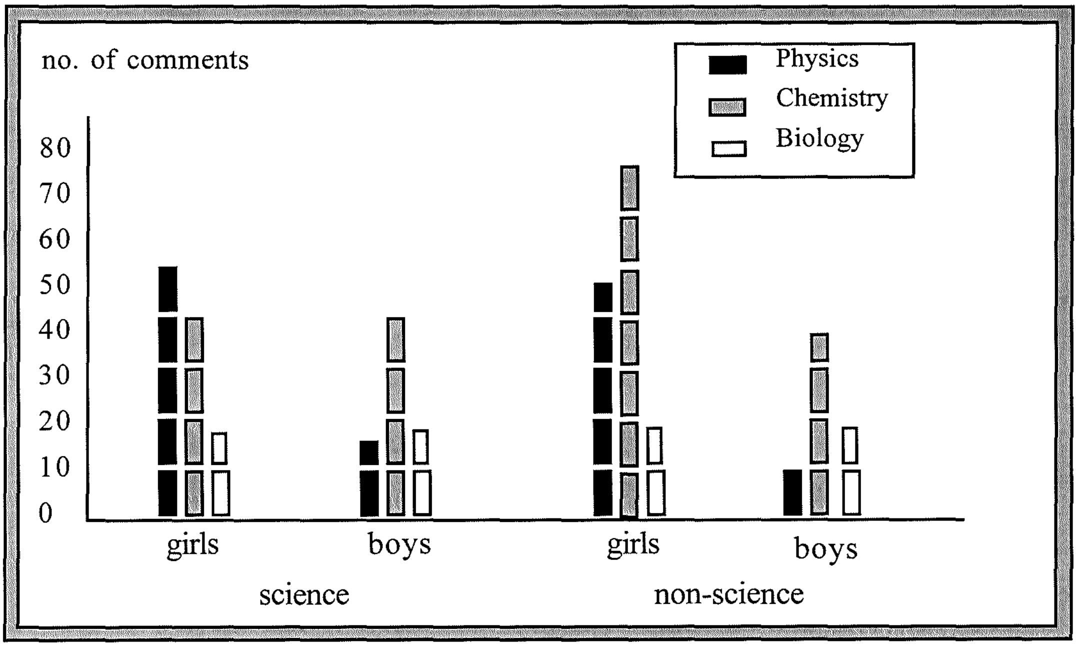


Figure 2.1 Chart Showing Number of Comments Coded 'uninteresting' for Each Science Subject.

Source: (Osborne and Collins, 2000)

The results of their study reveal chemistry as an aspect of science pupils find uninteresting contrary to the researchers' expectations. Both girls and boys in the science and non-science classes regard most of chemistry content material unrelated to their everyday life (See figure 2.1). When asked to say why they find most of chemistry uninteresting, the majority of students generally mentioned the lack of relevance and appeal to their everyday life. To explain the reason for the current students' view, Osborne and Collins, suggest that

> *"... the concentration in the past decade on aspects of chemistry such as atomic and molecular bonding, which are essential for explaining chemical combination, and the corresponding excision of 'hands on' practical activities, has placed an emphasis on a more theoretical element that appears to too many pupils to be abstruse and far removed from their daily concerns."* (p.25).

Gray (1999), also poses a similar question to those asked by Osborne and Collins, but much broader in intent and focusing on the other section of the world population, the developing world countries: "What kind of science curriculum is therefore appropriate for the developing world countries?". According to Gray, there has been a noticeable decline in the quality of science education in most developing world countries in the past few decades. He undoubtedly attributes this development to the fact that, historically, the structure and the nature of science curricula in the developing world countries has followed that of their colonial forebears despite the differences in the needs and perceptions of the recipients, and the technological needs and/or political aspirations.

The questions raised by Osborne and Collins, and Gray have always been used throughout the history of science education to address its relevance as a component of the broader school curricula. Answers to these questions, however, have varied with time, nature of the recipients and the levels of learning at which they were addressed. However, the issue of significance in these questions is the emphasis on the relevance of science education to the pupils' context. Perhaps, another issue concerns the time required to establish skills relevant for use in the scientific method without affecting the amount of science content to be covered under school curricula.

This chapter, therefore, discusses what science is, the way science is taught and learnt in schools, how science was introduced in school education and what are the approaches used to develop scientific thinking in young adolescents during early secondary levels.

2.2 What is Science?

The debates as to what really fits as a definition of science are on-going and, as such, no single statement has yet been accepted by all as an appropriate definition of science. Most people accept the notion that science is the 'systematic study of the natural environment'. The Oxford Popular Dictionary (1995) defines science as, "a branch of knowledge requiring systematic study and method, especially dealing with substances, life, and natural laws. The use of the word 'systematic' here is seen as implying a distinct pattern of study. Its significance will be discussed later.

An (unnamed) well known philosopher (cited in Lindsay, 1963) has defined science as, 'the search for the perfect means of attaining an end'. Lindsay considers the definition "very broad" and one that has been criticised by some authorities as including 'criminals in search of a perfect crime'. Needless to say, he claims this is not necessarily scientific!

Mason (1962) argues that science is a function of practical and theoretical elements and produces results which have both technical and philosophical aspirations. He then defines science as, "a human activity developing an historically cumulative body of interrelated techniques, empirical knowledge, and theories, referring to the natural world". Mason (1962) cites an American authority on the history of science, Sarton, who refers to science as 'the only human activity which is truly cumulative and progressive'.

However, Mason has singled out the practical techniques and their empirical facts and laws, as having been cumulative to the present time. He claims that, judging by the long time scale, most theories of science have either been modified or rejected on the basis of new evidence. Mason further points out that, given the continuing present high rate of scientific activity, it is almost impossible to suppose that any of the scientific theories of today will remain unmodified for long.

Lindsay (1963) uses Albert Einstein's statement that, "the whole of science is after all nothing but a refinement of 'everyday' thinking". However, Lindsay is of the view that not everyone involved in everyday thinking is a scientist. He also acknowledges the use of the word 'refinement' in Einstein's statement as a word that suggests steps that can be termed scientific. Lindsay takes the word 'refinement' to mean "*an added improvement*" to an existing idea. This could imply that new observable evidence has been obtained through experiments to render the existing idea or theory inadequate to use in explaining a phenomenon. However, it is equally true that new evidence can make an existing theory obsolete in favour of a new and different theory.

Lindsay, therefore, suggests that science can be best defined by considering 'what scientists do'. This argument is cyclic in its nature. His definition of science is of the form: "Science is a method for the description, creation and understanding of human experience". It is certainly accepted by all that learning science enables one to describe natural phenomena better and develop a better understanding of his/her experiences. He describes human experience as that which involves all the sense impressions of human beings together with their mental reflections on these sensations. He suggests that the method of the description of experience refers to the manner of bringing order in what first appears to be chaos. At any rate, it may sound naive to accept that learning science can create human experience. Individual experience is largely dependent on the immediate surrounding of which science constitutes a small fraction.

Lindsay further argues that science, as a method that is used to describe the human experience, involves firstly defining the problem. This is considered as the first step in grasping the significance of any phenomenon since it involves describing the problem clearly and accurately so that there may be a common comprehension of it among all interested persons. Secondly, it involves designing experiments, considered the most important element in science as a method. This stage Lindsay contends "promotes active acquisition of experience as opposed to passive observation".

Sizmur and Ashby (1997), on the other hand, describes the purpose of science as being, "to develop ways of conceptualising how the world 'works' that enable people to understand it better and (often) to control aspects of how it works". This description of the purpose of science implies a process, which has a starting point and end point. Sizmur and Ashby also point out three elements that they consider paramount to this process called science, namely, the world or reality consisting of objects and processes, the language which comprises theories and concepts, and actions that define scientific knowledge. These will be discussed further in later parts of the chapter.

The Scottish Consultative Council on the Curriculum (SCCC) Science Review Group (1994 - 1996), given the difficult task of reviewing the Scottish science education, took on the view that science is "a distinct form of creative human activity which involves one way of seeing, exploring and understanding reality".

Form I and II *Nature Study* *Botany*: Roots, stems, leaves, fruits, etc. with reference to a few typical plants. Elementary plant physiology. *Animals, etc.*: Rabbit, Dog, Cat, etc. Birds. Butterflies, Moths, etc. *Objects in Common Life* Air, Barometer. Water. Clouds, Rain, Snow, etc. Some lighting problems, e.g. flame, Bunsen Burner, electric light. Electric Bell, etc., etc. Elementary Astronomy. **Form IIIB** *Elementary Science* Measurement of length, area, and volume. *Simple Effects of Heat*: Thermometer. *Weighing*: The Balance: Densities. Solutions, etc. Simple chemical operations and constructions of apparatus. Examination of Air and Water. **Form IIIA** *Physics* *Mechanics*: Graphs: Spring and Spring Balances. Levers, Moments: The Balance, Steelyard. Forces: Parallelogram and Triangle. Parallel Forces. Centre of Gravity. Mechanical principles, etc. *Heat*: Heat and Temperature. Fixed Points of Thermometer: Scales. Measurement of Heat: Calorimetry. Expansion of Solids, Liquids, Gases. Changes of State. Hygrometry.	**Form IV** Also doing Heat *this year*. Syllabus like IIIA, rather more fully; also: *Light*: Shadows. Reflection and Refraction of Light at Plane and Curved Surfaces. Formation of Images. Simple Optical Instruments. The Spectrum. **Form V** *Chemistry* The study of air and water, carbon, salt, without the introduction of theory, symbols or equations. The gas laws - leading to Avogadro's Hypothesis. The laws of chemical combination - leading up to the Theory. The further study of non-metals and metals - in the light of the Theory, especially the 'equation'. Volumetric Analysis. **SP. V and SP VI** Work up to Scholarship Standard (Chemistry and Physics) - subjects varying from term to term.

Figure 2.2. Scheme of Work in a Boys' Public School in 1908-9

Source: (Jenkins, 1979)

The implication here points to the notion that scientific knowledge is based on empiricism. Empiricism is not the only way that scientists use to generate scientific knowledge. Intuitiveness as well as deductive reasoning have also played roles in this regard. The group further states that science is both a way of investigating the world and an ever-increasing body of ideas and information "... about the way things work". This view of science is embodied by the present Scottish school science curriculum with minor additions.

The Science Review Group acknowledges science as one of the essential features of any society. As such, it has profound influence on the lives and environment of these societies especially through its practical applications. The group strongly recommends that new approaches to teaching science should emphasise this aspect. The Science Review Group suggests that this notion has been in the list of top priorities for the provision of science education for years in most countries. The Advisory Council on Education in Scotland in 1947 (quoted in Scottish Office Education Department, 1994), proposed that science should be studied by all pupils in the four years of the School Certificate course.

Surprisingly enough, their argument was not centred around the notions of technological needs or emphasis on acquisition of appropriate scientific skills such as observation and measurement, but on the significant role that science plays in shaping the human culture. The Council insisted that science is not merely a subject or a group of subjects to be learnt, but, "... a whole vast world of human thought, feeling and endeavour". Kerr (1966) suggested that "future changes in science teaching need to immediately consider (sic) the influence of social forces on our attitudes and standards in science teaching" (p. 302). This suggestion by Kerr came in at the time when the England and Wales science education had just successfully incorporated a campaign started at the beginning of the twentieth century. The campaign was geared towards introducing biology into the school science curriculum which was predominantly made up of chemistry and physics (See Figure 2.2).

Later the campaign grew to include "teaching science as a course of scientific study and investigation which has its roots in the common experience of children and does not exclude any of the fundamental special sciences" (Kerr, 1966). The campaign owed its success to three principal factors:

(1) The ever growing demand for education for all in the early 1900's which gave birth to general science courses.
(2) The increasing demand for general science courses from the 1940's to 1950's, as more children had to have access to secondary education.
(3) The collapse of general science courses in the 1960's as most schools reverted to teaching of the separate sciences, especially in higher secondary, with strong emphasise on "bringing science in touch with everyday experience" (Kerr 1966).

However, the SCCC Science Review Group notes that science should not be considered a "homogeneous human activity generating a single form of knowledge", but a domain comprising a variety of noticeable disciplines that are interrelated and overlapping in their nature.

The above arguments are included in order to illustrate how the definition of science and the nature of its teaching in schools are influenced by time and changing social perceptions. The definitions and perceptions presented by Lindsay (1963) and Kerr (1966) are reflected in the 1961 Policy Statement of the Association for Science Education (ASE). This statement stresses that the recognition of science as a human activity should encourage school curriculum developers to include teaching science to help children explore the realm of human experience. A special mention is made of the effects of science and technology on human life in the statement.

However, Lindsay's definition of science is very wide and its emphasis does not cover all aspects of science as perceived by contemporary society. The other limitation of Lindsay's definition is its focus on 'doing science' which does not necessarily imply theoretical learning of science concepts.

The ideas of 'what is science' expressed by the SCCC Science Review Group (1996) are a reflection of the new developments taking place in contemporary society. This is a society that is highly influenced by science and technology, a society that has to function well in a scientific world, a society that claims to use scientific evidence for decision making, and a society that insists on exploring its natural world further to improve on its life. However, looking at the third of these aspects, it is a sad observation that frequently society and science education do not make use of the available research evidence.

2.3 History of Science as a Body of Knowledge

Science is reported in many publications as an essential aspect of human activity from stone-age to modern times. The section discusses briefly factors that establish the link between human activity and modern day science.

Science is a part of human activity and, therefore, its origin is as old as the existence of a human being. This argument is based on the premise that human beings have been interacting with their environment since the beginning of their time. Popper (1963) asserted that the growth of human knowledge results from human attempts to solve problems encountered in their everyday life. The interaction involved experimenting with different things to find out which work better for a particular purpose: what is edible, how to survive the harsh weather, and many more. The experimenting could have been in the form of trial and error but, eventually, the elimination process led to development of patterns.

Mason (1962) proposes that the historical roots of science can be traced from two primary sources. The first source he terms the technical tradition, in which practical experiences and skills were passed on and developed or refined through generations. The practical skills in this instance were characterised by, for example, the simple art of tool making during the stone age to the more complex technological tools of modern day society. The second source is the spiritual tradition, in which human aspirations and ideas were passed on and augmented. This tradition entails cultural values and religious beliefs.

These traditions, Mason asserts, started with the first human, long before signs of modern civilisation appeared. According to Mason, evidence from the study of the ways of life through the ages indicates that, from the stone age era to the mediaeval times, the two traditions have been working parallel - none claiming supremacy over the other. During the period of the ancient Greeks or Babylonians, the two traditions, judging by the continuity in the development of the tools used, the burial practices and cave paintings, were practised by all.

In the Bronze Age, the two traditions appeared to have largely separated. The separation appears to have been perpetuated on one hand by the craftsmen and on the other by corporations of priestly scribes. This separation is maintained in the subsequent civilisations, though both becoming highly differentiated.

During the Middle Ages and into the Modern Ages, some elements from the two traditions begin to converge and then combine, producing a new tradition - science. The new tradition was born out of the need to use empirical evidence to influence human perceptions and ways of life. What is evident from this historical development of human perceptions and techniques is an active refinement of practices and aspirations.

An interesting point to note here is the fact that the element of spiritual aspiration still plays a part in science. As Mason (1962) points out that, "scientists generally have adopted the values of the society to which they have belonged, even in the cases where those values have been detrimental to the advancement of science". Perhaps Lindsay is right to suggest that, "not everyone involved in 'everyday thinking' is a scientist".

2.4 Development of School Science Education

This section presents a rationale for the introduction of science in schools from the twentieth century to the present time. The aims are to illustrate the importance of passing on useful knowledge from one generation to another through schools, and the increasing demand for technical knowledge over spiritual knowledge. The mark for modern western civilisation is believed to be the start of the scientific revolution (Jenkins, 1979). The revolution starts from Nicolaus Copernicus (1473-1543) and finally defines its place in humanity during the Isaac Newton (1642-1727) era. The development of scientific knowledge about the universe throughout that period is testimony to this change in perception that gave science a new role in education - 'liberal education' (Jenkins, 1979).

Teaching science in schools did not come without causes and/or reasons. Like all other disciplines that are presently offered in school curricula, science evolved from the ever increasing human desire to increase his knowledge of nature (Layton, 1995; Pomeroy, 1994; AAAS, 1989; Science Council of Canada, 1984; Armstrong, 1925). The continued interaction of humans with their environment has already been noted as the main cause for searching for better ways to develop or come up with new or refined knowledge (Armstrong, 1925).

It is believed that a way of life that is random or does not follow a certain pattern is unpredictable and generally leads to uncertainty (Hazen and Trefil, 1990; Sizmur and Ashby, 1997). Sizmur and Ashby further describe the world or the universe or reality as "relatively stable and amenable to descriptions that capture something of the kind of entities and processes that comprise it". It is common knowledge that the sun rises from the east and sets in the west. People have worked out most of their daily routine around that pattern of the universe. Any set back to this pattern will surely cause temporary commotion and eventually a search for an alternative to their daily routine.

In a city, for example, a person's life pattern may include waking up to an alarm clock in the morning, taking a shower, eating breakfast and brushing teeth afterwards, paying bills on time, taking kids to school, arranging for a baby-sitter, and fastening a seat belt before driving a car. These actions are an indication of the acknowledgement of the power of predictability in human beings. Hazen and Trefil (1990) declare to be true the fact that all human beings seek order to deal with life's uncertainties by looking for patterns. Scientists as human beings constantly examine nature, looking for patterns and guided by the overarching principle: "The universe is regular and predictable" (Hazen and Trefil, 1990).

The predictability of the universe is characterised by the sun coming up every morning, seasonal patterns, and stars sweeping across the sky at night and many more. Again one cannot resist the temptation to consider the link between human characteristics and school science teaching and learning. Has science teaching in schools been successful in enabling children to understand and appreciate the predictable and regular nature of their environment? If not, how can this important characteristic of human beings' ability to make sense of nature and be able to predict its course be promoted through school science teaching?

2.5 Teaching and Learning Science in Schools

In education, teaching and learning are interrelated processes and one cannot assume successful teaching without meaningful learning. Meaningful learning has been described in varying ways depending on the underpinning theory of cognitive development.

Ausubel (1963), in his subsumption theory, describes meaningful learning as the ability of (verbal) instructions to integrate new material with previously presented information. Ausubel asserts that this process takes on the form of 'comparing and cross-referencing of new and old information or ideas'. According to Ausubel, a child has to learn the basic ideas first before being confronted by more complex material. However, the complexity of the information presented afterwards should be "... progressive and differentiated" (Ausubel, 1963). This refers to details and specificity of its content materials.

The argument here is that verbally presented information has the ability to encourage rote learning as long as a child may not be able to recognise the necessary link between old and new ideas. For example, learning how to add numbers requires previous instruction on counting numbers and the concept of addition of numbers for it to be meaningful. A child learns meaningfully how to write sentences when previously presented with information on alphabets, how to use alphabets to construct words and how different words are combined to form sentences.

Mayer (1987) outlines five components of a cognitive model of the learning-teaching process. A learning-instruction process that has all of these components is sure to produce meaningful learning in learners according to Mayer. The list includes:

(1) Instructional manipulations. This component refers to external influences on content to be learnt at a given level, appropriate methods of teaching, availability of resources and teacher qualifications.
(2) Characteristics of the learner. This involves the internal existing knowledge gained outside and inside the classroom, and the cognitive capability or the information-processing system of the learner.
(3) Learning processes. The learner's internal cognitive processes engaged during learning constitutes this component.
(4) Learning outcomes. This refers to the development of new or improved internal cognitive structures during learning.
(5) Performance outcome. This component points to the external performance of the learner on tests.

The measure of whether meaningful learning has occurred (an assessment of learning outcomes), can be in the form of "... retention tests and transfer tests" (Mayer, 1995). Retention tests primarily seek to make a judgment of whether a learner remembers what was taught. Transfer tests are said to measure the extent to which a learner apply what has been learnt to solve new problems related in context. Mayer contends that in any learning-teaching process, there can be three possible outcomes of learning, namely, no learning, rote learning and meaningful learning. An evaluation of the learning outcomes can yield three results:

(1) No learning in a student means one can expect poor retention and poor transfer performance.
(2) Rote learning in a student means one can expect good retention and poor transfer performance.
(3) Meaningful learning in a student means that one can expect both good retention and transfer performance.

According to Mayer (1995), transfer performance occurs after a learner has successfully made an effort to make sense of the presented material (internalisation of knowledge). Learning that is transferred consists of existing cognitive structures being extended to future life experiences of an individual. Transfer performance, therefore, is a measurable outcome of the effect of transferred learning (Mayer, 1995).

Mayer also suggests that, "for transfer of learning to occur, students must be able to form meaning, expectations, generalisations, concepts, or insight". The ability to perceive the application of a concept learned in one situation to a similar but, different situation, constitute transfer performance.

Teaching, therefore, should involve providing a sort of cognitive guide for students engaged in genuine educational activities. In this case, teachers have the role of facilitating learning as opposed to providing knowledge for the students to learn (Mayer, 1987). Mayer has strong belief that a teacher who acknowledges and practice this role stand a good chance of assisting students to internalise new information. Teacher must always keep at the back of their mind that students are not tape recorders. Students learn better when they are actively involved in the learning process.

Science teaching and learning involves both verbal and practical presentation of information. The present trend in science teaching and learning emphasises among other approaches a 'problem solving approach' which is expected to

> *"... encourage them* (pupils) *to link the ideas they are being taught with common-place objects and events and to apply new ideas in a wide range of situations"*. (Science Curriculum Development Committee (SCDC), 1987, p.5).

Penick and Yager (1986), reporting on the findings of the 1982 major project undertaken by National Science Teachers Association in the United States entitled '*A Search for Excellence in Science Education*', reveals that programme planners developed and implemented new curricula that reflect the background knowledge of the learner, the nature of science and "also what we know about society". The argument is that science that is not applicable to society within which pupils originate has little meaning to pupils and consequently "... to citizens alike" (Penick and Yager, 1986).

The science programme developed under the National Science Teachers Association curricula enabled pupils to use their learning by taking active roles in solving concerns and looking for new information about problems within their community. Penick and Yager are of the opinion that "good science teaching requires students to perform real operations in a real world on real problems".

> *"Real laboratories for science and science instruction exist almost anywhere. Classical science almost anywhere begins outside, in nature. As knowledge and ideas grow, many are brought inside, for controlled investigation, analysis and discussion. So it should be for students."* (Penick and Yager, 1986, p.5).

According to this view the school science laboratories, which do not necessarily have to have unique equipment, should be places where students go to test the validity of their already existing explanations of objects, events, and ideas they encounter in their everyday life. It is the hope of Penick and Yager that through this approach a new breed of citizen will be produced, who no longer perceive science as "... an enigma to be avoided", but "... a mystery, rich in adventure and excitement waiting to be explored, understood and used".

The Science Council of Canada (1984), reports that science teaching mainly prepares Canadian children to study more science. Another crucial point reported is that science teaching gave more priority to content coverage over all other science educational objectives. As the report state:

> *"Science at this level* (secondary school) *is often presented as a catalogue of facts for the students to assimilate as quickly as possible"*. (p.29).

However, the Science Curriculum Development Committee (SCDC) (1987), reporting on a two phased science curriculum review project for England, Wales and Northern Ireland from 1981 to 1986, claims that science teaching can give meaning to students' learning. The learning in this regard refers to the acquisition of new ideas and skills. The report states that science teaching can enable students to acquire new ideas and skills by enabling students to "... see some point and personal significance in doing so". The SCDC maintains that this approach is likely to "... engender in students curiosity, interest, enjoyment, enthusiasm and a sense of satisfaction", which are assumed to be the main ingredients necessary for studying of science. The SCDC therefore suggests two types of approaches that can effectively make school science personally relevant and applicable to students:

(1) learning to work as scientists or problem solving, that is, investigating phenomena in a systematic way and finding solutions to scientific problems,

(2) relating science to out-of-school context through investigations of

socially related problems or concerns.

In section 2.2, a description of science teaching in Scotland was presented with emphasis on the changing nature of science education with time and changes or advancement in human perception. Research has shown that the purpose of school science education has had many dimensions. These dimensions, as already pointed out in the above sections, were greatly influenced by political systems, development of new ideas in science, human aspirations, advancement in technology and more.

To make school science more relevant, stimulating, enjoyable, and of course, accessible for pupils, teachers have to present more positive and realistic images of science and scientists, by demonstrating its scope and limitations and by showing science as it is - a social activity motivated by human purposes (Harrison and Mannion, 1997; Walton, 1997). The suggestion here is that, for human beings to understand their natural environment better and be able to predict its actions, school science teaching has to equip pupils with the necessary skills to do so - through 'active science' (Walton, 1997; Hazen and Trefil, 1990; Johnstone, 1997).

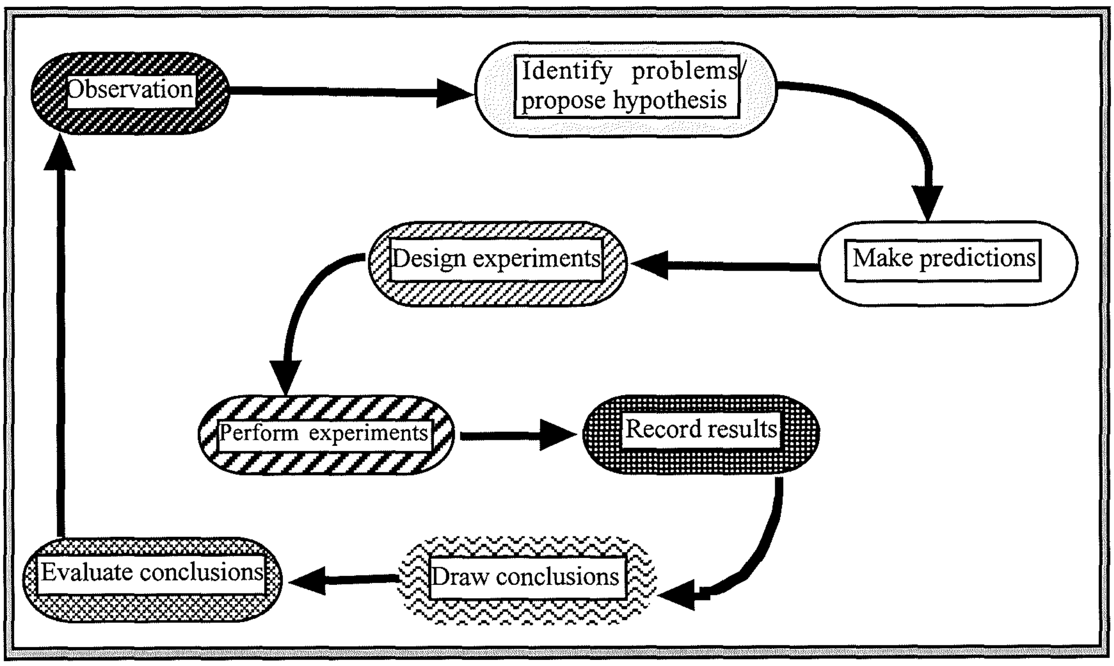


Figure 2.3: Basic Steps of the Scientific Process

source: (Yip *et al.*, 1998, in Al-Shuaili, 2000)

Active science involves the use of the scientific process approach. These views echo the findings of researchers working on the improvement to science teaching and learning. The findings unanimously point to the fact that, when pupils engage in active learning activities which promote active mental experiences, then increased motivation and achievement results (Harrison and Mannion, 1997). The basic steps involved in the approach are represented by the diagram above.

Figure 2.3 is an illustration of a simplified version of what actually happens in a problem solving situation. The scientific process usually is more complex than this. The cyclic representation of the process suggests that observations made after the evaluation of the conclusions may usually leads to more problems (Popper, 1959). Continuous evaluation of every stage in the process is essential in order to modify or redefine the parameters of each stage.

Science in schools was introduced primarily to enable learners to understand the nature of science, and for the training of new scientists. To a lesser extent, at least as perceived by some teachers, science in schools was introduced as part of the general knowledge to be required by all in a scientific world, and for the promotion of a technology appropriate to a community. Other stakeholders in science education in schools believe that learning science in schools will subsequently develop a meaningful culture within the community. These facets are discussed in detail below.

2.6 Science for Understanding Nature

The growth of human knowledge is seen as a process that starts from problems encountered to attempts made to solve them (Popper, 1959) (See figure 2.3). Empiricism became the panacea for differentiating science and 'non-science' during the Enlightenment period in European history. The notion of using observable data to verify a theory dominated the human ways of understanding nature and natural phenomena from then onward.

The success of science in explaining and predicting the natural world, thereafter, could not be ignored by educators. The study of science then strongly focused on the need to understand nature through the scientific method. Debates leading to the development of better ways of increasing human knowledge gave birth to use of experiments rather than the deductive approach alone.

It is fitting to point out that this study does not claim any authority on this topic. The researcher also acknowledges that space does not permit this topic being discussed fully but a few issues relevant to this study are now explored.

The empirical studies of nature, believed to have been pioneered by Sir Francis Bacon (1561-1626), inspired some educators to want to teach a science that will "... put the records straight concerning human experiences of the world for the benefit of future generation" (Cowley, 1661). Cowley's proposal to the Royal Society entitled 'The Advancement of Learning - Philosophical College' may have come as result of this unrestrained scientific investigation. Through this proposal Cowley expressed his wish to erect a new institution where students would study nature through experiments.

Cowley suggested four aims to the Royal Society to be achieved by his proposed institution:

(1) *To weigh, examine and prove all things of nature delivered to us by former ages, detect, explore, and strike a censure through all false monies with which the world has been paid and cheated for long, and (as I may say) to set the mark of college upon all true coins that they may pass hereafter without any further trial,*

(2) *to recover the lost inventions and, as it were, drowned lands of the ancients,*

(3) *to improve all arts which we now have, and*

(4) *to discover others which we yet have not.*

The aims indicate strongly how Cowley believed in the scientific approach using experiments, perhaps a direct influence of Francis Bacon's (1561-1621) empiricism. However, there was no formal education at the time, and therefore, science education did not exist in the whole of Europe. Public school education in England and Wales, during the time of Cowley, did not exist.

In Scotland, however, many schools did exist for public access from the late seventeenth century (Cockburn, 2002). These schools were a result of the Scottish Education Act of 1696. The Cockburn asserts that the Act is presently proclaimed by some education authorities as the first National system of education in the world since ancient Sparta, a remarkable claim! Compared to the rest of Europe in the mid-nineteenth century, Scotland had the largest percentage of primary, secondary and tertiary educated population (See table 2.1). It is believed that the Scottish Enlightenment (unrestrained scientific investigations to understand nature) spearheaded the European Enlightenment.

Country	Number of educated persons in every 10 000 people at secondary level
Scotland	49
Prussia	40
France	18
England	8

Table 2.1. Number of Secondary School Educated Population per 10 000 People in 1864.

Source: (Cockburn, 2002).

The understanding of nature through the use of the scientific approach was considered by Cowley as an instrument capable of playing a significant role in promoting public appreciation of scientific knowledge. Cowley also believed that establishing such an institution could arouse more curiosity in young people (in private institutions) to develop new knowledge based on scientific evidence.

The discussion of this topic, therefore, starts from the time of Henry Edward Armstrong, the main advocate for the heuristic method of teaching science. This time coincides with the provision of public secondary school education in England and Wales under the 1902 Education Act (Jenkins, 1979). This period more or less marks the recognition of what Cowley had requested during the seventeenth century. The unrestrained scientific investigation suggested by Francis Bacon enabled scientific information to grow and have a lasting impression on people's minds. The generation of new knowledge through empirical data or observable evidence reshaped people's thinking. Armstrong's heuristic method of teaching and learning science strongly demonstrated this fact.

The primary purpose of the heuristic method was to enabling students to think for themselves, to have confidence in their ability to do and find things out, and to be critical and curious of things claimed by experts (Armstrong, 1925). The method involved the use of induction, deduction, being systematic and accurate in taking measurements. Armstrong insisted on active learning as opposed to passive learning of science. He believed that students learned science better through practical work and practical activities individually.

Heurism, therefore, refers to a learning situation where students take on the role of discoverers and the teacher act as a guide and facilitator for the path of discovery (Armstrong, 1925). Students had to be left to work blindly through their problem solving activity with the teacher providing guidance, references, and sources. According to Armstrong, the heuristic method is applicable in other subjects besides science. He also acknowledged the fact that it is not possible for students to learn everything through discovery.

It is claimed that he learned his chemistry and teaching through personal discovery and his ability to compare his experience with those found in texts and experts. Writing about the English educational system, Armstrong successfully campaigned for provision of grants to introduce science in school curricula at the beginning of the twentieth century. Armstrong's science provided for both the understanding of nature and the development of future scientists. This approach was subjected to a lot of criticism in the early 1900s by some teachers.

It is reported that most teachers were opposed to the over-emphasis on heurism. Their opinion was that it narrowed the coverage of science courses and limited the students' overall comprehension of science (Sherratt, 1982). Some science educators even consider its expensive nature a disadvantage. Adey (2001) says this of Armstrong's heuristic method: "proved rather expensive in time and laboratory facilities."

However, Adey acknowledges the fact that its intentions may have "... met one of the demands on science learning", that is, the development of deep understanding of some topics. The Gregory Committee Report instead suggested that teaching about the lives of scientists and the history of science would redress the situation (Newton, 1986).

2.7 Science for the 'Development of Future Scientist'

The debates on the provision of science in schools grow even stronger during the first half of the twentieth century (Jenkins, 1979; Jenkins, 2001). The debate took place within a society characterised, initially, by views influenced by the coming of a new century and later, by the effects of World War I and developments in science and technology (Jenkins, 1979).

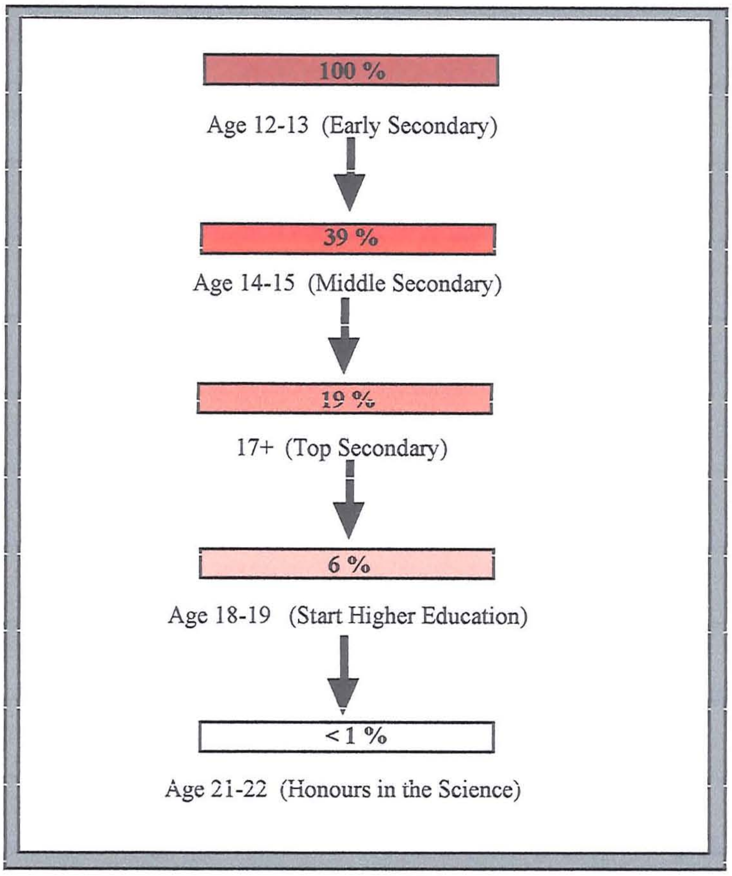


Figure 2.4. The Pursuit of a Science (Scotland)

The intensity of the debate was further fuelled by the "... interest in the intellectual development of the individual" (Sherratt, 1982). Science education in schools was considered by its advocates as providing a foundation on which to train future scientists successfully.

New reforms in school curriculum in England, for example, were in favour of science education in schools that would develop human interest alongside its material and mechanical aspects as reported by the Thomson Committee Report of 1918 (Newton, 1986). However, other educators felt that there was just too much emphasis on the learning of science in schools.

For example, Livingstone (1917) argued against the idea of over-emphasising the need for England to depend solely on the application of scientific principles. Livingstone contended that it is not possible for all who study science in schools to become scientists. His point was that teaching science in schools should not be done in such a way that it over-shadows the importance of other specialist subjects like, "... agriculture, architecture, and pedagogics" (Livingstone, 1917).

The situation in Scotland concerning the pursuit of science from early secondary to university levels, is illustrated by figure 2.4. This situation is generally true in other parts of the world, even though, the figures may be slightly different (Reid, 1999). In his article titled, "Towards an Applications Led Curriculum", Reid is trying to answer the question 'why study chemistry'. The table 2.4 illustrates the argument raised by Reid that, although biology, chemistry and physics appear to be liked by children from early secondary to university levels of education in Scotland, there is still the question of what proportion of the children pursue them up to university level.

The situation as described by Reid (1999) is such that, for every 100 pupils at early secondary levels (12-13 years olds) in Scotland, 40 are most likely to pursue chemistry at ages 14-15. By the ages of 16-17 (top secondary levels), about 20 pupils will continue with chemistry. However, Reid cautions that despite the popularity of chemistry at secondary levels, roughly 1% may continue to study chemistry at university degree (honours) levels. These figures, according to Reid, are relatively similar to those associated with physics and biology. He asserts that there is no evidence which supports the notion that schools encourage pupils to take these subjects in order to prepare them to become chemists, physicists and biologists. The question of why teach chemistry, biology and physics therefore, cannot be answered by considering the pupils' career interests.

Do all pupils in the early secondary level consider their pursuit of science necessary? At what age is it assumed that pupils have acquired adequate scientific knowledge and skills? Are these skills and the knowledge acquired necessary to those pupils not interested in the pursuit of science at higher levels? Out of these arguments and report findings came the idea of 'Science for All' advocated by the Gregory Committee.

2.8 Science for All

As grants for science in schools increased in England and Wales schools, the number of student doing science also increased (See table 2.2). This increase in the size of science classes meant that the heuristic method could not be sustained. The idea of developing new scientists through school science became modified to include 'Science for All' as advocated by the Gregory Committee.

Year	No. of departments in which Elementary Science was taught in England and Wales.
1890	32
1891	173
1892	788
1893	1,073
1894	1,215
1895	1,396
1896	2,237
1897	2,617
1898	2,143
1899	21,301
1900	19,998

Table 2.2. No. of Departments in England and Wales Day Elementary Schools in which Elementary Science was Taught as a Class Subject, 1890-1900

Source: (Jenkins, 1979)

Jenkins (1979) points to the suggestion made by the Gregory Committee Report of 1917 to the British Association for the Advancement of Science. The suggestion is that school science should not only focus on preparing students for vocations but should also equip them for life. The considerable growth in the teaching of elementary science in the public schools during the last decade of the nineteenth century, according to Jenkins (1979), meant that more students qualified for grants to do science.

A marked increase in grant in respect of the science subjects was recorded in 1897 which then explains the sudden rise in the number of departments in which elementary science was taught as a class subject (See table 2.2).

Science for all is described by the Gregory Committee Report of 1917 as a move towards broadening and humanising science. The report argued that science teaching of the time was biased towards preparing students for further studies in science and did very little to promote acquisition of skills necessary to deal with life problems. Out of this notion of science for all, new science curricula were born (Newton, 1986). General science courses were introduced first with strong emphasis on learning basic science skills of observation, measurement, scale reading, interpreting data, and so on.

For Scotland, the importance of science to general education, according to the Scottish Office Education Department (SOED) (1994), was recognised as far back as 1947 by the Advisory Council on Education in Scotland. This was to cover pupils from primary school going age to age sixteen. The case for the Advisory Council on Education in Scotland was based on the arguments that,

> *"Science education provides all pupils with a basic understanding of physical and biological phenomena and equips them to adopt a scientific approach in dealing with practical, social and economic issues. It is imperative that all pupils have some understanding of how their bodies work when healthy or diseased, of the supply and effective use of energy, of the behaviour and uses of natural and artificial materials, and of the finely balanced relationship they themselves have with the natural environment."* (SOED, 1994, p.3-4)

In England and Wales, the teaching of the General Science courses in the upper secondary stages declined by the 1960's and many schools opted to teach separate science courses (Kerr, 1966). According to Kerr, General Science courses were primarily concerned with the nature of the content of science. Kerr maintains that the decline of General Science courses, especially at upper secondary level, was due to the inadequacy of the course to meet effectively the increasing demand for more scientists in the different fields of science.

The other reason advanced by Kerr is that the complexity of the society after the Second World War became a very strong force to prompt a more rigorous treatment of science courses. These limitations found in General Science courses gave birth, in England and Wales, to new science courses like Nuffield Science courses of the 1960's (Jenkins, 2001; Kerr, 1966). Nuffield Science courses were primarily concerned with teaching science as a process of inquiry (Kerr, 1966) rather than a body of information or content to master (Solomon, 2001). Adey (2001) pointed out that one of the major weakness of guided discovery or the inquiry process was lack of theoretical support to validate its legitimacy as an effective method of teaching science.

According to Jenkins (2001), by the mid 1970's,

> *"... hugely expensive curriculum projects associated with Nuffield Foundation ... were regarded as less successful than their advocates had hoped."* (p.28).

Schools had to build special science laboratories equipped with special apparatus. Teachers had to undergo in-service training while schools had to employ laboratory assistants to maintain and prepare the apparatus. Some of the equipment and apparatus required special storage at an extra cost to the school. The expensive nature of the Nuffield Science courses rendered 'Science for All' an impossible task for most schools with small funding (Adey, 2001) and especially in developing countries (Gray, 1999). Some educators still believe that lack of this equipment and apparatus contributed or still contributes to low attainment in science observed in most developing countries (See chapter 3).

Nuffield developments did not apply to Scotland. However, physics and chemistry dominated the Scottish science curriculum until around 1960. The Higher Grade examination was usually set with one paper in chemistry and one in physics (although the award could be made with combinations involving biology). However, pupils tended to be taught the physics and chemistry by separate teachers.

In the late 1950's, radically new syllabuses in chemistry and physics were developed and the subjects were separated for certification purposes. A new Higher biology syllabus was developed shortly afterward and, by the mid 1960's the three sciences had separated fairly clearly. The Scottish developments did not reflect Nuffield developments in terms of the strong emphasis on scientific processes. Nonetheless, the Scottish curriculum involved large amounts of pupil practical work and this tended to be based on a general principle of guided discovery. The Scottish syllabuses proved to be highly successful and were maintained, with repeated minor revisions, until the curriculum changes of the early 1990's.

Aikenhead and Jegede (1999) assert that

> *"cultural clashes between students' life-worlds and the world of Western science challenge science educators who embrace science for all, and the clashes define an emerging priority for the 21st century: to develop culturally sensitive curricula and teaching methods that reduce the foreignness felt by students."* (p.269).

This assertion is supported further by Cogan *et al.* (2001) and Ryder (2001). Cogan *et al.* (2001) consider education, of which science is a part,

> *"... one of the fundamental infrastructures that supports and shapes society ... the nature and content of an education system's curriculum would also reasonably be expected to vary just like its purpose and goals set out by each country."* (p.107) .

Kahn and Rollick (1993), reporting on the present situation regarding science education in South Africa, argue that "the key to developing an equitable society is through ... developing all its citizen into a scientifically literate community." This point may have been wildly optimistic but it signifies the importance of learning and teaching science for the development of a specific society which shares a more or less common culture. Equitable in the above statement has been described as referring to the sharing of a common understanding of the technological, cultural and economic needs by the society within South Africa (Kahn and Rollick, 1993).

The strong belief held by two the biggest reform programmes in the United States of America, *Science for All Americans* (SFAA) and the National Science Teachers' Association's *Scope Sequence and Curriculum* (SS&C), that "good science education for a diverse student populations will also be good science education for a homogeneous, mainstream student population", has taken a new turn. Simply stated it now reads, "what is good for all will be good for one" (Pomeroy, 1994).

It is, therefore, obvious that 'Science for All' has its limitations when considering the cultural, economic, social, or technological difference found in countries of the world. These disparities have prompted the science educators and curriculum reform committees all over the world to review the purpose for science education in schools. This has given birth to Scientific Literacy under the umbrella of Science Technology and Society (STS) movement.

2.9 Science, Technology and Society (STS)

Science, Technology and Society (STS) in England and Wales is regarded by some science educators as an attempt to remedy a situation that has been described by a majority of students at almost all levels as boring, difficult, not related to every day life (Solomon, 1981). In the United States of America, there are reports that students regard science as unrelated to other disciplines (American Association for the Advancement of Science (AAAS), 1989). Ratcliffe (2001) traces the origin of STS as far back as 1930's during the 'Science for All' period promoted by a 'left-wing group' led by Bernal, Hogben and Haldane. They proposed a scientific knowledge for all "that strongly promoted ... the relevance of science to society" (Ratcliffe, 2001).

Post World War II developments and advancements in technology made the movement of science education towards STS stronger. Science educators in England and Wales started realising the restricting nature of Nuffield science courses as Solomon (1981) puts it:

> *"In traditional science instruction, personal opinion is not involved and may be actively avoided".* (Solomon, 1981).

Solomon, on the other hand, regards STS instruction as encouraging debates or discussions between students which are hoped to assist them to arrive at a common understanding of science that "combines scientific knowledge and moral responsibility". Poole (1990), writing from a Christian perspective, examines some beliefs and values which are inherent in the nature of science. Poole agrees with those who suggest that science has increasingly become a social activity. He asserts that the society component of the 'science, technology and society' (STS) will inevitably strengthen the element of "value judgment" in scientific investigations. Poole further argues that the teaching of science in its social context (especially at secondary school levels) will greatly improve on the present (negative) perception majority of people have about scientific knowledge and explanations, which he says, "lack a sense of awe".

The negative perceptions about some aspects of science have been observed, particularly in chemistry (See figure 2.1). The word *chemical* is been commonly used as "a synonym for dangerous, harmful, noxious, distasteful", even by those who did chemistry courses at upper secondary schools levels (Paoloni, 1981). Reid (1981) supports the notion that the teaching of chemistry as a science has come under greater pressure than before. Reid attributes the rise in pressures to four sources:

(1) The expansion of knowledge that has caused the chemistry syllabus to grow in content.
(2) The occasional shortage of qualified chemists to teach in schools.
(3) The integration of chemistry into science at junior levels that has left chemistry with less well defined identity.
(4) The extension of chemistry into social and environment areas.

Reid recommends that it is important to facilitate a learning situation where pupils are involved in "assessing information, taking decision and living with their decisions" (Reid, 1981). However, Reid cautions against the perception that the suggestion implies the inclusion of extra content. Instead, he highlights the notion that the approach places emphasis on attitude development towards the social aspect of science through the use of interactive units and none on extra content which will definitely demand extra time on the coverage of the syllabus. Whatever the reason, the trends in Scottish science education have led to the popularity of science at Higher Grade (Scottish Qualification Authority (SQA), 2000).

Ratcliffe (2001), consistent with Scottish model of teaching science in its social context, proposes that characteristics of STS can be recognised by considering the responses given to three questions, raised for science teachers. In the study conducted by the 1984 ASE working group, teachers were to respond to the questions in a manner that reflects their future practice. The questions and their responses are presented below on figure 2.5.

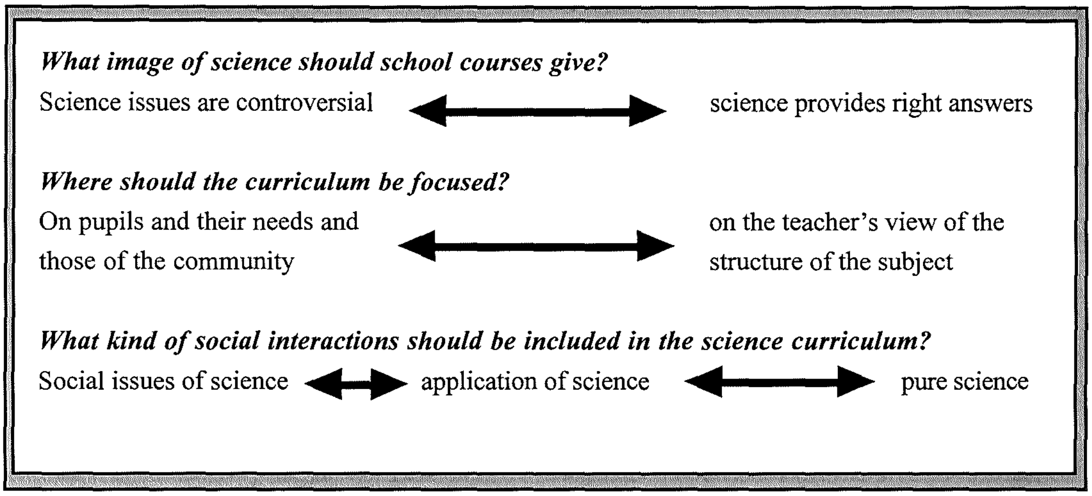


Figure 2.5. Teachers' Responses to 1984 ASE Working Group Survey Questions.

Source: (Ratcliffe, 2001)

The responses on the left-hand side of the continuum (figure 2.5) provide partly the description of the nature of STS education. A concise description of the nature of STS must include the "... integration of science and technology with society for democratic action." (Ratcliffe, 2001). Is knowledge of the interaction between science and technology with society enough? What should society do with this knowledge? These are some of the questions being raised to make scientific knowledge more accessible to society and its presence be appreciated by all. The need for a scientifically literate population dominates the discussions. Answers to what should be the nature of this scientific knowledge and how it should be passed on to students effectively are still being debated.

2.10 Scientific Literacy as a Component of STS

Scientific literacy is defined in a variety of ways by many (Jenkins, 1990; Solomon, 2001; Ryder, 2001). Hazen and Trefil (1990), writing in the American context, argue that scientific literacy refers to the aspect of 'using science' and has very little or nothing to do with 'doing science'. Their view concerning scientific literacy is that it

> *"constitutes the knowledge you need to understand public issues. It is a mix of facts, vocabulary, concepts, history, and philosophy. It is not the specialised stuff of the experts, but the more general, less precise knowledge used in political discourse"* (Hazen and Trefil, 1990, p.xii).

According to Hazen and Trefil, scientific literacy should enable one to understand everyday instances as they relate to science and vice versa. These instances could be in the form of news articles, political claims, explanations given to phenomena by people and even science news. Scientific knowledge in the scientific literacy sense, therefore, involves acquisition of background information and a knowledge of what effects the advancement in science would have on the environment and societies (present and future). Solomon (2001) states that scientific literacy in England and Wales, is generally defined as the science that enhances "public understanding of science". She regards this definition as having a similar meaning to that used in America but a bit different in the overall focus. Solomon reports that, in England and Wales, scientific literacy presently emphasises five major outcomes:

- The ability to read about and comprehend science.
- The ability to express an opinion about science.
- Paying attention to contemporary science now and for the future.
- Participation in democratic decision-making.
- Understanding how science, technology and society influence one another.

However, Solomon asserts that this set of outcomes of scientific literacy cannot be realised individually. She acknowledges that they are "clearly interactive and, to a varying extent, interdependent". On the other hand, Ryder (2001) warns against attempts by curriculum developers and policy makers to foster the development of a school science that includes details relevant to every context of humanity. Ryder contends that teachers' understanding is limited, particularly if they are required to function well in a science curriculum that aims to "... support people's engagement with science ... in areas not typically part of the current school science education. He gives an example of the inclusion of areas like the history of science.

2.11 Why the Need for Scientific Literacy

The debate on the nature of the scientific literacy has generated a series of arguments related in their objectives but different in their depth of focus. The depth of focus depends to a large extent on the level of technological development and complexity of the society (Ryder, 2001). An individual residing in a complex society with a high level of technological development will inevitably require a more advanced scientific literacy.

Hazen and Trefil (1990) attempt to provide answers to the question, 'why the need for scientific literacy', in the form of three arguments. The first argument points out that every citizen will be faced with public issues whose discussion requires some scientific background (the civic argument). The debates could be on family issues, community issues, political issues or global issues. The impetus is on the ability of the individual to debate the issues with a better understanding of the nature and implications of the concerns (Science Council of Canada, 1984; SOED, 1994; Ryder, 2001; Solomon, 2001).

The second argument says that the world operates according to a few general laws of nature. If all that we do is governed by these laws, then there is a strong need to know and understand the laws (the aesthetics argument). Historically, Western civilisation is said to be a result of the need to know more about the way the universe operates. (AAAS, 1989). Hazen and Trefil assert that this argument is responsible for setting the wheel of science in motion.

The third argument campaigns for an appreciation of the scientific knowledge as a trend setter of human thinking (the argument for intellectual coherence). Unless individuals understand the science behind the current thinking they can never appreciate the thinking. Scientific findings influence change in human thinking and eventually the thinking context of other subjects areas (Layton, 1995).

Ryder (2001) discusses the reasons why people should know something of science by restating arguments provided by Thomas and Durant (1987). The arguments are grouped into five categories, namely: The economic argument; the utility argument; the democratic argument; the social argument; and the cultural argument. Accordingly, the titles of the arguments describes the settings or the context as is the case in Hazen and Trefil (1990). The arguments are discussed in this work to highlight primarily the nature of the subject matter knowledge required in each setting.

The Economic Argument

The economic argument suggests that the economic wealth of a nation dictates the level of science education required for the continued development of professionals in the science related careers. This means that the depth and complexity of the content material to be taught in school science depends to a large extent on the impact that scientific knowledge on the economic development of a nation. However, the notion of a global market simply does not promote such an argument. A technologically advanced item sold to a nation with a small economy will definitely have the same impact on the environment and probably a devastating effect on the ignorant society. This argument, like the cultural argument, is not considered as part of the need for all people to know something about science. It focuses primarily on the development of science graduates who will enter the science profession (Ryder, 2001).

The Utility Argument

The utility argument views scientific knowledge or the understanding of science as a practical tool necessary for survival in a technologically advanced society. This tool, according to this argument, should be useful in specified everyday contexts. An example of this could be someone drawing on the knowledge of the danger of sexually transmitted diseases to practice safe sex. Apparently, it appears like either people's habits, survival needs, or curiosities simply override the need to do what is right or safe. Merron and Lock (1998) carried out a pilot study to investigate the level of scientific knowledge with regard to healthy eating and improved diet on young teenagers. The results of the study suggest that young teenagers' eating habits have improved, possibly due to the uncovered poor levels of knowledge about healthy eating. Whether a strategy of relating work in science more directly to personal eating behaviour, could lead to to both higher levels of knowledge and to an improved diet, is still a debatable issue.

The Democratic Argument

The democratic argument presents a view that the need to know something about science enables individuals to "engage in debate and decision-making" (Ryder, 2001) in settings or contexts featuring scientific information. This argument assumes that, for example, a debate by local cattle farmers concerning the effects of keeping too many cattle during a drought season could benefit immensely from their fundamental understanding of the consequences of soil erosion. Is knowledge of the effects the only factor that influences decision-making? It is common knowledge that sometimes the process of decision-making does not follow on a logical path. Sometimes personal interests based on some enigmatic factors influence the decision-making process, with the ability to yield selfish, catastrophic, unproductive or surprisingly useful results.

The Social and Cultural Argument

The social argument and the cultural argument are somewhat related in their emphasis. The emphasis is on the appreciation of science and its influence on the development of human culture. Learning science provides a richer human knowledge in addition to learning other disciplines. Likewise, it is perceived that a scientifically literate individual "would feel less alienated from science" (Ryder, 2001) and perhaps appreciate science as a major achievement of human culture. It would really be a remarkable achievement in the history of science teaching to attain a undiluted perception of science.

Ryder says that the utility, democratic and (to a less extent) the social arguments for why people should know something about science collectively describes what he calls "functional scientific literacy". This is the scientific knowledge that enables an individual to function effectively in a specific setting (Jenkins, 1990).

2.12 Scientific Literacy: a Scotland View

In Scotland, science education continues to be popular with pupils at upper secondary levels (SEED, 1999; SCCC, 1996; SQA, 2000). The aim, therefore is to sustain the situation in the process of reforming the science curriculum to address adequately issues of scientific literacy. Justifying the commitment of the Scottish Education towards developing new science knowledge and skills, SEED (1999) states:

> *"All young people, not just those intending to follow careers in science, must be scientifically literate. They need to have a good knowledge and understanding of science and scientific ways of thinking in order to function effectively in a global and evolving technological society. They also need to have the skills and critical awareness to interpret and make sense of what they see and read about science in the media, where messages are often conflicting and where topics increasingly cut across a range of social, ethical and moral issues."* (p.2)

On the use of technological products and the impact of science and its application on young people's lives, the SEED contends that:

> *"As responsible citizens they will need to be able to evaluate the benefits and risks associated with developments in science and their applications."* (p.2)

The statements reflect on the arguments raised by Hazen and Trefil (1990) and Ryder (2001). Generally, the emphasis is on the need for people to attain some basic understanding of science and its implications to everyday situations. Solomon (2001) suggests some useful strategies for achieving scientific literacy. At the top of the list is the need for pupils to be able to "write and speak their ideas". She suggests that these skills can be achieved through training on oral presentations in science lessons, taking part in occasional role play and debate, following new developments is science through press and television (self-learning). Proficiency in the science language is definitely a prerequisite in these cases since a simplified version requires professionals and may lead to distorted meanings.

Similarly, SEED recommends that "pupils must develop a secure knowledge base and good decision-making and problem-solving skills". In addition schools have the responsibility to promote students' interest and enthusiasm for science and encourage them to ask well-informed questions and find answers. However, these are very bold statements and recommendations that do very little to assist teachers and schools to prepare meaningful lessons and conducive environments to facilitate the achievement of the objectives for scientific literacy.

2.13 Summary of the Views Expressed in this Chapter

Clearly, school science education has a beginning, and has been evolving ever since. The definition of what is science and the nature of science teaching (methodologies) in schools are strongly influenced by developmental changes in society's environment and changes in societal perceptions. Developmental changes on the environment depend, to a large extent, on the economic status of the society or nation, while changes in societal perceptions are impacted upon by growth in human knowledge. At the centre of the need to improve science education in schools is the desire to attain meaningful learning. It is generally agreed that meaningful learning depends greatly on the choice of instructional approaches (See figure 2.6).

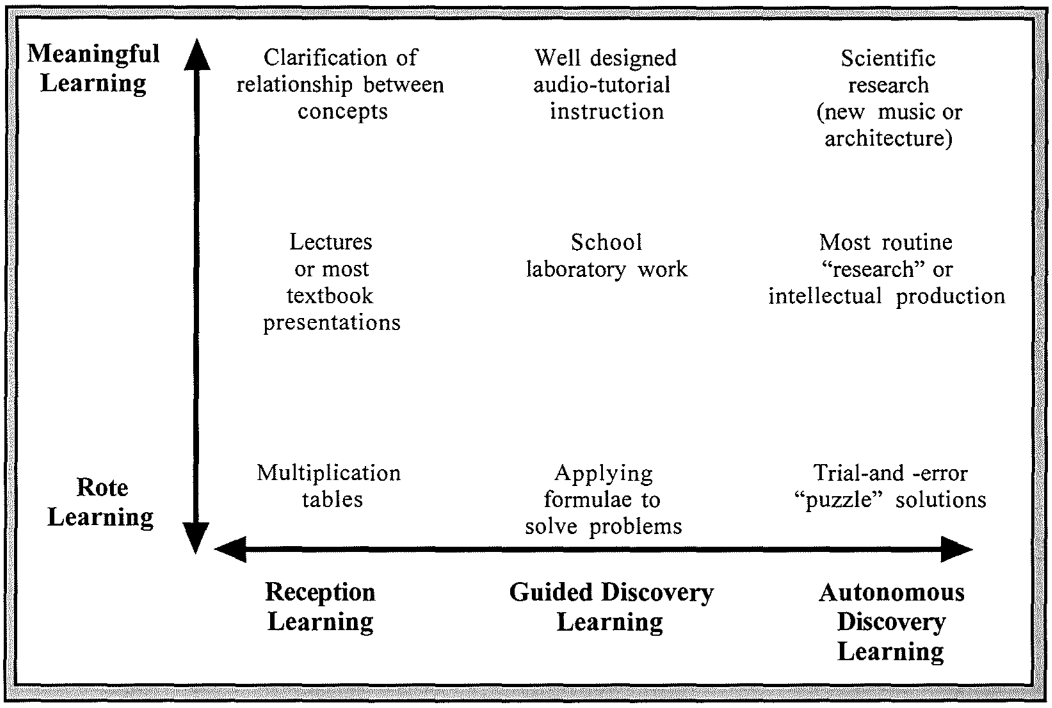


Figure 2.6 The Relationship Between Learning Outcomes and Instructional Strategies

Source: (Ausubel *et al.*, 1978)

Ausubel *et al.* (1978) provide a comprehensive comparison between the development of a learning outcome and the choice of instructional strategies. However, this model may not adequately represents new developments in school science teaching and learning, but it provides a good basis for discussions on what constitutes meaningful learning in the twenty first century. The model can also be used to question some of the claims by science educators which place strong emphasis on what has been described earlier in this chapter as pupil designed investigations. Evidently, the model illustrates the importance of using thinking skills for meaningful learning to occur. These thinking skills are the necessary tools required for an effective scientific literacy programme (See sections 2.9 to 2.11 of this chapter).

Interactive teaching and learning involves practical activities. Arguments raised in this chapter points to the need to engage learners in practical work. It is argued that through practical work learners get the opportunity to work in groups, engage in a thinking process of discussion, compare their ideas to those advanced by other pupils and eventually develop a critical mind. Investigating credible solutions to everyday problems by pupils is assumed to have a positive impact on the development of meaningful learning. The next chapter, therefore discusses practical work in school science. Special attention is given to the idea of pupils' ability to design their own investigating tools or experiments to provide scientific explanations to problems related to their everyday life.

CHAPTER THREE

PRACTICAL WORK IN SCIENCE

3.1 Practical Work in Science Education

Science teaching in schools, in some countries, has always maintained the tradition of imparting theoretical concepts and engaging learners in some forms of practical activities. This tradition has been in place for more than a century. This tradition stems from the curious nature of human beings (Millar, 1998). The immense benefit that human beings have had from observing nature, manipulating it and acting on it in varying ways, since the beginning of their time, is a major driving force behind scientific investigations of today (Woolnough, 1991).

However, there is a growing concern amongst science educators that school science education is in most cases failing to encourage and sustain this curiosity in pupils (Hodson, 1990; Woolnough and Allsop, 1985; Osborne, 1997; Hawkey, 1998). Research evidence strongly indicates that practical activities done in schools do not sustain the sense of wonder in pupils. Woolnough (1991) says this of practical work in English schools:

> *"There is much cheerful activity involved but, because the purpose of the exercise is not always clear, any sense of achievement or prizes won remains uncertain."* (p.3).

Apparently, the sense of wonder has been observed to be strong at primary level, declining slowly through secondary level and almost non-existent at tertiary levels (Poole, 1990). The observed trends in Scotland present a different picture in terms of measurements of levels of themes like enjoyment and interest in integrated science and physics. The trend shows a decline in these aspects from primary to S1 (age 12) followed by a remarkable rise from S2 to S4 (ages ~13-16). The primary, S1, and S2 pupils observed study science while the S3 and S4 pupils observed study physics. However, as pupils are introduced to more content, their levels of enjoyment, interest and like were observed to dramatically decline from S4 to S5 (age ~17) followed by a sharp increase at first and second year levels of University (Hadden and Johnstone, 1983; Reid and Skryabina, 2002) (See figure 3.1).

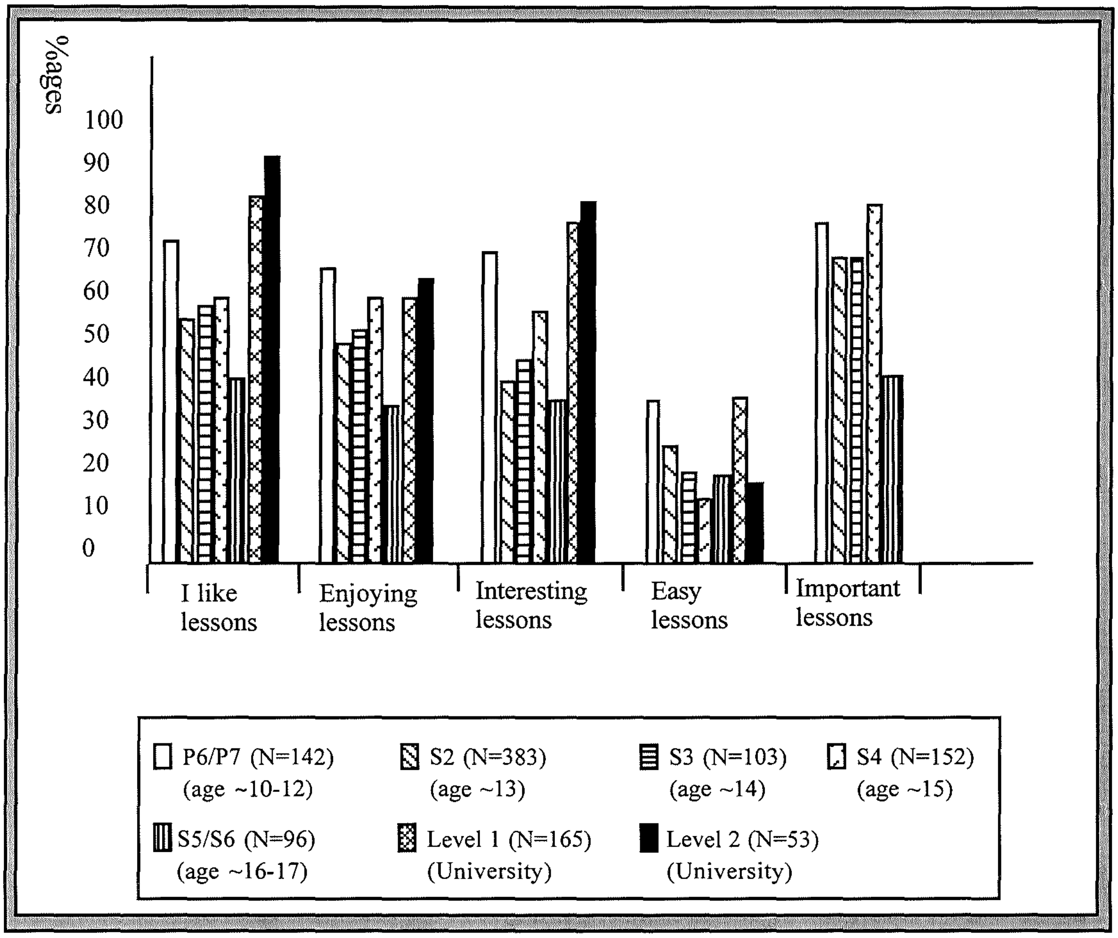


Figure 3.1. Pupils'/Students' Attitudes Towards Current Science/Physics Courses

Source: (Reid and Skryabina, 2002)

Writing from a Christian perspective, Poole expresses the view that for some people the "scientific explanations of the amazing world around them has the effect of banishing" astonishment. Osborne (1997) associates this decline to the failure on the part of science educators and policy makers to differentiate between 'doing science' and 'learning science'. According to Osborne, the two are not "one and the same thing". Doing science refers to practical activities meant to "... discover and establish new knowledge of natural and living world".

On the other hand, learning science involves a number of learning strategies of which practical work is a part. These views by Osborne are reinforced by Hodson (1990), who makes an observation that practical work as conducted in schools does not "... engage them (pupils) in 'doing science', in any meaningful sense". The general concern regarding science practical work in schools is how can it be used effectively to arouse pupils' curiosity and promote a sense of wonder in and outside school environment. However, research work in science education claims that practical work greatly enhances the different methods available to the teaching and learning of science in schools if and when used to fulfil its intended purposes (Osborne, 1997; Hodson, 1998). This is true, particularly during the early years of secondary science education as reported in Reid and Skryabina, (2002). The researcher takes on the position assumed by the Scottish Office Education Department concerning the aims of teaching science that:

> *"The major aim of science education is to encourage pupils to think and act as responsible scientists through providing opportunities for them to acquire knowledge and understanding of relevant concepts and through practising the problem-solving and practical skills associated with the scientific process of enquiry".* (SOED, 1994, p. 6).

SOED does not provide a definition for the concept of 'responsible scientist'. No literature material has so far offered a definition of this concept. However, SOED vaguely links the notion of responsible scientists to the ability of these scientists to demonstrate appropriate problem-solving skills or draw conclusions and make predictions leading to generation of socially acceptable new knowledge. Knowledge which promotes development of "a progressively deeper understanding of important scientific concepts" is regarded by SOED as a prerequisite for these problem-solving skills (SOED, 1994).

The big question being asked by many in science education is how best should school science teaching be organised and conducted in order for it to achieve this aim? The specific interest of this work is to investigate pupils' (early stages of secondary science) cognitive ability to identify, design and carry out experiments that provide the most reliable solutions to problems. The problems in this case have to be related to the pupils' everyday experiences.

It is asserted that meaningful science involves pupils actively investigating everyday problems using the scientific approach (SCDC, 1987; SEED, 1999; SCCC, 1996). This includes identifying and defining a problem, making hypotheses and deciding on variables to be manipulated, planning and setting up experiments to collect data, analysing the data and making conclusions. The question to be answered here is whether pupils, at this stage, have developed cognitive strategies that can enable them to plan and carry out experiments capable of providing a tenable solution to a scientific investigation?

The continuous review of the methods and strategies used in the teaching and learning processes in school science illustrates the importance of science to developments in society. Meaningful science education, for the purpose of this work, is seen as that which fulfils the aspirations and needs of a society. It is clearly obvious from historical trends that human needs and aspirations have increased with time (See chapter 2). An evaluation of these strategies and methods, therefore, should be carried out to establish their appropriateness to age and level of science education in schools.

These can be done by raising the following questions: what has been gained so far through the use of the current methods and strategies of teaching and learning science at the early stages of secondary science? Which scientific skills should be taught to pupils for them to be scientifically literate? At what stage in a child's cognitive development should these skills be developed and how? In this chapter the focus is on the aspect of engaging learners in school science practical work. The purpose of practical work in science, the role of laboratory activities in science lessons, and the perception of teacher and student on the place of experiments in scientific investigations are discussed. The discussions will be limited to establishing the place of experimentation in pupils' mind and their ability to identify the most significant experimental evidence that establishes the validity of a scientific theory.

3.2 Why Practical Work in Schools?

Millar (1998) presents a strong view that scientific knowledge depends mainly on the quality of evidence obtained through active investigations that take on the form of practical science. However, Popper (1963) points out that the sustainability of the scientific theory is heavily dependent on the extent to which evidence or data collected falsify it. This means that the survival of scientific knowledge greatly depends on the resistance of the underpinning theories to criticism or falsification (Popper, 1963). Throughout human history, challenges to strongly held theories have either been ignored or met with a strong resistance.

Kuhn (1962) asserts that ideas based on strongly held theories, when challenged by whatever form of evidence, tend to resist change. Popper stresses that it does not matter how many times the theory has been verified. It just takes one falsifying evidence to nullify it. Millar (1998) considers science as a study of the nature of the universe that has so far produced reliable knowledge and understanding of natural phenomena. Millar also acknowledges the notion of falsification proposed by Karl Popper. However, Millar is of the opinion that the falsification theory "... does not apply in the teaching laboratory (even if it applies in 'real science')". Pupils in science laboratories should be more concerned with verification of existing facts to cover the content of the science syllabus.

Millar asserts that science education should aim at passing this reliable knowledge and understanding of the material universe to young people which modern society feels is valuable to them. Passing on this knowledge and understanding to young people will inevitably "... involve acts of 'showing' and 'telling'" (Millar, 1998). On the whole, practical work, which is primarily the 'showing' aspect of science teaching and learning, is considered an essential mode of instruction in the teaching of school science (Woolnough, 1991; Millar, 1998; Woolnough and Allsop, 1985; Tamir, 1991).

To highlight some of the indicators of the importance attached to practical work, significant portions of the grants from governments for the running of schools has and is still been allocated to building new laboratories and improving on old ones (National Commission on Education, 1993; Wellington *et al*., 1994; Woolnough, 1991). For example, science departments in Botswana schools allot about two-thirds of their annual budget to the provision of chemicals, apparatus, and instruments, including the repair of existing instruments, general maintenance of the laboratories, and transporting pupils on educational excursions. Teachers spend more than half of their teaching time planning laboratory activities, collecting materials needed for use during the practical activities and supervising these activities (Hodson, 1990; Wellington *et al.*, 1994).

Practical work is believed to engage students effectively in an active learning situation through practical activities which include laboratory work, problem solving, active interaction with the natural environment through guided investigations (Wellington *et al.*, 1994). Through this active involvement, it is claimed that a student will develop appropriate practical skills and techniques, get a 'feel for phenomena' and appreciate being a problem-solving scientist for a day (Woolnough and Allsop, 1985). Science educators and science curriculum developers have always considered the development of the main aims of practical work as a means to sustaining and developing the curious nature of human beings. The ability to interact with nature, and the eagerness to manipulate it, have been assumed to be a way of promoting hands-on experience in school science from the last third of the twentieth century (Hodson, 1990).

However, science teachers from different schools have had varying perceptions of these purposes of practical work. Some teachers have found it difficult to embrace the use of hands-on practical work as an enjoyable and effective form of teaching and learning in science largely due to "... costs or through a belief that external examinations would not adequately reward such a heavy investment of time and energy" (Hodson, 1990). Similarly, Nott (1997) outlines some of the reasons for the unpopular nature of the sciences, particularly practical work, in English schools:

> *"There are few well-qualified teachers to teach them and examinations stultify any attempts to teach them imaginatively. In secondary and higher education there is a shortage of equipment for students' laboratory work which mainly consists of demonstrative and illustrative work and verifications of known knowledge, principles and facts."* (p.51).

Does the kind of practical experiences provided in school science result in the acquisition of desirable scientific skills? Why is it still reported in some parts of the world that sciences are unpopular amongst pupils in schools despite the emphasis by school science curricula that student should be taught science such that they are able to appreciate and enjoy the work of scientists? Do students who are academically excellent in science necessarily have the 'feel' for science? The logical way to address these questions is to debate issues relating to what is considered, by curriculum developers and science educators, effective school science practical work.

3.3 The Effectiveness of Practical Work in Schools

The educational effectiveness of practical work has always been questioned in some developed countries. Schools in these countries are normally characterised by good supplies of laboratory facilities, sizable amount of time allotted for practical activities, enough staff for teaching and technical assistance in laboratories, small class sizes and adequate inclusion of assessment of practical skills by the examination systems (Wellington *et al*., 1994; Woolnough, 1991). Lack of these factors is assumed, particularly in developing countries, to be the cause of failure by planned practical activities in school science to fulfil their purposes (Zesaguli, 1988; Prophet, 1988).

On the contrary, the ineffectiveness of practical work is sometimes associated with the nature of the practical activity planned for the lesson (Osborne, 1997). The practical activity may be characterised by the use of complex apparatus, the long time taken by pupils to get results from the activity, the use of dangerous chemicals, unfriendly instructions in the activity and lack of an obvious relationship between students' experiences and the purpose of the practical activity (AAAS, 1989).

Based on a series of investigations conducted in schools and tertiary institutions in Scotland, it was found that the emphasis on doing "... much practical work does not transmit to students the outcomes intended by the designers." (Johnstone and Wham, 1982). This research work indicates that greatest learning occurs when there is a combination of formal skills teaching and miniature projects which place demands on students to design and conduct "their own experiments using the skills taught" (Vianna, 1991).

It is possible to look at the wider implications of encouraging pupils to engage in group activities and discussions and the notions of affording pupils the opportunity to design experiments and interpret their results are discussed by Osborne (1997). However, Osborne is arguing for a move away from too much emphasis on laboratory investigations and, instead, he suggests that pupils discuss the extent to which daily life instances are scientifically true. Another alternative suggested by Osborne is that pupils can be involved in an activity of rearranging jumbled up scientific sentences or false concept maps through group discussions. These suggested alternatives to laboratory investigations, used on their own, cannot develop conceptual understanding of scientific facts and principles (Osborne, 1997).

The Scottish HM Inspectors recommendation, reported by the Scottish Executive Education Department (1999), states that improving science education for pupils (5-14 years) in schools lies in the use of a wide range of learning and teaching strategies. Whether the Scottish HMI recommendation implies the incorporation of the suggested alternative approaches to conducting practical activities that promote thinking rather than doing science is not clear.

Hodson (1998) registers the concern over the inability of science teaching to enable border-crossing by pupils into the culture of science. Hodson is of the view that school science teachers and curriculum designers are still embracing the distorted notion that "observation and experiment can provide secure and certain knowledge". This assumption, according to Hodson, has for many years promoted the emphasis on 'doing' science as opposed to 'thinking', which comes from discussions, arguments and coming up with concerted meanings. Hodson, therefore, advocates a shift from pupils as technicians to pupils playing the role of 'creative scientists' through inquiry which involves laboratory work, field work, computer simulation activities.

According to Hodson, the inducement and zest for the increased development of the pupils' conceptual and procedural knowledge is sustained by their "... ownership of and sole responsibility for the inquiry". Publishing the inquiry work and presenting the findings of the inquiry to colleagues for that critical feedback is claimed by Hodson (1998) to reinforce the feeling of ownership in terms of decision making and knowledge development. Hodson asserts that, in this free-inquiry approach, the teacher should offer minimal support to avoid 'interfering with the pupils' thought processes'. Hodson then summarises the effectiveness of the inquiry approach in the following manner:

> *"In any scientific inquiry, students achieve three kinds of learning. First, enhanced conceptual understanding of whatever is being studied or investigated. Second, enhanced procedural knowledge - that is, learning more about experiments and correlational studies, and acquiring a more sophisticated understanding of observation, experiment and theory. Third, enhanced investigative expertise, which may eventually develop into scientific connoisseurship".* (Hodson, 1998, p.102).

Research evidence demonstrates that equipping teachers with more skills for handling practical work in schools, on its own, simply does very little in ensuring a more authentic presentation of science practice (Matthews, 1994). Even a positive attitude towards scientific inquiry is not an assurance that such a teacher will consistently plan practical work in accordance with his/her views (Hodson, 1998).

The immediate need to cover much of the syllabus content, drill pupils to pass the examinations (Nott, 1997) and general lack of control on the curriculum by the teacher simply dictate on the nature of the purpose of practical activity planned. Nevertheless, some science educators assert that a long lasting effective change will emanate from a situation where teachers are accorded a "substantial measure of control of the curriculum" (Connely and Clandinin, 1988). This suggestion by Connely and Clandinin perhaps, may not be appreciated by policy makers and politicians but may be greatly welcomed by teachers and science educators.

3.4 Current Practice in School Science Practical Work

The nature and the practice of the 'showing' aspect of science education or practical work is described by Woolnough (1991) as having considerably undergone changes with time. This observation is confirmed by Hodson (1990), who expresses his professional discontent with the current practice in England and Wales schools that practical activities, especially those associated with laboratory work, are "... ill-conceived, confused and unproductive" (Hodson, 1990). Hodson further asserts that most pupils do not attach any educational value to the inclusion of practical activities in their learning of science.

In England, for example, Woolnough (1991) reports that some teachers still consider practical work a waste of time and resources. Despite a wide range of practice available in schools, some teachers still resort to the use of 'chalk and talk'. To reinforce further the discontentment with current practice, Wellington (1998) is of the view that practical work in school science has not effectively reflected what he termed 'real science'.

Woolnough and Allsop (1985) cite a scenario in the English and Welsh schools where it is reported that children in primary schools are becoming increasingly involved with scientific activity while science students in higher education have traditionally found the practical class unessential, if not a low status and largely unexplained part of their courses. The perception that students in higher levels have of practical work is, "... a succession of exercises, with apparatus, through which they are led in the hope of solving an unasked question" (Woolnough and Allsop, 1985).

In Scotland, Aitkenhead (2002) looking at the teaching of science in S1 and S2 (ages 12-14) and the teaching of physics in the middle years, S3 and S4 (ages 15+), reports that at least two thirds of the total sample in S2 pupils indicate that science is an enjoyable, interesting subject and easy subject. The physics component of science is considered difficult by roughly half of the total sample of S4 pupils. Nonetheless, both groups highly regard practical work as enjoyable. Perhaps the reason for this overwhelming regard comes from the opportunity pupils get during practical activities to discuss ideas in groups as evident from the high percentage (>80%) of positive responses shown towards the preference of working in groups.

Less than 30% in both S2 and S4 groups prefer teacher planned investigations (Aitkenhead, 2002). Surprisingly, the preference towards teacher planned investigations is even greater in S4. Much evidence suggests that this trend illustrates the effect of the insecurity observed in adolescent. Noticeable in this comparison is the observation that pupils in S4 are more concerned about learning more factual information and remembering it, while pupils in S2 still indicate an interest in science as an investigative activity. These differences are noted by SEED (1999) who highlight the exceptionally high performance of 13 year olds in science practical tasks published by the Third International Mathematics and Science Study (TIMSS) 1996-1997.

It is also reported by SEED that pupils in S1/S2 demonstrated limited understanding of investigative work which could possibly result from the illustrative nature of the practical activities organised at that level. Pupils are usually asked to carry out practical activities or observe demonstrations that require following a set of instructions from worksheets to verify known concepts (SEED, 1999).

Hodson (1990) reports on several studies conducted in English schools that indicate that a significant population of children involved with school science regards practical work as a 'less boring' alternative to other methods, rather than as something to be enjoyed in its own right. He asserts that pupils hate doing anything that they are asked to do following the practical activity, especially writing down notes, and being asked questions on what has happened. Most significantly, pupils hate practical activities where things go wrong. Hodson is of the view that most practical activities planned in schools are dull and as such suppress curiosity in learners.

Practical work would claim its place as having a motivating power "... if we allowed children to pursue their own investigations, in their own way" (Hodson, 1990). Whether this is a practical proposition is open to question. On the contrary, Aitkenhead (2002), obtained the following results with respect to S4 pupils' preference towards own-planned investigations or teacher-outlined investigations:

> *"A larger percentage of S4 pupils prefer to work alone and yet a smaller percentage of the same pupils wish to be left on their own to plan investigations".* (p.25).

According to Aitkenhead, this could possibly be interpreted as suggesting that some pupils enjoy carrying out individual experiments coupled with support from the teacher. The aspects of adequate amount of equipment that will enable individuals to conduct their own experiments and safe handling of these equipment are some of the restricting factors that cannot be ignored when debating Hodson's proposal.

Almost everyone who has done science during their school days still has vivid memories of some practical activities he/she took part in or observed during science lessons. The memories will be predominantly those associated with exciting results from an experiment, accidents during experiments, observing the unexpected and seeing science in action generally. Unfortunately, very few can be able to demonstrate an understanding of skills learnt during these activities. Neither can the majority of people who did science in school apply the thinking skills that practical work is purported to develop to explain natural phenomena scientifically.

What has been achieved through the use of practical work in school science? What impact is there on the way people perceive and explain natural phenomena? Are curriculum developers and policy makers satisfied with the extent of the impact? If not, what can be done to improve on the situation? (Woolnough and Allsop, 1985; Hodson, 1990; Millar, 1998; Johnstone and Wham, 1982). Perhaps it is necessary to look at some of the main purposes of practical work in school science.

3.5 Purposes of Practical Work in School Science

White (1971), concerned about the decline of radicalism, an emphasis in education that advocates social equality, notes that:

> *"The 'new' thought in education has avoided ends and substituted an obsessive devotion to means. ... our very fascination by machinery has made us forget what we are about".* (p.274).

White refers to the 'ends' as products of an education system designed to "create a good society". In this good society, schools must provide a compulsory curriculum in the higher forms of thought to all 'normal' children. Special assistance must be given to those who show signs of weariness until they get to the end of the programme. An education system that aims for 'means' relegates some individuals to a lower status in society denying them the opportunity to acquire higher forms of thought. White is against curricula tailored to meet individual's needs at an early level in education.

Contemporary societies function as units that embrace democratic principles characterised by equal opportunities and freedom of expression. The need for an individual to function well in society has therefore become one of the main emphasis in educational outcomes (SEED, 1999; AAAS, 1987; Presidential Task Group for a Long Term Vision for Botswana, 1997; Science Council of Canada, 1984). Intrinsically, teaching and learning approaches must be designed to achieve this major goal in education. Selecting the use of a particular approach, therefore, should be seen as targeting the development of specific skills in learners. This exercise defines the purposes of the approach selected.

Practical work is considered an essential approach in school science teaching and learning. For example, the Scottish Office Education Department (SOED) (1994) outlines some of the main reasons or purposes for including practical work in secondary school science courses. These purposes are believed to have effects on individual pupils or small groups of pupils. These are:

(1) To gain first-hand experience of scientific equipment, materials, living things and artifacts;
(2) To practise basic skills such as observation, measurement and manipulation in different contexts;
(3) To learn how to behave safely and responsibly;
(4) To practise specific techniques and procedures;
(5) To realise the limitations and accuracy of equipment;
(6) To extend and consolidate knowledge and understanding through the use of concrete materials; (See Wham, 1977)
(7) To gain insight into applications of science;
(8) To design and carry out scientific investigations; and
(9) To observe phenomena through pupil experiments or teacher demonstrations.

Without assuming that this list is a definitive set of aims, it is worth exploring them critically in terms of their teaching and learning implications. However, implicit in these aims is the element of motivation. It has been noted already that, generally, children at the early stages of secondary science regard practical work as an enjoyable alternative to other methods of teaching science. No evidence so far has been produced to suggest the link between enjoying science and development of the required thinking skills through practical activities. Hodson (1990) is of the view that this link could be developed as long as curricula are designed to allow pupils to "pursue their own investigations in their own way". This argument is explicit in the purposes of practical work suggested by HM Inspectors of Schools through SOED (1994).

Purposes (1), (3), (4) and (5) emphasise the development of basic laboratory skills necessary for carrying out investigations. Teachers usually find it difficult to determine those skills that are necessary for long term benefit. The tendency, therefore, is to teach those skills that pupils find enjoyable and those skills that teachers consider easy to plan for (Hodson, 1990). As mentioned earlier in this chapter, practical activities requiring pupils to follow a set of instructions to solve a teacher determined problem does very little to result in the acquisition of skills.

Hodson (1990) suggests that improving this state of affair requires teachers to "teach only those skills that are of value in the pursuit of other learning" (transferable skills). It is, however, still debatable as to whether skills are really important and if so which ones are important to teach. Some skills like observation and measurement which are not context dependent have been observed as transferable. Reid and Yang (2002) concluded that some skills like those associated with problem-solving are context dependent and not easily transferred.

Millar (1998) asserts that certain practical activities need not be undertaken at all, particularly, in the areas of the science content where conceptual understanding can be developed from lecturing to pupils. Millar argues that as long as a practical activity requires little expertise and the outcomes of the activity are easy to remember and recall, pupils should not be asked to waste time doing them. Instead, teachers must "ensure that those skills (transferable skills) are developed to a satisfactory level of competence" (Hodson, 1990).

On the contrary, the SOED (1994) still has confidence in the illustrative practical work but acknowledges its limitations. The SOED asserts that, besides doing very little to teach skills associated with "planning experiments, analysing the outcomes of an investigation, overwhelming open-endedness and creativity", illustrative practical activities provide pupils with opportunity to "follow instructions, consolidate understanding and practise important techniques or procedures" (SOED, 1994).

Purposes (6), (7), (8) and (9) express the desire by instructional designers to develop thinking skills appropriate for scientific investigations and the use of such skill in novel situations in pupils. The effectiveness of practical work in learning scientific knowledge has been questioned strongly. Yager *et al.* (1969) reported on a study conducted in the United Sates of America that compared the effects of three teaching styles: lecture/discussion, laboratory work/discussion, and lecture/teacher demonstration/ discussion. The evidence from the study revealed that practical work had significant advantage over others methods only "in respect of the development of laboratory skills" (Yager *et al.*, 1969).

The SOED (1994) contend that practical activities "extend their (pupils) understanding of concepts and principles" in certain areas of science like examining structures of living things through microscope, observing the passage of light through lenses and others. It is also believed that teacher demonstrations provide answers to "questions that would otherwise be asked several times" (SOED, 1994) by individual pupils when working on their own. The alternative to practical work suggested by Osborne (1997), pointed to earlier in this chapter, is assumed to be efficient in developing conceptual understanding as well as establishing interest in pupils towards science. This alternative approach involves the use of group work and discussions.

3.6 Laboratory Activity as a Component of Science Practical Work

It is hard to imagine science teaching that does not involve pupils in some laboratory activities. Why? Some people attribute this notion to the nature of science as the study of the natural environment. For example, Solomon (1980) says this of science:

> *"Science teaching must take place in a laboratory .... Science simply belongs there as naturally as cooking belongs in the kitchen and gardening in the garden. ... so the teaching of it must involve real contact with those aspects of nature which are to be studied"* (p.13).

In addition to Solomon's opinion, Tamir regards the laboratory activities as part of the school science practical work that offer a greater number of

> *"... opportunities for satisfying natural curiosity, for individual initiative, for independent work, for working in one's own time and for obtaining constant feedback regarding the effects of what one has been doing"* (Tamir, 1991)

These are some of the current opinions expressed about laboratory activities in science teaching. The ideas expressed here do not necessarily include other forms of practical work but may touch on some common aspects of all practical activities. The purpose of this section, therefore, is to discuss the laboratory activity as an important aspect of practical work and its historical nature in science education. When did the idea of laboratory work instruction in science come about? How did it evolve through the years to the present times? These question are important since they help establish the rationale for laboratory activities planned in schools as part of the school science practical work.

Where it All Started

In this section, a brief account of the origin of laboratory work in science teaching is given. The focus is on the developments of the purposes of laboratory work throughout its evolving period. The term laboratory work, in this case, is associated with experimental work. It is used loosely to refer to those school science practical activities that are planned by science teachers and that requiring pupils to carry out experiments inside a school science laboratory.

Wham (1977) traces the use of laboratory work in science teaching at tertiary institutions from the early nineteenth century during the time of Friedrich Stromeyer of the University of Gottingen. Of significant influence to the use of laboratory work in the UK is the pioneering example of Thomas Thomson who established the first undergraduate course in practical chemistry at Glasgow University in 1818 (Duff, 1997).

The Demonstration Method versus the Individual Laboratory Method.

The laboratory work of the time was restricted to occasional demonstrations meant to "capture the interest of the students" (Jenkins, 1998). According to Jenkins (1998), besides the concern on the cost and design of laboratories, the dilemma rests in justifying the expensive laboratory teaching in terms of attainable aims. Other minor concerns involved aspect of safety on the use of laboratory chemicals and apparatus.

By the mid-nineteenth century, the demonstration method in science laboratory was now replaced by the individual laboratory method advocated by Henry Edward Armstrong in England and Wales (Woolnough and Allsop, 1985) and, some educators in the United States of America (Wham, 1977). This purpose of the laboratory work in science was primarily meant to enable students to discover new scientific knowledge on their own (Solomon, 1980) as opposed to verifying taught concepts. This new developments in laboratory science teaching resulted in the construction of laboratories and provision of apparatus (Woolnough and Allsop, 1985). The investigative approach was also extended to school science and restricted to only those topics considered practical and less hazardous to learn practically (Woolnough and Allsop, 1985).

Laboratory work in school science for England and Wales started as early as the mid-nineteenth century (Solomon, 1980; Jenkins, 1998; Woolnough and Allsop, 1985). The activities were characterised by the use of the lecture-demonstration mode of instruction, primarily to illustrate and verify scientific concepts (Woolnough and Allsop, 1985). This practice soon changed as schools and those who funded school science education bought into the Armstrong heuristic method towards the end of the nineteenth century.

Armstrong's science course, as outlined in Woolnough and Allsop (1985), consisted of six stages:

(1) Lesson on common familiar objects.
[Involves observation, description, classification]
(2) Exercise in measurement.
[Numerical measurements in a physical setting, e.g. volume, density]
(3) The effect of heat on various elements and compounds.
[Observation and recording]
(4) The problem stage.
[The most radical, with problems such as determining what happens when iron rusts, separating the active from the inactive constituents of air, determining what happens when sulphur burns, emphasising observation and hypothesising]
(5) Quantitative determination of the composition of compounds.
(6) Introducing theory, particularly the molecular and atomic theories.

The fourth stage completely embodies the heuristic approach. However, the approach emphasised continual use of the method of enquiry, the importance of individual work, complete and accurate recording of all observations, exact representation and correct conclusion, and no concern on the learning of the subject matter. This approach required laboratories to be well equipped and teachers to be trained in the heuristic method. Criticism of this method are discussed in chapter two. However, Solomon (1980) articulately sums up the fall of Armstrong's method of science:

> *"It was not the observations or experiments which were at fault, as they might be in the school laboratory, but the interpretations which were to be put upon them. If the findings of famous scientists could be thus reversed, what hope remained that children could make valuable discoveries by their own unaided experiments?".* (p.19-20).

Post World War I and World war II Developments

Too much time spent in the laboratory trying to emulate experienced and trained scientists was the main focus for those opposed to Armstrong's individual method in England and Wales (Jenkins, 1998). It is asserted that the students and pupils did not acquire enough conceptual knowledge in science necessary to help them demonstrate an understanding of science in and outside the school (Woolnough and Allsop, 1985). The introduction of biology and other highly abstract theories, in England and Wales, like Atomic and Molecular theories presented a challenge to the use of the heuristic method (Kerr, 1966). These shortfalls of the heuristic method in England and Wales gave rise to new approaches to teaching science designed to balance the laboratory work with content teaching.

The General Science courses were primarily introduced after the first World War to develop a scientifically literate society, a move that was criticised for ignoring the training of scientists as technological advancement increased. Less emphasis was placed on inquiry work and laboratory activities (Woolnough and Allsop, 1985). Woolnough and Allsop contend that the Nuffield Science courses were meant to address the shortage of scientists in an era where scientific knowledge was mounting and technological advances were escalating. These were the indicators of power for any given nation and, thus, the need to excel in those areas became paramount.

However, Woolnough and Allsop (1985) challenge the notion that practical work done in school science can be equated to the real scientific investigation. They acknowledge that indeed practical work in school science is practical in its nature, but question its authenticity as a science. This challenge is addressed particularly to laboratory work in school science, especially at the early secondary level. Jenkins (1998), referring to laboratory teaching in England and Wales, asserts that laboratory teaching of science in schools is still a "prisoner of the past". Commenting on the future role of laboratory work in school science teaching, Jenkins says that

> *"... school science teaching without laboratory work may be unthinkable," but, "attributing to laboratory activities outcomes that cannot realistically be met, or that might be met more effectively in other ways, is no longer an option".* (Jenkins, 1998, p.49).

The past practice that Jenkins is referring to is described by Solomon (1980) as characterised by providing "evidence in support of taught theory and not designed as a child-orientated exercise in research". Typically the practical evidence offered to pupils was an illustration of a situation where "the theory was announced and then practical illustrations were paraded in its honour" (Jenkins, 1998). To illustrate the differences between a typical school laboratory and a scientist's laboratory, Tamir (1991) presents a table of activities carried out in each laboratory (See table 3.1)

Activity	Scientist's Laboratory	School Laboratory
Identifying problem for investigation	Scientist	Textbook/teacher
Formulating hypothesis	Scientist	Textbook/teacher
Designing procedures & experiments	Scientist	Textbook/teacher
Collecting data	Technician	Student
Drawing conclusions	Scientist	Students & teacher

Table 3.1 Who Does What in the Science Laboratory.

Source: (Tamir, 1991)

It is obvious from the table 3.1 that in a typical school laboratory the student's work corresponds, largely, to that of a technician, which is data collection. Data collection involves the use of measurement, manipulation and observation skills, which, according to Bloom's taxonomy of cognitive skills, do not require high order thinking skills (Bloom *et al.*, 1956). All other activities outlined in the above table require high order cognitive skills, like, making judgment, analysing, evaluating, calculating and many more. The evidence presented on table 3.1 supports the argument raised by Woolnough and Allsop (1985), Solomon (1980) and Jenkins (1998) concerning the authenticity of the scientific investigations done by pupils in schools.

Watson and Fairbrother (1993) report on the OPENS project that was set up to investigate the potential for an open-ended work in science laboratories in England and Wales schools, made the following conclusions:

- A major difference between investigative practical work and much traditional practical work is the extent to which pupils are involved in thinking about the process in which they are involved.
- A lesson structure for investigations should, therefore, allow time for thinking need.
- Making practical work open does not mean that the teacher should no longer intervene in the practical work, but rather that the nature of that intervention is different - aimed at providing structure in an open situation.

3.7 Experimental Work in Schools

Johnstone (1997) reiterates the main purpose of having science in the school curriculum, which he claims is embedded in the nature of science, as providing an opportunity for young people to be introduced to a way of questioning which yields information from objects and helps to explain phenomena. According to Johnstone, achievement of this purpose is much less clear. His view is that:

> *"Although most science curricula advocate the use of practical work, there is the paradox that little cognitive gain is measurable as a result of practical work, and such psychomotor skills as are learned are generally trivial and of short-term value."* (Johnstone, 1997, p. 227).

Like most advocates of the investigatory approach, Johnstone believes that the strength of science lies in carrying out experiments in class which have so far proved to be the best methods of providing solution to problems with some degree of reliability.

However, Johnstone's suggestions were targeted at the teaching and learning of science at university level. Arguments raised in this chapter do confirm that this scenario described by Johnstone do prevail at lower levels of secondary science education. It has already been established that practical activities in school science have to emphasise the teaching of process skills. These skills are assumed to equip pupils with the ability to investigate real-life problems using the scientific approach with the primary aim of coming up with a scientific explanation. Some people argue, however, that adopting this approach has the potential to limit the amount of theoretical content prescribed by the science syllabus. In this context it is worth noting that people do not really need knowledge of science concepts to survive in this world. Whenever in doubt they can call the experts (Johnstone, 1997).

The first years of secondary school science education are perceived by many curriculum designers and educators as suitable for orientation of pupils into the science world (SED, 1969; National Commission on Education, 1993; Science Council of Canada, 1984; SCCC, 1996). This perception does imply that whatever is contained in the syllabus for these level should primarily emphasise skills development, particularly those associated with experimenting or the processes of science as describe earlier in this chapter.

Expected versus Common School Practice

In Botswana, for example, pupils do not carry out investigations which lead to a possible explanation for a phenomenon. Instead, teachers plan the experiments to investigate problems which they (teachers) have already defined in their own language. This approach provides the opportunity for the teachers to be in control of the lessons and cover the syllabus content in readiness for the terminal examinations at the end of the three years. Eventually pupils are reduced to the status of laboratory technicians who have the primary role of collecting useful data for teachers without really understanding the purposes of the whole exercise.

The SEED (1999) reports the findings of Her Majesty Inspectors (HMI) of schools in Scotland which indicate that experimental work in most schools visited still take on the form of the 'cook book recipe' approach. The report says that, even though pupils are provided with the opportunities to carry out experiments, these are often characterised by following instructions from textbooks or worksheets. To support the assertion made by Johnstone (1997), the report of the HMI on primary and lower secondary science education states that:

> *"HMI found little evidence of science teachers planning what purpose practical work (experiments) would serve and how it would enhance pupils' learning or attainment. Pupils were given too few opportunities to develop skills of investigating, including planning, collecting evidence, recording and presenting and interpreting and evaluating."* (SEED, 1999, p. 14).

However, how do teachers do this when current pressures almost seem to preclude it. Ironically, the guidelines meant to assist teachers to plan successful science lessons do not specify exactly what they ought to do. This presents some problems, particularly to the inexperienced teachers, who are yet to explored what works and what does not work in the classroom. Prophet (1988) asserts that such an encounter prompts teachers to adopt the easier strategies or methods, and these are mostly influenced by their own experiences during secondary education. In other words the inexperienced teachers try to emulate their own secondary school science teachers ways of teaching.

3.8 Curriculum Emphasis Based on Contemporary Science Education

Despite these classroom practices reported in some cases, most recent curricula initiatives emphasise experimentation, which, according to Howe and Smith (1998), have indicated a shift towards a contextualised experimentation. Pupils, in this respect, are expected to investigate life processes and other natural phenomena in order to offer scientific explanations for their occurrences and develop positive attitudes towards the scientific method of investigation (SOED, 1993; Department of Education, 1995).

Evidence in the literature on practical work in schools suggest that practical skills emphasised in the schools are not always perceived relevant for most pupils' expectations. There is also the question of whether these skills are transferable. It is the contention of this project that the ability of pupils at junior secondary level to transfer skills they learned in one context to a novel context is still not effective. However, there is a chance that illustrations or demonstration exercises preceding the practical skills development in a practical activity my make the science tangible. Incorporating 'fun' in practical skills development activities has been suggested as another positive innovation asserted to 'bring science alive' and 'add humour'. The contemporary focus for practical work is to develop the scientific method of enquiry in pupils.

This project, therefore, intends to explore the development of practical skills associated with the scientific method of enquiry in the *minds* of lower secondary school pupils. This involves the abilities of these pupils to plan which variables to explore, how to manipulate apparatus in accordance with the plan of the experiment, recording the results that are observed and comparing the results with those of other pupils, within the same hypothesis test (Howe and Smith, 1998). This gives a picture of what is involved in experimentation only.

However, experiments are carried out to test hypotheses in a problem solving situation. The pupils, therefore, are also expected to formulate predictions, that is, decide on the nature of the results to be obtained, and draw conclusions based on the pattern presented by the results they collected. Pentz and Shott (1988) stress the importance of recording some of the unexpected results, since they are important to refer to when making conclusions. It is apparent, therefore, that making observations and other skills used during experimentation require pupils to have some knowledge of the content domain within which the problem being investigated is based.

Driver (1983) contends that whatever is more apparent to the scientists may not necessarily be so obvious to the pupils. She suggests that whatever activities teachers plan for the learners should consider the ideas they (the pupils) bring to the learning tasks. Expectations on the roles of pupils during experimentation should not be equated to those of the experienced scientists. This contention, therefore, highlights the importance of the nature of the investigations to be carried out by pupils in schools and the amount of information to be provided by the teacher in order to minimise unwanted doubts and questions on the part of pupils and sustain their interests in the task. The next chapter therefore, explores some of the theoretical model of cognitive development influencing current thinking or ideologies in science education.

CHAPTER FOUR

THEORIES OF COGNITIVE DEVELOPMENT

4.1 Introduction.

Science teaching and learning have had numerous factors influencing them. These factors are outlined in chapters two and three. One of the most significant factors that prompted the Western countries urgently to review the content of the science taught in schools and the teaching approaches used was the successful launching of the Sputnik in 1957 (Bliss, 1995; Kerr, 1966; Novak, 1978). America, England, France, Germany, Canada, Sweden, and Australia invested substantially on the development of new science curricula (Bliss, 1995) designed to improve on two aspects of science: content and methods. Jenkins, writing in 1979, reviews some of the outcomes of the initiatives undertaken in England and Wales to establish a reformed school science curriculum:

> *"By 1960, over 60 percent of sixth-form boys were specialising wholly in science and/or mathematics. One non-scientist, reviewing the post-war grammar schools in 1960, concluded that the arts subjects were forced to recruit 'the weak students or careful plodders' and occasional 'gifted eccentric' flying in the face of fashion".* (p.99)

It was hoped that, with this new improvement in science teaching, a continued existence of England and Wales as leading scientific and industrial nations would be sustained and improved. This claim was made by Connell and James in 1958 (cited in Jenkins, 1979). Most disappointing was the realisation that, despite the huge investments and the interest shown by pupils to do science, children in general found learning science difficult (Bliss, 1995). This problem still prevails in contemporary teaching and learning of science.

The new curriculum reform initiatives, in the attempt to introduce innovative teaching and learning approaches in school science, engaged psychological aspects that focused on the child's cognitive and affective development (Bliss, 1995). The leading authority in these psychological aspects at the time was Jean Piaget.

4.2 Piaget's Cognitive Development Theory.

Many educators in the 1960s and the 1970s were directly influenced by the work of Jean Piaget (Bliss, 1995). Piaget was born in 1896 in Neuchatel, Switzerland. He studied biology from which he derived the notion that biological development, besides maturation and heredity, is also due to variables in the environment. This finding is believed by many to have been instrumental in shaping his views of cognitive development. He later described cognitive development as a "process of adaptation to the environment and an extension of biological development" (Wadsworth, 1989).

Piaget moved from biology to philosophy and eventually to psychology. These moves are seen as having directly influenced his beliefs in his theory of intellectual development. His interest in the idea of how children think grew while working in Binet's IQ test laboratory in Paris, France (Huitt and Hummel, 1998). Through his work with children, he observed that young children's answers are qualitatively different (Bliss, 1995) compared to those of older children. His fascination with children stemmed from analysing the wrong answers that children gave to intelligence tests.

To Piaget, this revealed something of how children construct knowledge of the world around them (Rowell and Dawson, 1979). From this observation, Piaget concluded that young children are, after all, not stupid, but, instead, they answer the questions differently from the older ones because they think differently. It was clear now to Piaget that concepts which are self-evident to adults are not at all obvious to young children, but are learned over time (Pycha, 2000).

In recognition of his scientific contributions, Piaget was honoured by organisations and several universities around the world, including the American Psychological Association and Harvard University. Piaget's theory can arguably be considered to have had long lasting effects on educators' compared to other theories of the time. According to Bliss (1995), many of Piaget's ideas are already part of the primary and the early secondary schools curricula in England and Wales, as exemplified by ordering and classifying objects (Bliss, 1995).

Piaget's work is primarily focused on describing in a very systematic way the "growth and development of intellectual structures and knowledge" (genetic epistemology) (Wadsworth, 1989). Wadsworth notes that Piaget's work was neither directly concerned with predicting behaviour nor with how to teach children. Vuyk (1981) asserts that Piaget saw his work (genetic epistemology) as "a science studying the conditions that make the development of knowledge possible". Bliss (1995) also cautions that Piaget's work does not stem, as it is often believed, from a psychological concern about children themselves as individuals, but from "philosophical issues about the structure of knowledge". Piaget (1972) articulately said:

> *"Genetic epistemology, then, aims to study the origins of various kinds of knowledge, starting with their most elementary forms, and to follow their development to later levels up to and including scientific thought."* (p.15).

Piaget is believed to be one of the first to advocate forcefully, with extensive supporting evidence, the notion that children construct their own knowledge and that this knowledge is different in kind from an adult's. He suggests that the constructed knowledge is "evolving and changing" (Bliss, 1995) over time. In Piaget's world, the child is perceived as an organism, growing in an environment that affects its development, adapting to its surroundings, absorbing (assimilating) what was required for growth and necessarily changing its behaviour (accommodation) at the same time. The thought process that brings about this adaptation is described by Piaget as schema (Wadsworth, 1989).

The Concepts of Schema, Assimilation, Accommodation and Equilibration.

Schemata (the plural of schema) is a word used by Piaget to refer to "cognitive or mental structures by which individuals intellectually adapt to and organise the environment" (Wadsworth, 1989). When a child consistently classifies any toxic or poisonous substance as a chemical, for example, then this may suggests something about the nature of the child's concepts (schemata) of poison and chemical. Figure 4.1 is used to illustrate the notion of how individuals construct cognitive structures in order to adapt to the environment. To construct his/her world amidst the different circumstances and situations arising during its growth, the child constantly creates schemata. Piaget suggested that, at birth, schemata are reflexive in nature. These schemata according to Piaget, can be inferred from simple reflex motor activities such as suckling and gasping.

As the child grows with age, the schemata become more differentiated, less sensory, and more numerous forming an increasingly complex network. As already mentioned in the early part of this chapter, the schemata of an adult evolve from those of the child through adaptation and organisation. Throughout this evolution period, the schemata become internalised and are organised into complex thought structures. The ability to comprehend and manipulate abstract verbal symbols and relationships and to employ abstract classificatory schemata is also thought to increase with age.

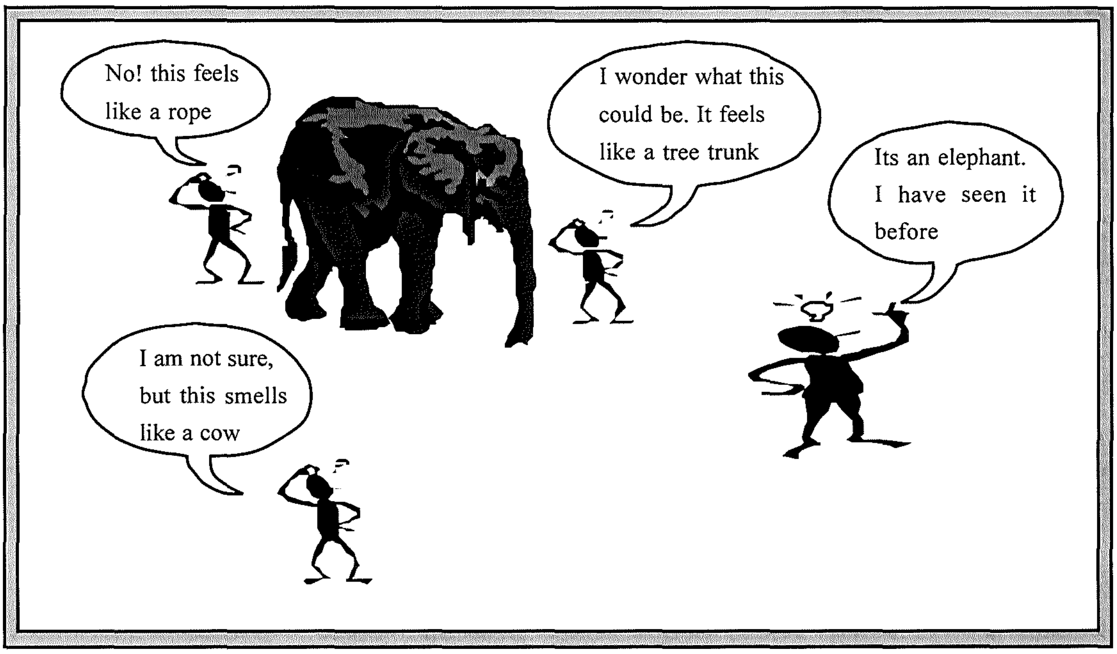


Figure 4.1 An Illustration of Schema Construction Based on the Three (little) Blind Men and a Normal Man's Concepts of an Elephant

Like the development of schemata, assimilation is a continuous process. Piaget refers to assimilation as a cognitive process by which an individual places or classifies new information or stimulus events into existing schemata. The process of assimilation takes place when a child experiences a stimulus through the senses and then tries to fit this new event into the schemata he or she has at the time. Figure 4.1 illustrates possible patterns of behaviour (verbal actions) that can develop as a result of experiencing new stimuli under different situations or conditions. The process of assimilation does not result in the change of the schemata but it does affect the growth of schemata (Wadsworth, 1989).

To illustrate the concept of assimilation, Wadsworth gives an example of a balloon. In this example, the balloon represents the schema and the putting of more air in the balloon represents the assimilation process. As more air is pumped into the balloon, the balloon gets larger (assimilation grow). However, the balloon does not change in shape, it just grows in size. The growth of schemata, and not the change of schemata, is accounted for by the process of assimilation. According to Piaget, the change of schemata is caused by the process of accommodation. In other words, assimilation is the end result of accommodation. Wadsworth describes assimilation as a part of the process by which an individual "cognitively adapts to and organises the environment" (Wadsworth, 1989).

It is not always possible for a child to place all new stimuli into existing schemata. This is mainly due to the absence of schemata which possess similar characteristics as the new stimuli. In this particular situation a child, according to Wadsworth (1989), naturally can respond to the stimulus in any one of the two ways:

(1) *He/she can create a new schema into which he can place the stimulus, or*

(2) *He/she can modify an existing schema so that the stimulus will fit into it.* (p.14).

Each of the actions represents the process of accommodation which will eventually lead to assimilation of the stimulus into the existing schema. However, the two ways may develop completely non-identical forms of schemata aroused by the same stimulus. The process of accommodation which results in the assimilation of stimulus does not immediately guarantee the formation of an accurate copy of reality (Piaget, 1962). Wadsworth (1989) considers the formation of schemata a reflection of the "... child's current level of understanding and knowledge of the world" which improves over time with increased experience.

Goldsworthy *et al*. (2000), writing in England and Wales, emphasise the importance of allowing pupils to develop appropriate schemata through scientific enquiry. They are of the opinion that school science should place scientific enquiry at the core of the science curricula in order to "develop pupils' understanding of the nature of scientific activity and the relation between data and scientific theories" (Goldsworthy *et al*., 2000). In their conclusion, they make the assertion that we should never be surprised if pupils have difficulties in writing or speaking about scientific enquiry if we never taught them how to do it. The scientific enquiry activities are presumed to assist in the development of appropriate new schemata essential for the development of scientific enquiry skills. While their ideas are intrinsically attractive, there is little evidence that what they propose can be achieved.

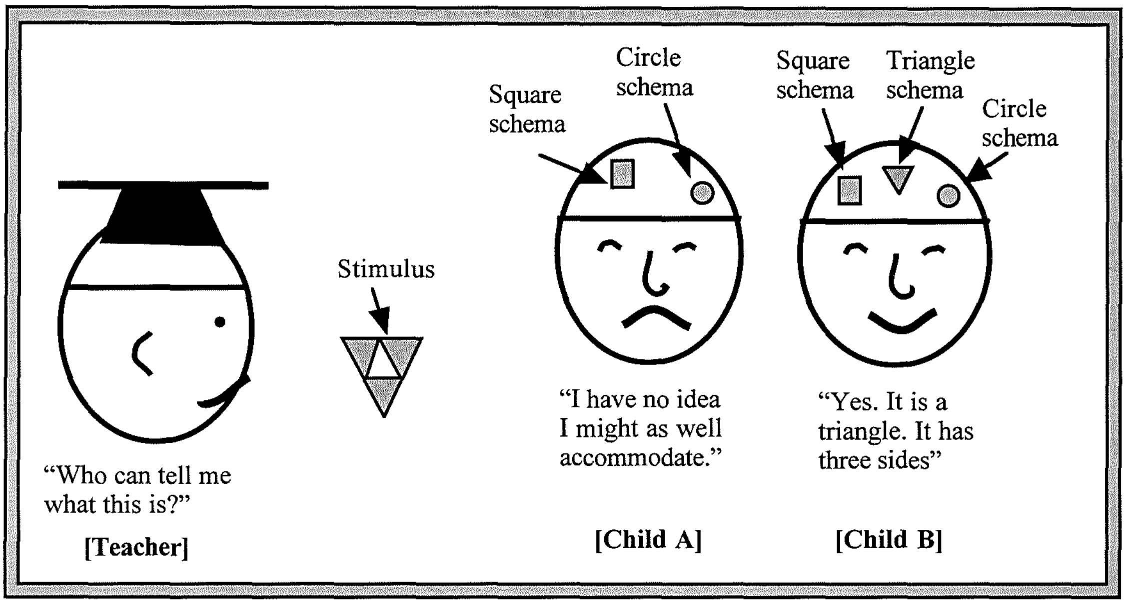


Figure 4.2 An Illustration of the Processes of Accommodation and Assimilation.

According to Wadsworth (1989), during assimilation, the child imposes his or her existing cognitive structure on the stimuli being processed. This results in the child forcing the stimuli to fit his or her existing schemata as illustrated by Child B. This process accounts for the development of change in the quality of the existing schemata. When the stimulus does not fit the array of existing schemata, accommodation occurs, in which a child is forced to change his or her schema to fit the new stimuli as illustrated by Child A. A growth in the number of schemata is effected through this process.

Piaget argues that, for a healthy development of a cognitive structure that eventually enables the individual to detect differences in things and detect similarity in things, there should be a balance between assimilation and accommodation (Piaget, 1962). This balance which Piaget referred to as equilibration is necessary to ensure that the individual develops adequate schemata and fits into the existing schemata an array of things that he or she encounters or experiences. The difficulties associated with the two extreme cases of the construction of fewer schemata due to accommodation and of too many schemata due to assimilation is believed by Piaget to result in an abnormal intellectual growth.

The process of equilibration is perceived as a mechanism that automatically ensures efficient interaction of the child with the environment (Wadsworth, 1989). Piaget (1962) contended that equilibration can only occur if the child experiences a state of cognitive conflict (disequilibrium), a situation which describes a moment in the intellectual development of a child where its expectations are not met. This is perceived as the major motivating factor in the intellectual development of an individual by Piaget (1962). When the discrepancy between what the child expects and what actually happened has been figured out, the mental state is referred to by Piaget as the state of equilibrium. This, in a sense, implies that the need to learn is a product of the individual learner experiencing disequilibrium and that meaningful learning occurs when the individual learner is motivated enough by the state of disequilibrium to establish a state of equilibrium (Piaget, 1970). This constant adjustment of the balance between assimilation and accommodation is said to start from birth through to adulthood and it is responsible for the construction of knowledge by the individual (Flavell, 1963).

The Hypothesis and the Stages of Cognitive Development

Piaget's hypothesis on cognitive development asserted that intellectual growth or cognitive development is a logical series of successive equilibrations of schemata, and that each schema is constructed from the existing one (Flavell, 1963). From the tests on his hypothesis, Piaget concluded that patterns like movement and language emerge from the child as the cognitive structures or schemata become integrated and internalised. Piaget's account of the differences in the child's thinking before and after full integration and internalisation of the cognitive structures has occurred is explained by his notion that each individual person goes through a series of stages that he called pre-logical and logical (Hyde, 1970).

According to Wadsworth (1989), Piaget's system requires that a child operates in the environment for cognitive development to take place. Apparently, the actions reflect the child's interpretation of the stimuli he or she receives from the environment and the patterns of the actions differ with age and the extent to which the child interacts with the environment (Kubli, 1979). Piaget identified three kinds of knowledge constructed by individuals through their continued interaction with the environment: physical knowledge, logico-mathematical knowledge and social knowledge (Wadsworth, 1989; Gallagher and Reid, 1981; Wadsworth, 1978).

Physical knowledge is constructed from a child's interaction with the physical properties of objects and events. Piaget believed that a child has to manipulate or act on the object

(Wadsworth, 1978) with his or her senses in order to acquire feedback about what objects can do and cannot do. The logico-mathematical knowledge, commonly referred to as 'invented knowledge' (Gallagher and Reid, 1981), is constructed from thinking about the feedback obtained from acting on objects. In this instance, the nature of the objects being manipulated by the child is not important. An example used by Piaget (1962) is that of a child using stones to develop the knowledge of counting. Piaget vindicated that the child could still develop the same knowledge using different items. However, what is important in this case is for the child to interact actively with the objects just as it is the case with the construction of physical knowledge (Gallagher and Reid, 1981).

Like physical knowledge and logico-mathematical knowledge, social knowledge construction involves active interaction of the child with other people. Through this social interaction Piaget believed that a child learns the rules, morals, values and languages and other aspects of human behaviour and actions (Wadsworth, 1978). In this case, the objects are the people. During the early stages of child growth, the actions are more overt and gradually becoming less overt with time as the child continues to develop the capability of representing some of the actions mentally and through the use of language (Wadsworth, 1978). However, it has been observed in real life that some people have unique natural abilities to construct 'reliable' knowledge of reality without interacting with all of its aspects. This unique human characteristic has been associated mostly with scientists and engineers. One of the advocates of this notion is Wheatley who argues that "objects do not lie around ready made in the world but are mental constructs". (Wheatley, 1991).

Basing his argument on the conclusion that changes in intellectual development are progressive and never impetuous, Piaget suggested that cognitive growth can be divided into four broad stages, namely: the sensori-motor stage, the pre-operational stage, the concrete operations stage and the formal operations stage (Piaget, 1963). The sensori-motor stage (0-2 years) is characterised by behaviour that is notably motor. The stage of pre-operational thought (2-7 years) is characterised by the development of language and pre-logical reasoning (Piaget, 1970b).

The stage of concrete operations (7-11 years) is characterised by the development of the ability to apply logical thinking to concrete problems. However, the reasoning is still not perfect. According to Piaget (1970a), the child at this stage has achieved the ability to reverse their thinking (conservation operations). During this stage, ego-centricism or the inability to accept other children's view points and the lack of the need to seek validation of his or her thoughts, is no more than it is the case at the stage of pre-operational thought. This ability to recognise the limitations of others' thoughts and the constant checking of one's own thought processes, is believed to develop primarily from the social interactions with peers (Piaget, 1952).

The child at this stage is able to assimilate many aspects of the stimulus to get a clearer picture. Apparently, Piaget argued that this ability enhances the logical thinking process at this stage (Piaget, 1952). Wadsworth (1989) reemphasises the view made by Piaget, that the stage of concrete operations is a transitional period between pre-operational thought and the formal thought. Most important to note during this stage is the notion of the development of the ability to order and classify objects according to their differences (seriation and classification).

The stage of formal (logical) operations ($11\text{-}15^{+}$) is characterised by the child's ability to handle abstract logic which is not restricted to the concrete world. According to Wadsworth (1989), the reasoning at this stage is "content free and concrete free". The child at this stage develops several cognitive structures which enables him or her to reason about the possible and the real world, deduce conclusions from hypothetical premises, reason from the specific to the general and derive new knowledge from existing knowledge through reflective thinking (Piaget, 1967).

It has been argued, however, that not all adolescents and adults develop formal operations fully (Gallagher and Reid, 1981). Needless to say, Piaget insisted that all 'normal' people have the *potential* to develop formal operations fully (Piaget, 1967). Debates on Piaget's theory concerning concrete operations and formal operations stages are discussed further in the next section of this chapter. The reason for this is that the project is based on early secondary school pupils aged 12-14 years in the case of Scotland and 13-15 years in the case of Botswana.

4.3 Criticism of Piaget's Theory of Cognitive Development.

Although Piaget's theory of cognitive development has greatly influenced teaching and learning in schools, it has been criticised for over-generalisation on the concept of knowledge development. In education, universal statements about individuals are not always sufficient to explain individuals' cognitive and affective positions at any given time and situation. If this were the case, teaching would be a less difficult task than it is perceived at present. It is true that some individuals do find themselves capable of formal operations in certain areas at secondary school while in some areas of the school curricula they still operate at the concrete level.

One of the major criticism levelled against Piaget was the rigidity of the boundaries he used to define the developmental stages of knowledge construction (Ausubel, Novak and Hanesian, 1978). Ausubel and his colleagues are of the view that the notion of stages in itself implies a sequence of distinct periods of change in the individual's mental state from one mental operational state to another. The suggestion, therefore, would give the impression that cognitive development is not progressive but abrupt in its nature. Ausubel *et al*. contend that cognitive development should certainly be progressive with the individual experiencing periods of transition from one stage to another (Ausubel *et al*., 1978).

Another criticism on Piaget's theory is levelled at his method of data collection (Flavell, 1963). The controversy stems from the use of an unsystematic methods. He used a statistically small sample to collect data and he is, therefore, accused of not considering the importance attached to the significance and reliability of the data collect on the validity of his conclusions. Consequently, lack of a standard statistical analysis and the insistent on the use of carefully selected illustrations to generate his theory lowers the validity and reliability of his conclusions. However, Flavell (1963) terms the criticisms that focus on the limitations of sampling and contingent limits of generalisations, the complexity of Piaget's instructions, and the arbitrariness of his scoring procedures "undergraduate criticisms". To support this claim by Flavell, Brown and Desforges asserts that:

> *"Theorists who seek data only from the random sample, and eschew the insights of clinician, cut themselves off from an important source of information."* (Brown and Desforges, 1977, p.8)

However, they acknowledge that Piaget did not test his hypothesis in order to "eliminate alternative explanations". Instead he presented his data as an illustration rather than a confirmation of the theory. Brown and Desforges (1977) further support Flavell by suggesting that there are more serious criticisms which need consideration and these are concern with:

(1) The shared assumptions which have governed the interpretation of data in the replication studies and in the original studies.
(2) The extent to which 'stage' can be meaningfully defined.
(3) The nature of the developmental process. (p.8)

With respect to criticism (1) Brown and Desforges argue that those who endeavour to replicate Piaget's findings usually do so in order to confirm that Piaget's data can be reproduced in other samples, ignoring the confirmation of the meaning which Piaget attributed to that data. Brown and Desforges (1977) provide evidence to this argument by outlining studies conducted by Bryant (1974) and Bower (1974). They report that, evidence from both studies indicate that Piaget's failure to test alternative hypotheses validated the utility of the mental operations he suggested (Shayer, 1979), resulting in incoherent association of the developmental stages to the accepted age at which certain operations occur.

Concerning criticism (2), Brown and Desforges take on the assumption that if the stage concept is to have utility, there must be a substantial degree of homogeneity within the behaviours of most children for the greater part of each stage. Assuming this position, therefore, means that if the performance of most children within a stage is characteristically more heterogeneous than homogeneous most of the time, it is not acceptable to make predictions about behaviour or make provisions for educational tasks. The acceptable step to take would be to look for alternative explanations to the observations.

Brown and Desforges report on several studies conducted by Pascual-Leone (1970), Hamel (1974), Inhelder *et al*. (1974), Neimak (1975) Schwebel (1975), Blasi and Hoeffel (1974), Watson and Johnson-Laird (1972), Lunzer (1974), Povey and Hill (1975), Harris (1975), Gelman (1972), Gelman and Tucker (1975) to determine the correlation between formal operational thinking and the developmental stages associated with it. Evidence from these studies suggest that Piaget's description of the stages can be rejected. They, however, acknowledges the presence of a systematic growth in intelligence which they conclude cannot be adequately defined by the stage description offered by Piaget as evidence of intellectual growth.

Evidence from studies undertaken with respect to criticism (3) indicate that Piaget's emphasis on conflict as an important feature of the equilibration process may be justified.

However, there is little evidence to suggest the utility of the model on the development of instructions that optimise transfer of learning skills (Brown and Desforges, 1977). A typical example is that of adults who demonstrated competency in solving concrete problems but failed to transfer the operating skills they used at that stage to solve similar problems of abstract nature.

Furthermore, the theory is said to attribute an insufficient role to the teacher, parent and peer since it stresses more the role of the individual in the process of knowledge construction (Bliss, 1995). Bruner (1996) asserts that the child's experience and environment, compared to his or her actions on the environment, contribute significantly to his or her intellectual growth and development. This view is shared by many other psychologists who now consider the theories advanced by Vygotsky, Ausubel and Bruner much more relevant to contemporary learning and teaching (Bliss, 1995; Kubli, 1979; Lovell, 1974; Rowell, 1984).

Although a majority of the psychologists and educators mentioned above point out some of the inadequacies in Piaget's theory on cognitive development, they still regard his views as fundamental to modern day teaching and learning. Bruner, for example, is said to have been partially influenced by Piaget's ideas to develop an interest in the mental development of the child and the notion of how a child acquires language.

4.4 Bruner and the Discovery Learning Model

Although partially influenced by Piaget, Bruner's approach to cognitive psychology concentrated on child development as opposed to Piaget's cognitive psychology on knowledge development. While Piaget's strong point is evident from his rich and detailed descriptions of the development of children's ideas about specific areas of knowledge (Bliss, 1995), Bruner is greatly inspired by Vygotsky's idea that thought and language were instruments for planning and carrying out actions.

According to Bruner (1986), Lev Semyonovich Vygotsky believed that human beings have the capacity to recognise ways to go beyond the limitations of their own knowledge, which he referred to as the Zone of Proximal Development (ZPD). He asserted that, through proper guidance from an experienced adult individual or competent peers, a child can be assisted to reorganise his or her thought processes to reach a higher level of thought, from which he or she can reflect more abstractly on a specific subject area.

The division between the level of potential development unearthed through problem solving under adult guidance or in collaboration with more able peers, and the developmental level determined by independent problem solving, represents the Zone of Proximal Development proposed by Vygotsky (Bruner, 1986). A typical example of this notion is evident in children's inherent ability to take advantage of others to help them reorganise their thought processes. In Botswana primary school education, for example, this idea is translated into two new approaches referred to as "Breakthrough to Setswana" and "Project Method" (National Commission on Education, 1993). The commission describes the main purposes for these approaches as:

(1) to enhance and accelerate the mastery of the reading and writing of Setswana (in the case of the Breakthrough approach).

(2) to enhance meaningful learning and assist academically weak pupils to attain almost the same level of understanding as the more competent ones (in the case of the Project Method).

In both approaches, group work, peer coaching and teacher guidance strategies are encouraged.

Bruner (1986) rejects Piaget's unwillingness to accept the influence of experience on the child's cognitive development. According to Bruner, the child's cognitive development can be enhanced significantly by careful curriculum design and strategic teaching. He asserts that this approach has the potential to enable underachieving children "leap to higher ground". He is renowned for the statement that "any subject could be taught to anybody at any stage in some form that was honest" (Bruner, 1963). In response to Bruner's claim, many countries introduced a spiral system of curriculum design and an emphasis on group work. In the 1960s, for example, the Scottish science curriculum involved extensive practical work which was apparently based on a general principle of guided discovery. The curriculum proved to be highly successful and was maintained with repeated minor revisions over time.

Bruner's model of discovery learning is based on the assumption that learning is an active, social process in which learners generate new knowledge or concepts based upon their prior knowledge (Bruner, 1966). With a strong bias towards learning of science and mathematics, Bruner contends that a learner selects and modifies information, formulates hypothesis and makes decisions, all the time relying on an existing cognitive structures to do so. He asserts that these cognitive structures are essential for the provision of meaning to experiences. To "go beyond information given", Bruner (1973) affirms that the cognitive structures also are responsible for the reorganisation of the selected information within a specific content domain.

According to Bruner (1966), knowledge development should take on the form of "skill integration". His model then proposes that learners should be taught such that they acquire skills necessary for the provision of meaning to new information. An integrated use of these skills should therefore enable a learner to reorganise the information in order for increased generalisation in novel situations to occur. Bruner's ideal theory of instruction emphasises four major aspects:

(1) The influence towards learning. The learner should not just routinely interact with the information, instead, the information should be compelling and relevant to the learner in order to elicit the three mode of information representation, namely: Enactive, Iconic and Symbolic (these are defined later in the chapter). The nature of the information to be learned should be structured such that the learner can easily identify it as important and relevant. In science this could mean, for example, asking pupils to work out a scientific explanation to a problem that they encounter everyday within their local environment.

(2) The structure of the the body of knowledge to be learned has to be readily understood or comprehended by the learner. This ideally implies modelling the language to suit the level of the learner, eliminating too much 'noise' to avoid overwhelming the pupils' minds, requiring the pupils to apply skills that they are capable of handling.

(3) The order of presenting the information effectively to the learners in such a way that they can make meaningful connections between stages. The steps within the activities that pupils are to follow a logical sequence which pupils can identify with.

(4) The appraisal of pupils's work and the correction of their work should be planned and done at the appropriate moment.

The structure of knowledge as perceived by Bruner (1966) is characterised by the mode of representation, its economy and its power. He asserts that development of human thinking is a function of experience which, according to Bruner, is independent of maturational factor. The mode of representation describes the way human beings represents their knowledge. Bruner proposes three modes of knowledge representation and he labelled them as:

(1) Enactive - the mode is characterised by the physical action representing the individuals' response to information presented. Likened to Piaget's stage principle, this mode is associated with the sensori-motor stage.

(2) Iconic - events and relations are portrayed as internal visual imagery. In Piaget's stage system this mode of knowledge representation is associated with the pre-operational stage.

(3) Symbolic - characters or symbols are used to represent information as in mathematics symbols, language letters and science models and formulae. This mode is associated with the concrete operational stage in Piaget's stage system.

The economic aspect of the knowledge structure describes the number of concepts that the learner has to manipulate at a given time to comprehend the task at hand. Bruner argues that too much information given at a time during a task has the *potential* to interfere with the construction of meaningful knowledge. On the contrary, too little information provided may slow down the process of knowledge construction as there is a high chance that learner may spend time requesting clarification at almost every step during a task.

The power of the structure of knowledge entails the capacity of the knowledge to be remembered and be applied in novel situations. A lecture on the relationship between the concepts of force, mass and acceleration may prove impossible to grasp, but a symbolic representation of this relationship using the formula [F = MA] is more powerful in terms of its applicability and more economic in terms of the amount of information one has to manipulate. However, Bruner cautions that the learner cannot start by learning the symbols first. They will have to start with the individual concepts and gradually work towards representing the relationship using symbols.

Bruner suggests that even though symbolic representation of knowledge is more evident at the adult stage, the three modes of knowledge representation are independent of the maturational factor. This notion provides a significant difference between Piaget's model and Bruner's model. According to Bruner (1966), adults need to use the three modes to represent their information. The extent to which they are used depends on the individual ability. This forms the basis for his suggestion that the structure and the form of the knowledge to be learned and the sequence in which the materials to be presented should be matched to the ability of the learner (differentiated learning material).

Like Piaget, Bruner considers motivation of learner and reinforcement of the learning process important. Bruner's influence in the design of science curriculum has been on the emphasis to use guided discovery learning as a general method of teaching. Ausubel (1968) on the other hand, believes that people acquire knowledge primarily through reception. He advocates for a more organised presentation of concepts instead of discovering them. Novak (1978) reiterates this view by pointing out that:

> *"What was overlooked was the fact that discovery teaching approaches do not guarantee meaningful learning and that didactic or reception teaching methods can be effective in developing highly functional conceptual frameworks in our students. ... It follows, therefore, that the central task of schools is to make expository teaching and reception learning meaningful, and I will argue ... that Ausubel's theory of cognitive learning is more relevant and more powerful for science and mathematics education than the developmental psychology of Jean Piaget."* (p.1-2).

Figure 2.6 in chapter two illustrates that reception and discovery learning are on a continuum distinct from rote learning and meaningful learning. For his part, Novak (1978) argues that educators did confuse the rote - meaningful continuum for learning with the reception - discovery continuum for presentation. However, Bruner recommends that no single teaching methods can adequately expedite learning. The availability of a variety of teaching methods may facilitate learning.

4.5 Ausubel and the Model of Meaningful Verbal Learning

Ausubel's theory came into the scene at the time when discovery learning approaches were firmly entrenched in the educational ideologies and, therefore, received little attention in the United Stages of America (Novak, 1978). The model is concerned mainly with two aspects of human conceptual functions during instructional presentation, namely:

(1) how individuals learn information meaningfully from verbal representation in the classroom.
(2) the significance of the learner's prior knowledge during the learning process.

Ausubel and Robinson (1969) clearly differentiate between the acquisition of subject matter and the ways that knowledge is presented during instructional activities. They classify the types of learning into two main categories, namely, rote learning and meaningful learning. The ways of presenting knowledge to the learners are also identified as reception learning and discovery learning (see figure 2.6).

According to Ausubel (1968), the aspect of prior knowledge places an important role of providing a bank of frameworks in the learner's mind. This bank or store of frameworks grows and develops with time towards formal reasoning. The extent to which meaningful learning occurs in an individual depends largely on the quality and the organisation of what the individual already knows (prior knowledge). Therefore, the existing knowledge is perceived by Ausubel as the most important element that predetermines the learning process (See chapter two for the discussion on how meaningful learning occurs, and the distinction between rote and meaningful learning).

Meaningful and Rote learning

However, it is important to note that Ausubel considers the main distinguishing factor between rote learning and meaningful learning to be associated with the role of previous knowledge on the construction of new knowledge. In rote learning, previous knowledge does not generally play any part. The new knowledge is predominantly verbatim and sequential. For example, the learning of counting numbers, letters of the alphabet, and, in the case of school science, names of elements. According to Ausubel and Robinson (1969), conditions that are most likely to encourage rote learning are:

- When the information to be learned lacks logical meaningfulness.
- When the learner does not possess the appropriate schemata for the construction of new knowledge.
- When the learner has never been exposed to skills that enable meaningful learning.

The conditions that must prevail before meaningful learning occurs to some extent depict the opposite of the situation described in the case of rote learning. These are:

- The information to be learned must, with relative easiness, enable the learner to relate it to some symbolic cognitive structure in a consistent and substantive manner.
- The learner must possess appropriate schemata or cognitive structures which relate to the new information.
- The learner must possess the determination to relate the relevant ideas which are associated to the new information in a symbolic and substantive manner.

In a learning situation where any one of these conditions is lacking, there is a high possibility for rote learning to occur. However, Ausubel and Robinson acknowledge that rote and meaningful learning form two extremes of the continuum and that the two positions of information acquisition are not necessarily considered true division of the whole process of knowledge acquisition. For example, it is not possible to learn every aspect of a concept meaningfully, some parts of the concept may require memorisation or a bit of both. Within a learning situation, a number a of uncontrollable variables affect the individuals and eventually the kind of learning that may occur during instructions. This view is expressed by Gardner (1983) as part of his theory of Multiple Intelligences that, the different intelligences represent not only different content domains but also learning preferences.

Reception and Discovery Learning

Ausubel and Robinson (1969) assert that reception learning in schools is associated with didactic forms of teaching. The information is presented in an understandable form to the pupils during a lesson. Ausubel and Robinson note that under such conditions the pupils are not engaged in any tenable independent discovery learning since all they need to know about the material to be learned is given to them by the teacher. An assessment of this way of acquiring knowledge requires that pupils have to recall only that which they have been taught in the specified lesson.

On the other hand, discovery learning requires pupils to discover the main content of the topic presented during a lesson. It is up to the pupils to rearrange, combine and integrate the new information using their existing knowledge for meaningful learning to occur. Again the notion of individual differences in terms of information handling, interpretation of incoming information and the general differences in learning preferences influence the knowledge construction, therefore, producing differences the learning output. Ausubel *et al.* (1978) suggest that it is important to provide some form of guidance in a situation where the learning outcomes have to be homogeneous in nature for the purposes of assessment.

The relationship between rote-meaningful mode of information acquisition continuum and the reception-discovery presentation as illustrated by Ausubel *et al.* (1978) shows a pattern shown in figure 4.3.

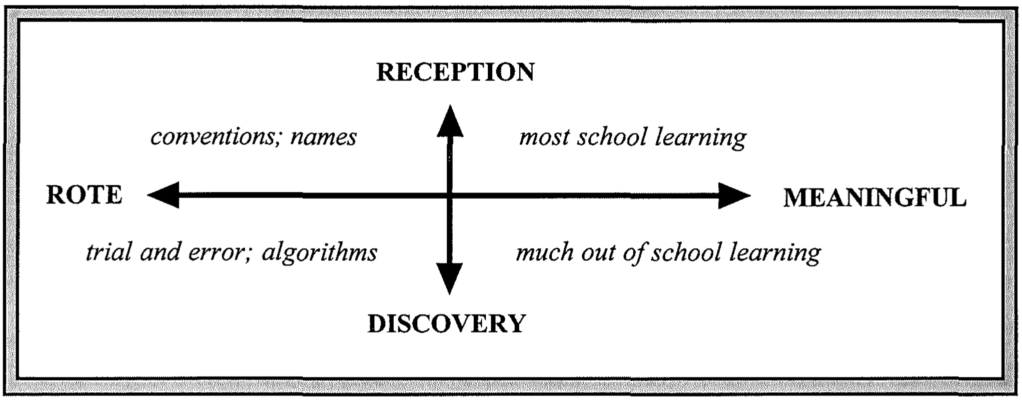


Figure 4.3. The Dimensions of Learning.

Source: Ausubel *et al.* 1978.

Ausubel and Robinson (1969) assert that there is no cognitive relationship so far known that links reception and discovery learning despite the distinction made concerning their roles in the learning situations. It has already been pointed out that the kinds of knowledge acquired, rote and meaningful learning, can happen simultaneously during a particular topic presentation. It is equally true that, by applying a variety of teaching methods and using different teaching materials, a combination of reception and discovery learning can arise out of that single lesson. The difficult task faced by teachers in schools is to determine when and where during an instruction each category, if any, takes place. Ausubel *et al.* (1978) refute claims by some educators that reception learning will inherently generate rote learning and that discovery learning is predominantly an agent for meaningful learning (see figure 4.3).

The Concept of Subsumption

Subsumption is considered the key concept in Ausubel's assimilation theory of learning based on the notion that what the learner already knows is the most important single influencing learning (Ausubel, 1968). Ausubel's contention is that meaningful learning does not result in new knowledge added to concepts, instead, the new knowledge "interacts with the existing relevant concepts" and it is "assimilated into these concepts". Out of this interaction and assimilation processes, an altered form of both the anchoring concepts and the new knowledge assimilated emerges. The anchoring concepts are labelled subsumers in Ausubel's theory. The process of interacting and assimilating the new knowledge for meaningful learning to occur is labelled subsumption.

Novak (1978) outlines the differences between Piaget's assimilation process and Ausubel's subsumption process. The differences are based on the conviction by Ausubel that older children are by and large capable of solving more complex problems than younger children not because they possess some unique cognitive structure but because their subsumption process is much more enhanced. The differences between Piaget's assimilation process and Ausubel's subsumption process are:

(1) New knowledge is linked to specifically relevant concepts or anchoring concepts.

(2) The process of subsumption is continuous and its effectiveness is not dependent on Piaget's stages of cognitive development but on the growing differentiation and integration of the anchoring concepts in cognitive structure.

Novak asserts that the distinction between these two processes may account for the reports that most adults, in some instances, fail to perform some of Piaget's tasks, while a significant few young children may succeed with these tasks. Like Bruner's theory, Ausubel's theory rejects the notion that cognitive development is predominantly dependent on maturational factors.

Advance Organisers

To link new knowledge effectively to existing relevant concepts in cognitive structure, Ausubel (1968) proposes that advance organisers ought to be used. The use of these advance organisers will inherently facilitate meaningful learning. He describes advance organisers as more abstract representations of the new material to be learned. For them to facilitate meaningful learning, advance organisers have to be meaningful to the learner and the new material to be learned has to be meaningful. Novak (1978) suggests that it is unlikely for any type of advance organiser to function when the new material to be learned is novel and that no relevant concepts exist in the learner's cognitive structure.

4.6 The Usefulness of the Model

Ausubel's model is considered by many educators more sensible and consistent with what is mostly happening in reality: for example, Novak (1978); Johnstone, (1987); Johnstone and Moynihan (1985); Ennis, (1975); Toulmin, (1972). Johnstone (1987) reemphasises the notion that pupils are not 'empty vessels to be filled'. He stresses the point that pupils come to the learning environment like schools with some knowledge which invariably controls what they learn. On the other hand, Ennis (1975) and Toulmin (1972) are convinced that Piaget's concept of cognitive stages presents some serious problems in as far as explaining the performance of both young children and adults on abstract and concrete reasoning is concerned.

A study conducted by Johnstone and Moynihan in 1985 on Scottish pupils within the age range of 14-15 years and drawn from different secondary schools in Scotland, revealed some evidence that tended to support the views of Ausubel on the effect of anchoring concepts on the occurrence of meaningful learning and retention. The study was designed to cover a section of the Scottish Chemistry syllabus, using a word association test to determine the relationship between the cognitive structure reflected by associations in the word association test and the pupils' performance in an achievement test. The analysis of the results from the study indicates that there is a positive correlation between performance in the word association test and in the objective test.

4.7 Conclusions

Both Ausubel and Bruner stress the importance of organising learning to suit the individual learner and the aspect of existing knowledge as a prerequisite for the meaningful acquisition of knowledge to occur. Ausubel does not associate learning to the age of the learner as is the case with Piaget's model. He believes that it is not the intellectual process that distinguishes a child's cognitive ability from that of an adult, but the amount of knowledge they both possess.

A closer scrutiny of Ausubel's model gives an impression that a child's cognitive capability with respect to handling of more complex (abstract) problems can be accelerated, as Shayer (1999) and Adey (1999) suggest. The discussion on their work is in the next chapter. However, Bruner and Ausubel are adamant that no single method of teaching can effectively enhance meaningful learning or improve the child's level of thinking. Teachers have to plan lessons to include a variety of activities which introduces learners to different ways of presenting information. Information organisation is favoured by both Ausubel and Bruner which involves providing guidance and ordering the sequence of events for the learner to comprehend.

CHAPTER FIVE

THE COGNITIVE ACCELERATION THROUGH SCIENCE EDUCATION MODEL (CASE) AND THE INFORMATION PROCESSING MODEL.

5.1 Cognitive Acceleration Through Science Education (CASE)

Cognitive Acceleration through Science Education (CASE) is an new teaching approach developed out of research into cognitive development based primarily on the works of Jean Piaget and encompassing some of the main principles of Lev Semyonovich Vygotsky's theories of learning (Adey, 1999). The principal focus of the programme is to improve children's thinking processes by accelerating progress towards high-order thinking skills (Shayer, 1999; Adey, 1999).

Shayer, was investigating the problem of difficulty in chemistry. An analysis of the curriculum for science in England and Wales by Shayer, Kuchemann and Wylam (1976), shows that "formal operations were generally required from higher level secondary upwards" (Shayer, 1991). The implication of this finding is that many of the concepts included in science curricula in England and Wales and some parts of the world actually made demands beyond the current intellectual capability of the pupils (Shayer and Adey, 1981). A number of their assumptions have been criticised for being over ambitious (see criticisms of the theory in section 5.4).

The initial brainstorming exercise by the team on the possible solutions to the problem generated two proposals, namely:

(1) Make the science curriculum easier for pupils to cope with.
(2) Increase the intellectual capability of the pupils.

The former was rejected as a "defeatist solution" (Adey, 1999). The team considered the proposal an easy option that will inevitably engender political and academic difficulties. The subsequent proposal was described as "daunting" (Adey, 1999) but "challenging" (Shayer and Adey, 1981) as it is certainly the aim for the CASE project. The project was finally launched in 1982.

Piloted between the years 1985 and 1987 using ten schools in England and Wales, the programme has to-date recorded success in as far as increasing pupils' capacities for understanding science and in developing their general thought processes. Shayer and Adey (1992a) reports successful intervention for at least 25% to nearly 50% of the pupils involved in CASE. The programme is now widely applied in some schools in the United Kingdom as an intervention programme in the existing science curriculum (Adey, 1999). The original material has been designed to target pupils between the ages of 11-14 years in England and Wales, and 12-14 in Scotland. Adey (1999) provides a detailed description of the rationale behind CASE.

5.2 Development of the CASE Materials

The CASE materials are developed from science activities called Thinking Science designed to promote higher level thinking in lower secondary pupils. The rationale behind these activities stems from the observation that during adolescence, many people develop the ability to think in formal operational terms.

According to Piaget (1970b), concrete operational thinking allows the child to cope with only a limited number of variables. Another characteristic of concrete operational thinking is that child at that stage can only describe situations, and not explain them. Piaget, therefore, described formal operational thinking as that thought process that allows children to handle multi-variable problems as well as allow them to provide explanations to events. Thinking science activities were design to encourage pupils to improve on their abilities to control variables and provide explanations to situations (Adey, Shayer and Yates, 1995).

5.3 The CASE Theory

The assumption that cognitive development in a person is influenced by, among other factors, his or her immediate environment is being explored by the CASE programme. The school, in this case, is the environment within which certain conditions are controlled to enhance the acceleration in cognitive growth from concrete to formal operational thinking. The CASE project believes strongly that the influence of secondary school teaching can significantly optimise the accelerated growth in cognitive development of adolescents (Adey, 1999). The CASE theory is based on five principles or "pillars" (Adey, 1999). These are: cognitive conflict, construction, metacognition, concrete preparation and bridging.

Cognitive conflict, as a pillar of the CASE theory, is described by Adey (1999) as a condition of the mind that occurs when a child or pupil encounters a problem which he or she cannot easily solve, but which, with carefully structured help from an adult or more able peer, he or she can solve. Shayer and Adey (1981) believe that an individual's mind's ability to process information grows with the demands placed upon it by challenging problems. However, they emphasise the importance of a nurturing environment that enables the individual to gain in the understanding of the nature of the problem that will later provide a favourable chance for a solution to be worked out. This pillar encompasses Bruner's notion of careful curriculum design and strategic teaching, Piaget's concept of disequilibrium and Vygotsky's idea of a zone of proximal development (ZPD). Ideally the CASE theory proposes that a child can learn better and develop high order thinking skill if he or she is provided a challenge that stimulates cognitive growth.

Activities that provide cognitive conflict have the potential to enable a child to construct more reliable knowledge. Nevertheless, the nurturing environment or a well designed instruction by the teacher do not guarantee construction of higher-level modes of thinking. The CASE theory proposes that a child who is provided with cognitively stimulating experience has the potential to reach a point where he or she can function unaided. The process through which this condition of the mind is attained is slow (Adey, 1999) and it takes place within what he calls the "construction zone". The construction zone has the same properties as the zone of proximal development (ZPD).

Reflecting on the thinking processes that occurred during problem solving is encouraged in the CASE theory. Metacognition, commonly referred to as a process of thinking about one's own thinking, is considered a vital factor for the development of higher-level thinking in individuals. Pupils are encouraged to question their choice of methods of problem solving, debate on the difficulties they encountered on solving the problem, how they asked for assistance and the sort of assistance they required. Adey (1999) warns that metacognition is usually regarded as time consuming and difficult to do by both teachers and pupils.

Before pupils are asked to work on the cognitively stimulating problems, there is a need to introduce them to the language of the problem, the apparatus to be used and the context within which the problem is set. Adey (1999) claims that this preparation phase is meant to eliminate unnecessary 'noise' or reduce the amount of information that the pupil has to manipulate at a time. This pillar is called the concrete preparation. This is the equivalent of the guide or assistant referred to earlier by Bruner. The teacher should not assume that simply presenting pupils with a difficult problem is a guarantee for cognitive conflict to perform its perceived function of accelerating cognition.

The final pillar of the CASE theory is described in the United States of America as an Interdisciplinary Approach. The emphasis is on the linking of the ways of thinking developed in one context of the CASE activities to a different context within the school curriculum. A child who competently performs bridging is said to have completely attained formal operational thinking. Adey (1999) illustrates the relationship between the five pillars of the CASE theory as shown by figure 5.1.

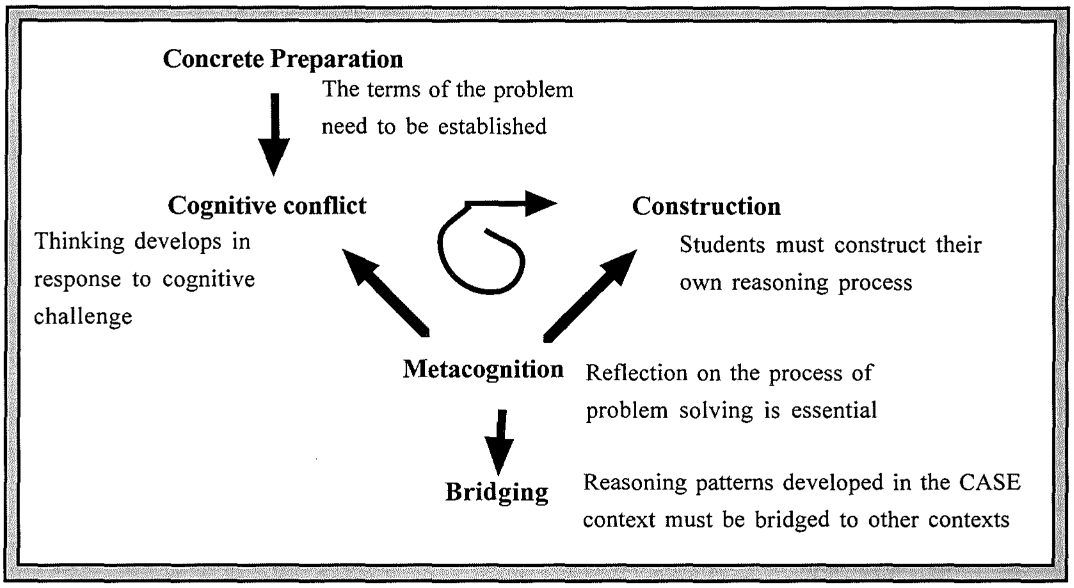


Figure 5.1. The Five Pillars of CASE Wisdom.

Source: (Adey, 1999)

The spiral link between the cognitive conflict pillar and the construction signifies the notion that cognitive conflict on its own is not necessarily a cause for the construction of concepts or the attainment of in depth understanding (Adey, 1999). Leo and Galloway (1996) are, however, concerned about the inadequacy of the intervention with respect to providing a theoretical framework which explain their findings. Shayer and Adey (1992b) are also challenged to explain why their claim to improve substantially children's examination results does not work with every child (Leo and Galloway, 1996).

5.4 Criticisms of the CASE Theory

Leo and Galloway argue that, if CASE materials are designed to stimulate pupils to think, why does this motivating effect function with some students and not the majority (Leo and Galloway, 1996). Their suggestion for this failure hinges on the concept of motivational styles. A number of explanations have been provided on the possible differences in the individuals' styles of motivation: for example, the self-worth motivation as described by Covington (1984), the concept of learned helplessness described by Seligman and Maier in the 1960s and the concept of mastery oriented motivational style.

Covington (1984) describes an individual who establishes and maintains a positive self-concept as being self-worth motivated. This individual perceives challenging tasks as a turn off. According to Covington, on encountering these difficult tasks, the individuals tend to generate feelings of anxiety which result in avoidance behaviours. Following failure, the individuals in this case avoid the temptation to be deterred in their good performance by a single experience of incompetence. To maintain their self-concept nature or self-esteem, pupils who present a self-worth motivational style are likely to be more concerned with the impact of their performance on the task on their self-esteem than the performance itself (Covington, 1984). For example, a more likely response to a difficult task by these kind pupils will be to declare the task "boring, irrelevant and hence not worth doing" (Leo and Galloway, 1996).

In as far as the learned helplessness style is concerned, Phillips (1984) reports that children who perceive failure as a result of their incompetence are likely to experience a negative feeling about their ability and invariably perform poorly in the future. Like the motivational style of self-worth, the learned helplessness motive has no effect on the actual performance of the pupil. It is asserted that the individuals in this case tend to give up quickly when faced with challenging tasks. Leo and Galloway conceive these individuals as having a poor academic self-concept. They quickly cease trying to work on the problem because they perceive themselves as not capable of succeeding in this regard (Diener and Dweck, 1978).

Mastery oriented pupils regard learning as essential and practically worthwhile. Difficult tasks are perceived as challenging rather than threatening. They are therefore concerned with developing strategies for success at all times (Ames and Archer, 1988). It is asserted that pupils who present this type of motivational style consistently make productive use of their teachers to focus their thinking with a view to succeeding in problem solving. A finer quality characteristic of these pupils' style lies in their considerable ability to control their own thinking processes (Leo and Galloway, 1996).

Leo and Galloway, therefore, suggest that these behavioural characteristics, characterised by the motivational styles, have the potential to explain effectively the inability of the CASE materials to produce the same effect on every individual. In response to the above claim, Adey (1996) eventually acknowledges the alternative explanations given by Leo and Galloway regarding the failure of the intervention to affect all pupils but insists on the need for more work to determine mechanics of how CASE intervention achieved its effects. In his own submission, Adey (1996) says:

> *"I do not mean to infer by my statistical pedantry ... that there were not an interesting minority of children for whom the CASE lessons seemed to have no effect ... In our work we were not able to undertake the classroom case-study work that might have thrown light on this question, and I am delighted that Leo and Galloway have taken the effort to try to provide a possible explanation. Unfortunately, I am not convinced of the usefulness of the explanation they propose, partly because it fails to account adequately for the results observed, and partly because it appears to be untestable."* (P.51-52).

Bliss (1995) commented that:

> *"Intervention programmes are often greeted with a degree of scepticism, people asking whether or not such interventions achieve what they set out to achieve."* (p.144).

Testimony to Bliss's statement is the work of Head Start, an intervention programme launched in the United States of America, initiated by Lyndon Johnson in the early 1960s (Bliss, 1995). The purpose of the intervention was to "compensate for cultural deficits" by introducing educational interventions at nursery or pre-nursery age. An evaluation of the effects of the intervention came up with two main findings: the immediate positive cognitive gains were no longer distinct after the second year of schooling and that the positive effects on self-esteem, academic achievement, motivation and social behaviour lasted a little longer, disappearing after the third year of schooling.

Bliss also illustrates his statement by considering the proposal by Desforges. Desforges argues that, if all the experimental groups are at the same Piagetian operational level, despite age or gender differences, at the start of the intervention, as claimed by Shayer and Adey, the obvious results should have been a similar improvement in performances for all groups. He, therefore, suggests that a well designed use of language during the intervention could play a vital role in ensuring a homogeneous increase in achievement by the experimental group. This assertion is rejected by Shayer and Adey (1993). Bliss, however, points out the reliance of the CASE intervention programme on the work of Vygotsky and insists that Desforges's suggestion may be plausible.

Nonetheless, there are other intervention programmes cited by Bliss (1995) which have yielded long lasting results in as far as attitude moulding is concerned. For example the Perry preschool project called High Scope (see Lazar and Darlington, 1992). To this, Bliss comments that:

> *"... while it is hard to know what effects interventions actually have, they do appear to have an impact on people's overall attitudes and commitments to a way of life, as well as on the 'feel good about me' factor which in the long term can be an investment."* (p.147).

5.5 Conclusions

It is interesting to note that theoretical concepts used by Piaget, Bruner, Ausubel as well as Adey and Shayer's CASE theory emphasises an active interaction with information, reduced alternative explanations and careful design of the curriculum content that enhances a logical acquisition of knowledge. Theories developed after Piaget, however, consider teacher guidance and the nature of the material to be learned essential components of meaningful learning. One aspect of the theories discussed that stand out as having a significant influence on pupils' assimilation of new knowledge, is the number of concepts that a child has to manipulate during the information processing stage of a given task. Bruner, Ausubel and CASE recommend that the design of instructions should take cognisance of the demand that the problem places on the learner's cognitive capability. The next section discusses information processing models proposed by various cognitive psychologists and educators.

5.6 Information Processing Models

> *"Cognitive psychology has its origins in the information-processing approach and the assumption that human performance can be analysed by studying inputs and outputs and from this deducing the function of the intervening 'black box'."* (Halliday and Hitch, 1988).

The behaviourist philosophy has been more concerned with the stimuli and the resulting observable responses and excluded the intervening central processes (Barber, 1988) or the functions of the intervening black box, as Halliday and Hitch suggest. This view has been dominating psychology until the 1960s when psychologists become curious about the internal workings of the brain. This enquiry about the internal workings of the brain, as a link between input information and output responses of a human being, during assimilation of new knowledge is asserted to have caused the undermining of behaviourist perspectives (Barber, 1988). Contemporary psychological perspectives that take on the information processing mechanisms underlying human performance simply assumes the brain as a communication system. Figure 5.2 shows the simple model of a basic communication system as illustrated by Barber (1988).

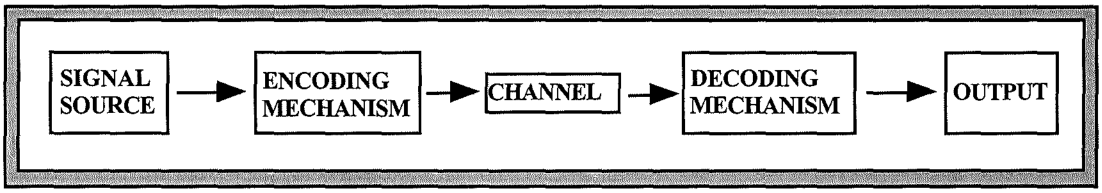


Figure 5.2. Components of a Simple Communications System.

Source: (Barber, 1988)

In this simple communication model, the sum of the output components from the encoding and the decoding mechanisms is not always equivalent to the sum of the input signal components. Another important aspect of the system is that the quality of the output components depends on the efficiencies of the encoding and the decoding mechanisms. It was, therefore, speculated that the human brain processes the stimulating information in a similar manner. This shift in the intellectual trend is believed by Barber to have been greatly influenced by rapid technological development, especially electronic computing. It is not the interest of this work to discuss any of the hypotheses advanced to account for this speculation. The purpose of the use of this illustration is to establish a revolution in human perception of the central mechanisms responsible for shaping the response offered by human beings to a specific stimulus.

5.7 Information Processing and Cognitive Development

This section of the chapter aims to establish how research into human construction of knowledge, particularly during the formal operations stage, employs the use of the information processing models to explain how meaningful learning occurs. As Barber (1988) suggests, a single piece of information presented to a learner may contain a number of signals, each of which stimulates a unique response. Therefore, Barber asserts that it is incumbent upon the efficiency of the learner's internal mechanisms to select or pick the appropriate signals and rejects the rest for the production of a meaningful or desired output.

One major aspect of human behaviour that Piaget's model of cognitive development has failed to address is the asynchronous appearances of variations of the same cognitive structure (*horizontal decalage)*. This expression was adopted by Piaget as his interpretation of a phenomenon of passing and failing tasks of the same logical structure. Neo-Piagetians have realised that knowledge construction is domain specific rather than dependent on the general operational schemes proposed by Piaget (Scardamalia, 1977; Case, 1974a; Pascual-Leone, 1974; Carey, 1985; Keil, 1986).

It has been argued by a number of researchers that even highly educated adults perform badly on tasks involving abstract hypothetical thinking. They contend that adults are different from children mainly by knowing more and not by possessing different general cognitive structures. Piaget's constant insistent on a context free nature of the formal reasoning has prompted wide investigations of this notion (Bliss, 1995).

Carey (1985) asserts that once domain specific knowledge has been learned in its context it is then that the learner may identify the nature of the knowledge and the limitations on it. Carey's contention is that the emergence of reasoning frameworks signifies the development of cognition within a specific domain. In other words, a child's ability to explain how the concept of weight relates to the concept of mass does not necessarily mean he or she is capable of handling the relationship between weight and density. A well design instructional programme has to be developed to establish this relationship with its apparent limitations. Gick and Holyoak (1980) believe that the psychological notion of the transfer of knowledge from one context to another should involve overcoming contextual barriers, a task which may not be easy.

Scardamalia (1977) indicates that the information processing demand of the task presented to the learner forms a significant aspect of the phenomenon of horizontal decalage. Numerous versions of the information processing models have been proposed to explain cognition: for example, Ashcraft (1994); Johnstone (1993); Child (1993); Klatzky (1975). Studies by Pascual-Leone (1974) and Case (1974a) have provided a basis for the development of the information processing models proposed in the past 30 years. Pascual-Leone's study was set out to explore whether the difference in performance in problem solving within a broad age range was dependent mainly on the number of units that the individual working of the task has to manipulate. His intentions, however, are not meant to challenge or disprove Piaget's findings, but to rather to come up with a psychological theory that is comprehensive and capable of providing explanations of the claims made by Piaget.

5.8 Pascual-Leone's Neo-Piagetian Theory

Pascual-Leone proposed that any performance by an individual on a cognitive task involves three major demands on his or her psychological system: the mental strategies used to work out solutions to the task which he calls the 'repertoire H', the demands that the mental strategies places on the mental span which he refers to as the 'M-demand' and the actual available mental capacity of the individual which he calls the central computing space or 'M-space'.

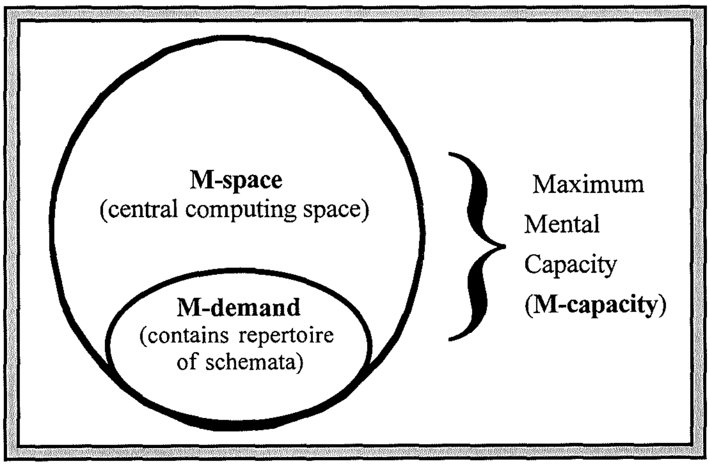


Figure 5.3 An Illustration of the Relationship Between the Repertoire, the M-demand and the M-space.

Figure 5.3 illustrate the relationship between Pascual-Leone's information processing structures. He then developed a hypothesis that the mental capacity or the M-space of an individual is a function of Piaget's stages of cognitive development and therefore, increases with maturation.

However, an observation of a learner's performance on a particular examination reveals that exposing him or her to certain strategies of preparing for the examination improves the performance. Pascual-Leone, nonetheless, cautions that this improved performance does not imply an increase in M-space, but an improved repertoire-H or mental functions.

The Repertoire-H

Case (1974a) clarifies the concept of repertoire-H used by Pascual-Leone by suggesting that mental strategies (repertoire-H) were constructed from Piaget's concept of schemata. According to Piaget, schemata are subjective units of thought which represented an individual's experience and influence his or her responses to stimuli. The manner with which these schemata operates to elicit any response is described as a repertoire or an itemised function. The function of the schemata to release a response, according to Case (1974a), is carried out in three distinctive ways: figurative, operative and executive. For the purposes of this project, discussions on these concepts are not necessary. However, Case (1974a) makes an assertion that Pascual-Leone's concept of the repertoire implies that a child is born with an innate repertoire of sensory motor schemata which grow in both function and size through maturation.

The Central Computing Space (M-space)

During a problem solving task, the individual working on the task processes the input information which usually result in the development of new schemata. The process involves matching the schemata that represent the information presented by the problem with the existing sets of schemata into the central computing space or the M-space. It is expected that from this operation taking place in the M-space, new schemata representing what is perceived as a solution to the problem will suffice and form part of the individual's repertoire.

Case (1974a) believes that during the problem solving task, the thought processes taking place in the individual's mental processor include the following: activating the appropriate executive schemata and subsequent activation of the figurative and operative schemata. The nature of the executive schemata activated at a given moment will depend on several factors: the individual's emotional state, the individual's perceived context of the problem, the type of the problem to be solved and the individual's prior knowledge or past experience. This process defines the cognitive strategy employed by the individual to solve the problem at hand.

The theory asserts that the figurative and operative schemata elicited during the problem solving mental strategy produced step by step functions. Firstly, an operative schema is activated which subsequently act on one or more of the figurative schemata to create new figurative schemata. The new figurative schemata are then rehearsed in readiness for assimilation and impending use in future mental processes. The stimulation and rehearsal of the schema is assumed to demand a certain amount of mental effort. The effort referred to is limited in its extent at any given time of rehearsal and activation of a specific number of schemata. Another assumption made is that the number of schemata available for any mental operational step is also limited. Finally, the theory assumes that the capacity of the M-space determines the number of schemata or units of information to be handled at a time, and it size increases proportionally with age (see table 5.1).

Piagetian substage	Age (Year)	Value of M-power (a+k)
Early pre-operational	3-4	a+1
Late pre-operational	5-6	a+2
Early concrete	7-8	a+3
Late concrete	9-10	a+4
Early formal	11-12	a+5
Middle formal	13-14	a+6
Late formal	15-16	a+7

M-power - the maximum number of schemata available to the individual at any given mental strategy operations.
The letter (a) - denotes the space taken up by the mental strategy (executive schemata) that are applied to the task or problem solving.
The letter (k) - denotes the number of units that can be manipulated by the individual simultaneously without causing any confusion.

Table 5.1 The Relationship Between Developmental Substage and M-power

Source: (Case, 1974b)

The executive schema responsible for determining which figurative and operative schemata are engaged in a given mental strategic operations deactivates its functions the moment the final schemata representing the solution to the problem is formed. The execution of a appropriate response to the task marks the final step which is assimilation of the new schemata. Case associates this process with Piaget's process of equilibration.

The Pascual-Leone theory assumes that the M-capacity increases by one schema for every two years, from childhood until maturity age. However, the theory stipulates that the individual's ability to solve problems effectively depends to some extent on a number of factors. These factors ranges from the nature of the repertoire of schemata activated during the problem solving activity to the maximum number of schemata that were attainable in the cognitive structure. Amongst other factors are the intellectual motivation which is said to influence the tendency to make full use of the M-capacity and the amount of guidance given to the individual to frame an appropriate perceptual field.

5.9 Conclusions

Case, on the other hand, was concerned with establishing the effects of well designed instructions on the size of the child's mental capacity to handle an increased demand of a problem (M-power). Case concludes that it is possible to train a child to develop complex strategies to solve problems but not to increase his or her mental capacity (M-power) (Case, 1974b). These findings correspond to those of Pascual-Leone who concludes that reducing the demand of a problem allows children below the formal operations cognitive stage to provide a quality performance like adults (Scardamalia, 1977). These claims, however, did not go without criticism. Some psychologists rejected the claims under the pretext of lack of statistical reliable analysis (Trabasso and Foellinger, 1978). To many psychologists, the studies conducted by Pascual-Leone and Case forms a basis for a number of studies on the information processing capacity and task demand.

5.10 Interpretations of the Basic Information Processing Model

Barber (1988) provides a basic structure that represents the information processing mechanisms (see figure 5.4). He, however, expresses the caution that this basic structure should not be considered a perfect representation of all models of information processing. According to Barber, each of the boxes in the structure represents a sequence of processing stages at which the input information is transformed in readiness for the next stage.

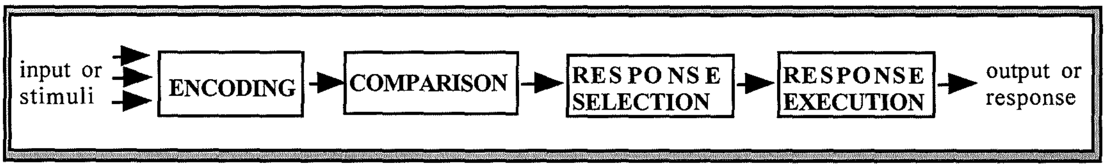


Figure 5.4. Basic Stages of Information Processing

Source: (Barber, 1988)

The box denoted by the term 'ENCODING' represent the stage where the stimuli is received and internally represented (acceptance or filtering of the preferred input signals). The next box 'COMPARISON' performs the function of comparing or classifying the internal forms of the stimuli with the existing possible representations of the stimuli. A possible classification results in the forwarding to the next stage, 'RESPONSE SELECTION', which indicates members of the memory set that match the incoming input signals and translates the input signal into a response code. The final box, 'RESPONSE EXECUTION', is thought to organise the response, directing the response to the relevant body muscles and by giving instructions on the extent of the response execution.

It was claimed that the flow of information within the stages is unidirectional. This nature of the basic model has been researched and new evidence suggests the contrary (Bruning *et al.* 1995; Johnstone, 1993). Another claim was that each stage action-time is independent of the action-time of the subsequent stages. The model does not indicate how the mechanism is able to handle this. This may give an impression that the whole process consists of a neat flow of information. However, there are variations on the time taken between receiving the stimuli and producing a response (Barber, 1988). These variations are dependent upon the complexity of the operations to be accomplished at each stage. Another characteristic nature of the basic model of information processing, which render it inadequate, concerns the aspects of 'attention' and 'memory' which, according to Barber (1988), determine what goes in and what comes out, respectively.

Attention

It is asserted that a person's perception picks up aspects of the task at hand that are given more attention than the others. Bruning, Schraw and Ronning (1995) believe that there is a link between perception and attention. They consider perception as a process by which stimuli are recognised and understood, and it is directly influenced by the learner's knowledge and the context of events created by his or her knowledge. For example, an expert boxer observes carefully the movements of his opponent to determine his attack strategies. Attention is described as an individual's allocation of cognitive resources to the task at hand (Bruning *et al*. 1995), it involves some sifting and selecting among the various information inputs presented to him or her at any instant (Barber, 1988).

Attention is generally influenced by some forces within the learner's external environment and some internal thoughts. A child's attention on an interesting biology lesson may be distracted at a given time during the lesson by the strong smell of food coming from the cafeteria. Within the same lesson, a short time later, the same child may shift his or her attention to a whispered conversation next or some internal thought prevailing at the time. Studies conducted on the theories of attention generally show that human beings are severely limited in the number of things they can pay attention to simultaneously (Bruning *et al.* 1995). When does the selection of what one attend to at a particular time occur and how does it operates? Answers to these questions asked by Bruning *et al.* (1995) can be elicited from discussion on the human memory system.

5.11 Components of the Human Memory System.

The earlier parts of this chapter are concerned with explaining what happens to information from its reception by the individual to the point where the individual execute a response. This next section of the chapter looks at components of the memory structure that play an active role in this process. It is important to add that, for a person to start processing information, he or she has to able to sense the environment (Bourne, Dominowski, Loftus and Healy, 1986).

The mechanism of information processing takes place within a part of the brain called memory. According to Bruning *et al*. (1995), memory is responsible for selecting what information enters the internal workings of the brain, what gets stored, and what to retrieve. Studies of the information processing models propose that a human memory consists of three major components, namely: sensory memory, short-term memory and long-term memory (Bruning *et al.*, 1995; Bourne *et al.*, 1986; Barber, 1988). To highlight what constitutes memory, Rose (1992) says that:

"memories are public records of the past events, more or less transformed to meet current ideological needs." (p.307).

However, a variety of the information processing models have been proposed, with slight variations on the functions and the relationships between the different components of the human memory system. Bruning *et al.* (1995) present a model that contains common features of the various models mentioned. This is referred to as the 'modal model'. Like the basic model suggested by Barber, the modal model provides a useful organiser for thinking about memory (see figure 5.5).

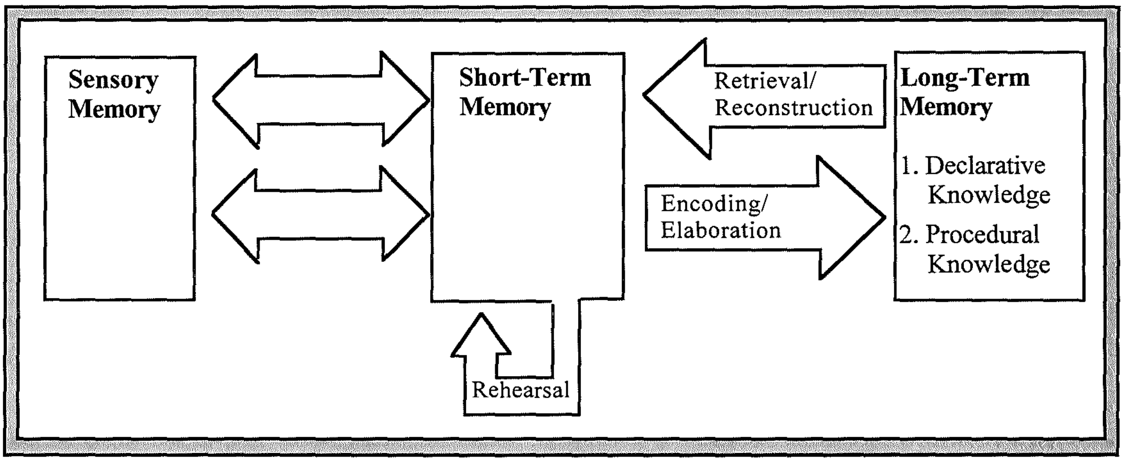


Figure 5.5 The Modal Model

Source: (Bruning *et al.*, 1995)

Sensory Memory

This is described a the part of the memory that selects information perceived important by the learner. The sensory memory also performs the function of holding on to information that is no longer available to our senses (Bruning *et al*., 1995). They argue that information coming to our senses constantly changes, and that, without a mechanism for holding on to the previous information, the old information will be lost immediately to new stimuli. The other important function of the sensory memory is that of holding on to the old information for perception to take place, since it requires some time to take place.

Aschcraft (1994) provides a description of the two types of sensory memory: visual sensory memory which receives visual stimuli and auditory sensory memory which receives sound stimuli. Ashcraft notes that the visual sensory memory can hold a visual stimuli for approximately one second for it to be encoded and rescued into more enduring forms. The auditory sensory memory holds sound related stimuli for about four seconds. The sensory memory is considered to have a high capacity which allows it to receive all sensory inputs in their original form.

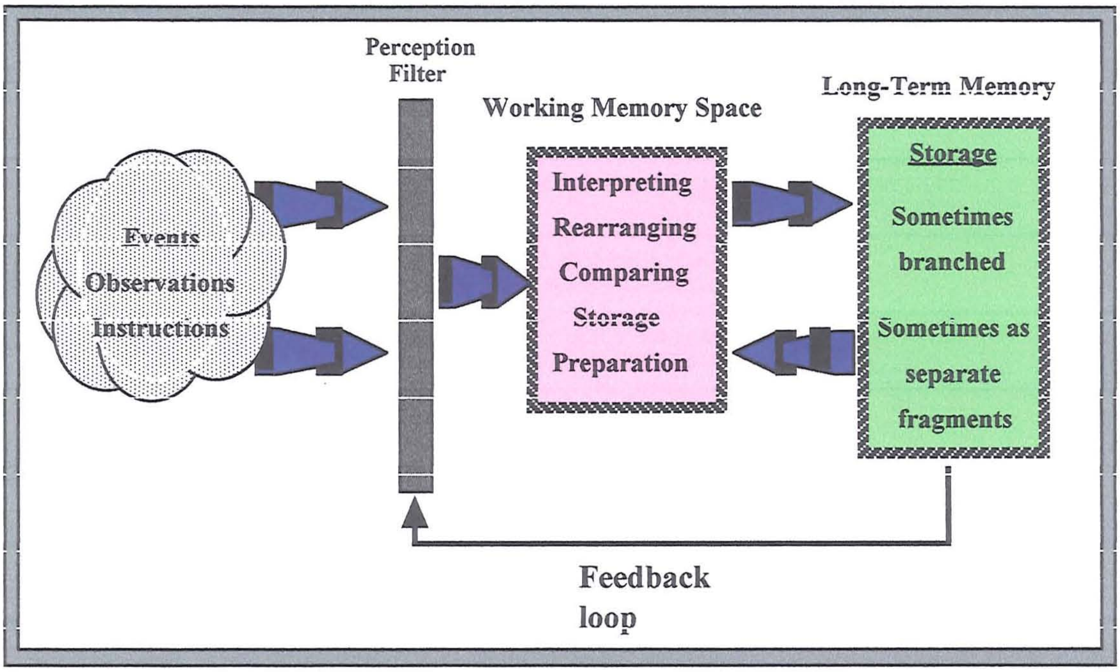


Figure 5.6 A Model of the Information Processing

Source: (Johnstone, 1993)

According to Johnstone (1993), the sensory memory receives events, observations, and instructions through the influence of the long-term memory. The long-term memory provides a mechanism through which the sensory memory or the 'perception filter', as referred to by Johnstone, selects information (see figure 5.6). A variety of factors from the long-term memory characterised by the learner's biases, prejudices, preferences and beliefs, assist in the mechanism of encoding filtered information for further processing in the subsequent stage of the system. Bourne *et al.* (1986) suggest that, for any event, observation, or instruction to have meaning and to be retained beyond simple sensory, it must be recognised and encoded through processes of pattern recognition and pattern encoding. The information in this case is converted into a more durable form, ready to enter the next stage of the memory. Researchers are not agreed on how the encoding is accomplished and in what form the encoded is presented to the short-term memory.

Short-Term Memory

One significant nature of the short-term memory (STM) is its delicateness which is symbolised by a rapid decay of the input whenever a learner's attention is diverted from what is to be remembered (Bruning *et al*., 1995). The other limitation of the STM described by Bruning *et al*. relates to its capacity which is observed to be limited to only a few chunks of information. For example, remembering new telephone numbers of colleagues at work will inevitably require repeated rehearsal and paying close attention to the figures. A slight diversion of the attention will results in immediate forgetting of the entire figures, especially on first encounter.

Short-term memory is considered by most researchers as the part of the information processing that people are aware or conscious of at any given moment (Bourne *et al*., 1986). It is the active part of the memory holding information that has just been encoded and some which has been retrieved from the long-term memory stores. Johnstone (1993) presents a model of information processing that depict short-term memory as having the function of interpreting, rearranging, comparing, storing and preparing for durability. He acknowledges the active nature of the short-term memory and calls it the 'working memory space'.

Chunking

The short-term memory has a limited capacity which is capable of holding a few chunks of information as already alluded to earlier in the section (Murdock, 1961). The measure of how many pieces of information an individual can retain in a given time and be able to recall accurately is believed to be the brain child of Sir William Hamilton, a Scottish metaphysician (Miller, 1956). According to Miller, Hamilton made the proposition following his experiment with a handful of marbles. From the experiment, he concluded that, if one throws a handful of marbles on the floor, one would realise that it is difficult to "view at once" (Miller, 1956) more than six or at most seven marbles with out getting confused.

Subsequent studies of the mental capacity do confirm Hamilton's speculation. Bruning *et al*. (1995) asserts that to date, a related and possibly better method of measuring the mental capacity involves experiments where symbols have to be remembered in sequence called the 'digit span'. The digit span is said to be the number of digits individuals can recall when given a series of them (Bruning *et al.*, 1995). Miller in 1956 proclaimed from his study that the capacity or the span of the short-term memory of an adult person is equal to seven plus or minus two items. Anything above this incurs errors during recall (Miller, 1956).

What is the nature of these items? According to Miller, the items referred to are individual stimulus information which can be in the form of words, letters, numbers and many more. Each of the stimulus items requires a specific response. Miller argues that, since there is a lot of information in words, the best form of representing information such that a lot of it can be retained is by using words. The analogy he uses is that of a purse which can be used to contain both coins and notes. In this situation, coins represent numbers and single letters, and the notes represent words. It is obvious from this analogy that the purse can only be stocked with a limited amount of coins which add up to a considerable amount of money.

However, the worth of the contents of the purse can be significantly improved by converting the large number of coins into notes. Miller contends that this analogy demonstrates how human beings are able to retain more information represented in words than numerically. For example, the sequence of numbers ***5-6-9***, the sequence of letters ***B-N-F*** and the sequence of the words ***monkey-boat-elephant***, all consisted of three stimuli information. Miller calls the individual units chunks. According to Miller, a chunk is a measure of the limit of the span of the short-term memory which can be improved in terms of its representation to include more information. An improved chunking system can possibly perceive the units [***235***], [***EEC***] and [***the soft centre***] as each representing one chunk. Bourne *et al*. (1986) believe that the maximum number of chunks that can be held in the short-term memory cannot be increased by practice. Instead, a person can increase the number of information units contained in each chunk. The example in the figure 5.7 illustrates the point raised by Bourne *et al.*

SERIES A

wasgotchnefgtluvrcnfiysietduaoetieeocseronrniec

SERIES B

thecentreforscienceeducationuniversityofglasgow

Figure 5.7 Lists of Letters to be Recalled

(Adopted from Bourne *et al.*, 1986)

Series A is a representation of series B in a jumbled form. An experienced individual can be able to remember and recall all of the information in series B on first encounter. This may prove impossible with series A. Ericsson *et al.* (1980) suggest that through extensive practice some individuals may be able to recall all the 47 units in series A. This may involve relating series of letters to familiar words. The individual who manages to accomplish this is said to have increased his or her digit span from seven to 47 digits (in the case of the example in figure 5.7). The maximum number of the chunks to be held by his or her short-term memory at any given time remains fixed.

5.12 The Effects of Overloading the Working Memory Space

The working memory is defined by Baddeley (1986) as a system that holds information temporarily and manipulates it during some cognitive activities that include comprehending, learning and reasoning. As already established, there is a limit to the number of individual items that can be held in the working memory or STM at a time. A problem solving situation which requires the learner to manipulate tasks equal to the working memory span is perceived easy to do by the learner. If the tasks are more than the working memory capacity can handle, then specific strategies ought to be use to rearrange the tasks into manageable chunks. Johnstone and Wham (1982) demonstrated that when students are presented with a quantity of information containing beyond the their working memory capacity, the students gradually lose concentration and attain what they referred to as the "state of unstable overload" (see figure 5.8).

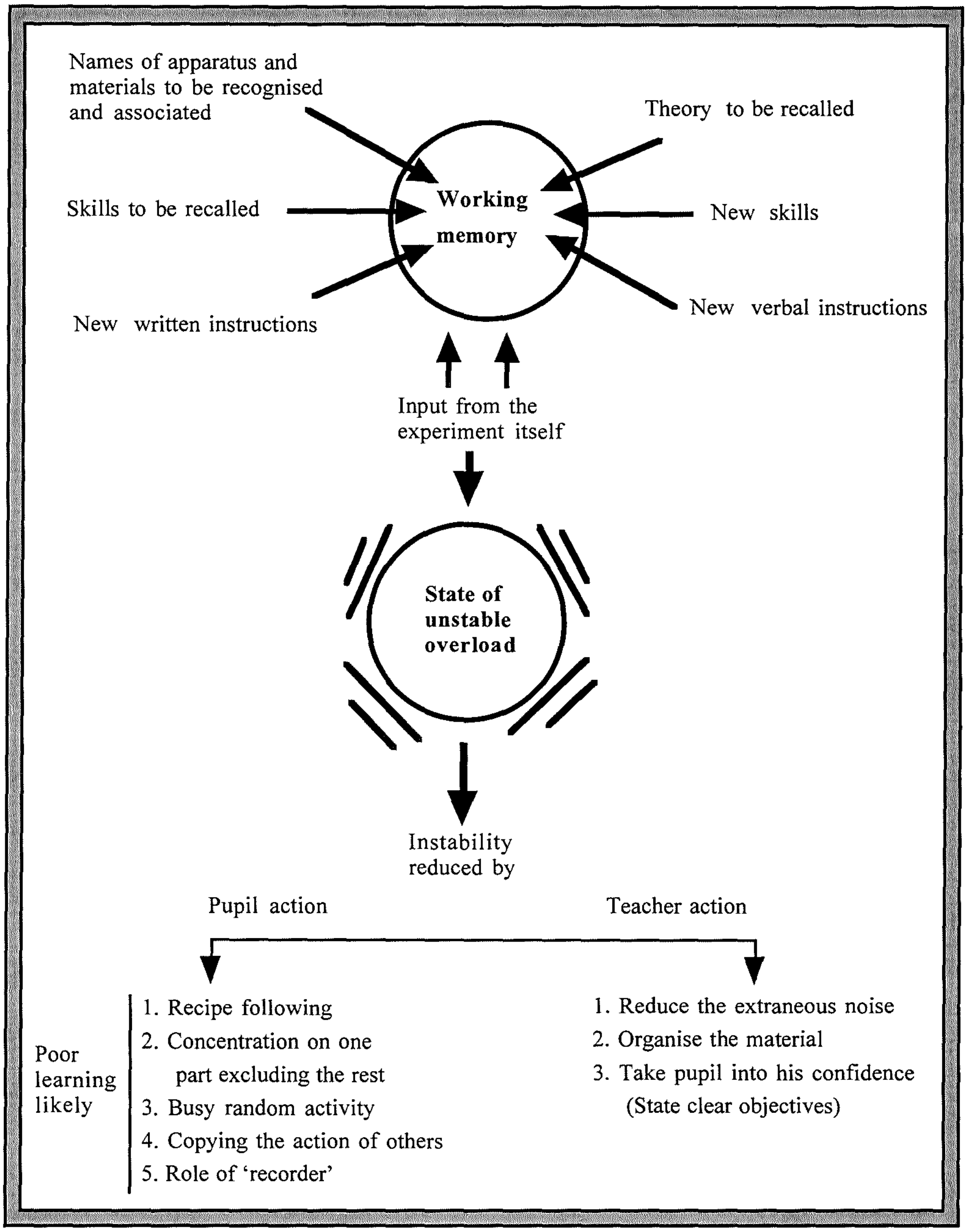


Figure 5.8 The Effects of Overloading Working Memory Capacity in Practical Work

Source: (Johnstone and Wham, 1982)

The extraneous material to the laboratory experimental activities is described as 'noise'. It is very likely that the noise has the potential of overloading the student's working memory during the practical activity. Findings of this study reveals that it is possible to reduce the noise and enable the students to respond to the appropriate signals or stimuli information during a practical activity through carefully design experiments. It is assumed from these findings that a similar approach can be used at all levels of learning to reduce noise and enhance meaningful learning.

However, Johnstone and Wham (1982) contend that the presence of the noise has potential value in some situations. The ability to distinguish successfully the difference between noise and useful information may eventually become a reinforcer for the student's understanding of the experiment. The argument is that the demands from selecting useful signals from potential noise material may enhance the student's grasp of the theory and methods.

Long-Term Memory

According to Child (1993), the long-term memory (LTM) is characterised by an extensive capacity which has the primary function of storing encoded information. The information stored in the long-term memory is not subject to decay as is the case with information found in other components of the memory structure (Bourne *et al.*, 1986; Baddeley, 1994; Bruning *et al.*, 1995). According to Bourne *et al.* (1986), the information contained in the LTM is considered by many psychologists as everlasting. They believe that the information merely becomes less accessible with time. This notion has not yet been confirmed through research.

Due to the seemingly limitless capacity of the LTM span, it is assumed that the information in contained in it constitutes the human being's representation of the world (Bourne *et al.*, 1986). Schacter (1993), therefore, suggests that processes of rehearsal and repetition that are essential for STM appear to be of less importance for retention and recall of the information stored in the LTM. For example, the intuitive actions that allows an individual to go to school every morning, stop at a stop sign, or tell a story come from LTM.

Knowledge from LTM has been divided into two major distinct types: declarative knowledge and procedural knowledge. Other psychologists prefer to further distinguish declarative knowledge as episodic (knowledge concerning personal history of an individual) and semantic (concerned with the individual's general factual knowledge). According to Bruning et al. (1995), declarative knowledge is "factual knowledge" or "knowing what". It enables the individual to recall information like: Botswana is a country in the southern part of Africa, the earth revolves around the sun, a cow produces milk from its udder.

Procedural knowledge on the other hand, is said to be dependent, to a large extent, on the amount of declarative knowledge an individual has. However, the demonstration of this knowledge is loosely linked to the declarative knowledge: for example, riding a bicycle, driving a car, or opening a bottle. Some of the procedural knowledge is automatic. It can be demonstrated without involving the individual's conscious attention: for example, making sense of information received, talking to a group of friends, or putting food into the mouth during dinner. Johnstone (1993) says that this information contained in the LTM is responsible for enabling the individual to select what gets encoded as STM information. His evidence indicates that a person's perception of the world is significantly influenced by the knowledge contained in the LTM.

5.13 Conclusions

It is clear that the number of units of information the individual can handle and manipulate at a time in order to produce the correct response is dependent on the individual's cognitive stage, which is a function of maturity (i.e. developmental). Shayer and Adey, on the other hand, are concerned with the belief that people's cognitive abilities can be increased beyond their developmental stage. However, their theory has been unsuccessful in resolving the issue of why the strategic learning is inapplicable to other individuals. The theory has also failed to acknowledge that individuals employ different strategies to arrive at the same solution.

The information processing models has the primary function of explaining the limit of the working memory space, which the theory suggests can be improved through chunking. The models can also be used to explain why Piaget's developmental stages happen. Through the information processing models, it may be possible to explain why cognitive acceleration through strategic learning is possible. This project, therefore, is intended to explore whether pupils can be taught strategies to function beyond their cognitive stages of development or whether their cognitive ability is simply developmental as Piaget had suggested.

CHAPTER SIX

EXPERIMENT ONE

6.1. Aims of the Survey

Arguments raised in the previous chapters established a need to investigate some aspects of practical activities planned and designed for science lessons, particularly at junior secondary school levels. The world wide desire by science educators and policy makers to promote scientific literacy is central to the search for effective approaches required for teaching and learning science in schools. Emphasis by some curricula to engage pupils at junior secondary school levels in pupil-planned and pupil-designed investigations raises some concerns about the cognitive ability of those pupils to handle such exercises and produce expected outcomes.

Do pupils at junior secondary levels (13-15 years old in the case of Botswana and 12-14 years old in the case of Scotland) have the cognitive ability to plan and design experiments which investigate scientific ideas? Can they formulate theories and identify critical experiments to test the theories? Have they covered adequate content material to use the scientific method without excessive assistance from teachers?

Experiment one seeks to establish a base-line as what extent the Botswana school pupils are able to conceptualise the place of experimentation in investigating scientific phenomena.

6.2. Research Instruments

To establish the base-line for the study, two methods were used:

(1) the card game called Eloosis

(2) a questionnaire/test specially devised for the purpose.

Before describing how the questionnaire/test method was used, it is important to review the literature on questionnaire and interview to establish the reason for the choice of using a questionnaire in this study.

6.3 Rationale for the Use of Questionnaires and Interviews

Research measures a wide range of characteristics in humans. Some characteristics are more observable than others. The data being sought will often determine the method to be used (Wiersma, 1995). Mason and Bramble (1989) suggest that those human characteristics that are less observable, such as values, goals, opinions, attitudes, preferences and so on, are best measured by using interviews and questionnaires.

Interviews

Mason and Bramble (1989) define the interview as a method of data collection that involves verbal discussion conducted by one person with another primarily to obtain information. Through interviews, useful information about an individual can be gathered that would otherwise be impossible to gain by merely observing the actions of the individual or otherwise.

The interview method is generally considered flexible and easy to adapt to a variety of situations (Mason and Bramble, 1989). The fact that the interviewer can probe for more information by exploring the responses and asking questions that clarify points, makes the interview method a viable tool for collecting vital information. Items constructed for the interview may be structured or unstructured.

Mason and Bramble assert that usually structured interview questions characteristically require restricted responses which are commonly constructed in the form of checklists. In the case of the unstructured interview questions, the respondents are afforded the opportunity to express their views or feelings in their own words. Further inquiry can be done by introducing probing sub-questions which are meant to elicit complete responses.

However, this method, because of the quantity of information the interviewer has to handle and its time consuming nature, is usually recommended for use with small samples. In addition, Weiss (1975) identifies some potential sources of error associated with the use of the interview method. Amongst them is the possible lack of motivation on the respondent to provide answers, the respondent may feel the presence of the interviewer intimidating or threatening, or the respondent may provide responses perceived by him or her to safeguard his or her integrity. Coupled with the these, is the inescapable possibility of the interviewer failing to maintain consistency in the manner of asking questions to all the respondents within the same survey which may have some adverse effects on the reliability of the data collected.

The construction of the items or questions for the interview has the potential to induce wrong interpretation by the respondent which may draw from the respondent an unexpected response (Weiss, 1975). On the contrary, the advantage derived from the unstructured interview questions of greater flexibility in data collection, is asserted to have an influence on the necessity to increase objectivity and confidence building in the interviewer. The flexibility of the unstructured interview questions presents, in addition, the difficulty of recognising patterns of responding to individual items and common opinions amongst respondents.

Questionnaires

Questionnaires are used for surveys that normally involves large samples ranging in magnitude from local surveys to national surveys (Wiersma, 1995). Questionnaires like interviews measure data relating to some of the less observable characteristics of humans discussed above. They consist of a sequence of items or questions which require respondents to answer. These items or questions can be open-ended for which the respondent has to construct a response ranging from one word to a few sentences. The items can sometimes be constructed such that respondents are required to select or make a forced choice from two or more options. Unlike the interview questions, administration of the questionnaire items do not necessarily demand the presence of the researcher.

Mason and Bramble (1989) describe some of the advantages offered by questionnaires which make them more reliable in certain situations compared to interviews. The fact that the use of questionnaires allows the researcher to reach a larger sample economically implies that a significant amount of data can be collected within a short period and with less expenses. The large data size further “increases generalisability” (Mason and Bramble, 1989) of the findings from the data. Another point which may be significant in certain conditions is that of maintaining greater anonymity to the respondents. They assert that the respondents have been observed to be more willing to provide genuine answers to the items whenever they feel not threatened or intimidated by the presence of the researcher and whenever they are assured of their anonymity.

Despite the positive attributes of the questionnaires, some disadvantages have been observed in some situations. For example, there are cases where respondents do not return the questionnaires, especially when the questionnaires are mailed and this is said to lower the validity of the survey research. In others situations, it has been observed that some respondents return the questionnaires partially completed, especially when the items are not simple enough for the convenience of the respondents. Both eventualities are asserted to have the potential of introducing bias to the generalisability of the data (Wiersma, 1989).

Clark and Boser (1989) recommend that, for questionnaires to elicit the provision of open and honest responses, the general presentation of the questionnaire structure should be attractive and professional. Secondly, Dillman (1978) suggests that the items should be simple and related to issues perceived important by the respondents.

Despite the overwhelming advantages of using the interview method, the overriding factors which render questionnaires more viable for the purposes of the first experiment conducted are the size of the sample to be studied, the time available to the project and the nature of the data required which does not emphasise too much specificity. The interview method, though effective, is considered suitable during the second experiment carried out, primarily to iron out a few issues of major concern using a smaller representative part of the sample.

6.4 The Card Game (Eloosis)

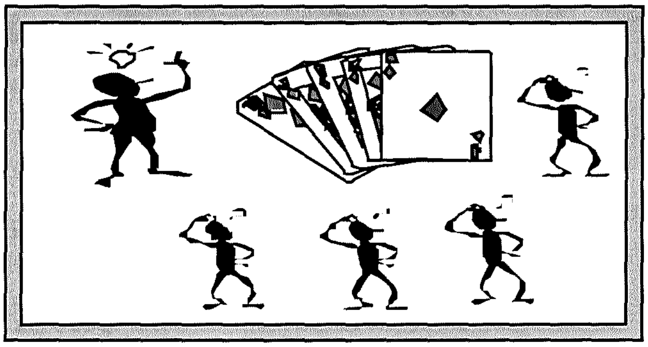
Eloosis is reported to have been used successfully in science courses to teach the scientific method, especially the nature of experimentation in problem solving activities (Ziegler, 1974). Some science educators refer to Eloosis as a card game that simulates the scientific method (Ziegler, 1974; Matuszek, 1995). It was hoped that pupils' play of the card game would demonstrate the place of experimentation in their minds.

Ziegler (1974), having used the game at high school level in the United States of America, makes the following comments:

> *"One topic that occurs in most high school chemistry courses is the scientific method of problem solving. Rather than simply lecturing to the class on the topic this experiment* (Eloosis) *allows the students to uncover the process themselves."* (p.532).

Matuszek (1995) reinforces Ziegler's comments by asserting that Eloosis requires the willingness to think from the player. Another characteristic fact about Eloosis is that it emphasises inductive reasoning or coming up with an explanation that fits the observed facts. This reflects how the game was used in the study.

The original version of the card game Eloosis was invented by Robert Abbott in 1956. The primary purpose of the game was to simulate the scientific method or demonstrate scientific investigations.



The technical purpose of the game is for the players to establish a pattern that could possibly be used to explain the rule of the game. Each player represents a member of a scientific research group working on a defined problem. The group is expected to discuss their thought processes once the game is finished as described by Ziegler (1974).

Ziegler suggests the following guidelines for the discussion of the thought processes and relating the activity of the game to the scientific method:

- Card Game: Place the acceptable card on the table.
  Scientific Process: Collect data
- Card Game: Find a pattern in the accepted cards.
  Scientific Process: Search for regularities and postulate a rule, law or theory.
- Card Game: Play the next card according to the pattern found.
  Scientific Process: Perform an experiment and predict the result.
- Card Game: If card is not accepted, modify or discard the previous rule.
  Scientific Process: Alter or discard a rule in favour of new experimental evidence.
- Card Game: Tell the rest of the players what the rule is.
  Scientific Process: Publish the results of the investigation.

The rules for the original version of Eloosis are very simple and involve less time for play. The rules for the version of Eloosis described by Matuszek (1995) are complicated and too time consuming for the purpose of this project. Ziegler (1974) uses the rules from the original version of Eloosis. The game generally requires the following:

- One dealer/chief and several (5-20) players known as scientists/players
- One pack or two packs of ordinary playing cards, depending on the numbers of players.

For the purposes of this project they are therefore referred to as chief and players. The chief basically invents a rule (a pattern of accepted cards) and deals the cards to players during play.

Basically, the procedures for playing the game involves the following steps as outlined by Ziegler (1974):

(1) The chief shuffles the pack(s) of cards and deals them out until all are gone. It does not matter if some experimenters have one card more than the others.

(2) The players sit around a table next to each other such that they are facing the chief and are able to see accepted cards placed on the table.

(3) The chief announces that s/he has a secret rule of play that the players have to figure out during play. The rules vary in complexity. An example of a simple rule can be: a series of 'a black card followed by a red card' or a series of 'any odd numbered card followed by any even numbered card' and so on. An example of a complex rule can be: a series of 'any first two black cards numbered lower than five followed by any red card numbered above five' and so on.

(4) The player to the left of the chief then starts the game by placing a card face up on the table.

(5) The first card played can either be accepted or rejected by the chief depending on whether the card fits the predetermined rule of the game or not. Any card accepted by the chief is left on the table and any that is rejected is immediately withdrawn by the player and play passes on to the subsequent player.

(6) Each player in turn decides on one card from the lot and places it face up next to those cards already accepted. This arrangement of the accepted cards provides a constant reminder to the players to work out the pattern that might explain the chief's rule. Players are allowed to assist each other with the decision of which card to play where necessary.

(7) A round of play is completed when all players have had a chance to play. At the end of each round the chief has to ask the players to fill in the checklists before they start the next round from the first player.

(8) At any point during play, a player may signal to the chief if s/he thinks s/he has figured out the rule. At this point the chief may stop the game or may ask the next player to play a card to verify or falsify the claim, if the player is right. A wrong claim means the game continues until one player proposes a correct claim.

(9) However, players are not allowed to discuss their thought verbally but, they can exchange cards to assist each other where necessary.

In practice, with large classes in the case of Botswana schools, the game was played with about 6 pupils who were at the front of the class and held up their cards for all to see. Subsequently, each of these 6 players became the leader or chief of a group of pupils who were also required to play the game themselves (See Appendix C).

The first set of rules was then issued to the chiefs, who were under strict instructions to conceal them until the players have worked them out correctly. The researcher assumed the role of coordinating the activity primarily to maintain consistency on the way the chiefs conducted the play. Each group was assigned an identity number, just before the start of the game, starting with the number **(1)**. Due to the limited time allowed by the institutions concerned, each group had a maximum number of six rounds to play the card game before they were told to stop and discuss its significance to the scientific investigations process (scientific method). Pupils also used a checklist as they played the game (see figure 6.1 and appendix E).

Progress Assessment Form for the Game Eloosis

Group Number: ☐

ROUND ONE

Have you worked out the pattern? (*Tick the box that applies to you*) ☐Yes ☐No

What is the pattern? (*Describe it*) ______________________

How confident are you? (*Put a tick in the box that applies to you*)

(*Tick here*)

I have no real idea, so I have just made a guess .... ☐
I cannot be sure, but I think I have it .... ☐
I am almost sure, but I would like some more information .... ☐
I really believe I have it .... ☐
I know it and I can prove it .... ☐
The next card I would play to prove it would be (*Name it*) ______________________

Figure 6.1 Round One of the Checklist for the Eloosis Card Game

[Note that the checklist extend up to round six and that the items are the same for all the six rounds].

6.5 The Questionnaire/Test Used

A three section questionnaire/test was devised to explore the following:

<u>Section 1</u> Personal information about the pupils.

Item 1.1 require pupils to state their ages.

Item 1.2 required pupils to identify themselves by gender.

Item 1.3 asked pupils to state their year of study.

Item 1.4 required pupils to state the language they frequently used to communicate at home.

Item 1.5 asked the pupils to select from listed statements those which describe how they learn.

<u>Section 2</u> The thinking skills pupils applied during the game Eloosis to work out the chief's rule.

Item 2.1 asked pupils to select from a list of problems they might have encountered when working out the chief's rule.

Item 2.2 asked pupils to describe in their own words how they worked out the chief's rule.

Item 2.3 asked the pupils to select any of the methods listed that they thought they used to work out the chief's rule.

<u>Section 3</u> Solving the genealogical problem

Item 3.1 required the pupils to complete a family tree diagram using information provided.

Item 3.2 asked the pupils to manipulate the information given to work out grandmother's age.

The questionnaire/test was administered to the pupils a week later following the play of the game Eloosis. Pupils were requested to spend 15 minutes responding to the questionnaire/test items. The full questionnaire/test is shown in the appendix G.

6.6 Reliability and Validity of the Research Measurements

Validity is considered the most important characteristic of a research instrument or test (Elmes *et al.*, 1989; Mason and Bramble, 1989; Wiersma, 1995). Elmes *et al*. (1989) assert that a valid test has to be reliable but a reliable test does not necessarily have to be valid. They define validity of a research test as the "trueness or honesty" of the test. In the same vein, Mason and Bramble (1989) refer to the validity of the test as the degree to which the test measures what it is intended to measure. According to Elmes *et al.*, a test which measures consistently what it is supposed to measure is preferable to a test which measures inconsistently what it is purported to measure. The term 'consistency' is used to imply the extent to which a test can be considered reliable (Elmes *et al.*, 1989; Mason and

Bramble, 1989; Wiersma, 1995).

Face validity was used to measure the extent to which the test and Eloosis measured what they were designed to measure. This was achieved by using the professional opinions of a group of experienced teachers. The two methods used in this part of the study provided evidence on the consistency of pupils' conceptualisation of the place of experimentation in investigations of scientific phenomena.

6.7 Population of Study and Sample Selection

A sample of 330 pupils randomly chosen from five lower secondary schools in Molepolole region (Botswana) was used in the first experiment of the study. The sample consisted of 157 boys and 173 girls taken from years one and two. There were some special reasons for choosing schools in the Molepolole region. Firstly, the project could negotiate quickly access to the schools compared to elsewhere since the researcher is well acquainted with schools in the area. Secondly, Molepolole is one of the major villages in the country nearer to a city (See Appendix A). The project therefore, assumes that the nature of the pupils in these schools encompasses both characteristics of rural and urban pupils.

The group selected from each school consisted of a class of pupils randomly chosen by the school. Unfortunately, all year three pupils were preparing for their end-of-year examinations and so could not be included as part of the sample. The schools had the entire prerogative to select a class from each year group to participate in the study. The system of selecting pupils to different classes within a year group in all the schools visited is based purely on mixed ability grouping. This means that within a class, there is a wide range of ability, especially in terms of language proficiency, reading and writing and subject knowledge.

All pupils in the sample studied science (integrated science) as one of their core school subject. Each group or class of pupils constituting part of the sample was visited for two hours during the afternoon session. Table 6.1 indicates the number of pupils selected from each school.

School	Year one	Year two	Totals
A	35	28	**63**
B	36	33	**69**
C	-	36	**36**
D	37	40	**77**
E	40	45	**85**
Totals	**148**	**182**	**330**

Table 6.1 The Number of Pupils Selected from Each School

Each year group from each school represents a class. A class, in the case of Botswana secondary schools, comprises a group of pupils who are taught the core subjects by the same teachers, share a class teacher or registration teacher and is of mixed ability.

6.8 Data Collection

To have access to the pupils in the schools, permission (Appendix T) was sought from the headteachers of the schools, science teachers and parents through the regional education officer (Molepolole region). This part of the study was conducted within a period of one month.

As a licensed secondary school teacher and a local, the researcher required less assistance from teachers in terms of language communication, class control, and supervision of activities. The activities of this part of the study were organised as shown by figure 6.2.

Dates	Planned Activities
1st Week October 2000	Organise access to schools and arrange dates for meeting the selected students.
2nd Week October 2000	Visit schools to play Eloosis with pupils, administer checklists and leave test papers with science teacher.
3rd Week October 2000	Continue activities from week 2
4th Week October 2000	Administration of test to pupils by teachers in all schools visited.

Table 6.2 A Schedule of Activities During Experiment One.

[Note: The test papers were collected from schools by week one of November 2000 by the researcher.]

The results from this experiment were analysed, interpreted and discussed below.

6.9 Playing Eloosis and Recording Results

To investigate the effectiveness of this method, pupils were asked to participate in activities which required them to play the game, continuously recording their confidence levels after each round of play until the end of the game. The results of the pupils' confidence during their play of Eloosis were recorded (Appendix L) and analysed. A null hypothesis was assumed for this investigation which is "*The change(s) on the levels of confidence from the start through to the point where the problem has been solved for the sample population is (are) unrelated to the year of study, to gender or to age*".

Each group in a class played the game twice followed by a whole class discussion led by the researcher. The rules of play used by the chiefs in the first sessions were simpler and only required the players to manipulate two variables, that is, colours and numbers on the cards. During the second sessions, the rule of play used by the chiefs were more complex, requiring more than two variables to manipulate. For example, pupils were expected to consider the colours, numbers, the colour patterns, the number patterns and probably the picture and non-picture cards patterns.

6.10 Analysis and Interpretation of Experiment One Results

The results of the confidence scores and the test responses were recorded as shown on Appendices L & M. Some of the results from the test were analysed using the chi-square as a contingency test.

Results of Confidence Level Measurement

At the end of each round, the pupils' levels of confidence were assessed (see figure 6.1, page 5). The number of pupils who responded to this checklist is 280. Even though the total sample is 330 pupils, 50 pupils were used as chiefs during the game and they did not fill in the checklist. The results of the measurement of the confidence levels after each round of play by year 1 group is shown in tables 6.3 to 6.6 as frequencies. In each table, the designation level 0 represents those pupils who failed to indicate their confidence level. The other levels are as follows:

Level 1 'I have no real idea, so I just made a guess.'
Level 2 'I cannot be sure, but I think I have it.'
Level 3 'I am almost sure, but I would like some more information.'
Level 4 'I really believe I have it.'
Level 5 'I know it and I can prove it.'

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	66	16	15	15	4	10
Round 2	40	24	21	25	6	10
Round 3	35	27	11	19	19	15
Round 4	35	23	11	21	21	15
Round 5	38	20	12	20	21	15
Round 6	39	20	12	19	20	16

Table 6.3 Year 1 Game 1 Confidence Level Results

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	41	32	5	26	35	15
Round 2	13	34	17	26	45	19
Round 3	13	25	16	31	50	19
Round 4	13	25	16	31	50	19
Round 5	13	25	16	31	50	19
Round 6	13	25	16	31	50	19

Table 6.4 Year 2 Game 1 Confidence Level Results

At face value, there was a hint of evidence that year 1 pupils showed a slight build up of confidence during game 1. At year 2, more pupils immediately after round 1 showed a greater increase in their levels of confidence. The number of year 2 pupils with higher confidence levels remained constant and greater than that of year 1 pupils throughout the subsequent rounds. This picture painted by the results clearly reject the null hypothesis proposed: "*The change(s) on the levels of confidence from the start through to the point where the problem has been solved for the sample population is (are) unrelated to the year of study*". However, year 2 appear more confident than year 1 pupils.

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	87	18	4	5	7	5
Round 2	49	25	9	17	16	10
Round 3	57	19	9	16	15	10
Round 4	51	24	12	15	15	9
Round 5	54	17	13	15	15	12
Round 6	42	19	16	19	18	12

Table 6.5 Year 1 Game 2 Confidence Level Results

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	106	20	7	16	5	0
Round 2	72	17	10	34	17	4
Round 3	53	19	14	34	30	4
Round 4	44	17	18	34	37	4
Round 5	44	17	20	36	34	3
Round 6	31	19	17	40	40	7

Table 6.6 Year 2 Game 2 Confidence Level Results

During game 2, year 1 pupils showed even less build up of confidence compared to the year 2 pupils (table 6.5 and 6.6). Year 2 were reluctant to indicate the high levels of confidence during game 2. The majority of the year 2 pupils believed they really knew the answer but, due to their experience of game 1, they indicated that they would like to have more information before they declared their highest level of confidence.

The results, therefore, clearly indicate a relationship between the pattern of the change in confidence levels during problem solving activity and maturity. As the activity became more complex, fewer younger inexperienced pupils assumed higher levels of confidence. The older more experienced pupils showed a more cautious approach to solving the problem by steadily assuming higher levels of confidence (see table 6.6). However, both groups demonstrated similar difficulties in solving the rules of the game.

For both games with year 1 and with game 2 for year 2, the responses for each round tends to follow the following pattern:

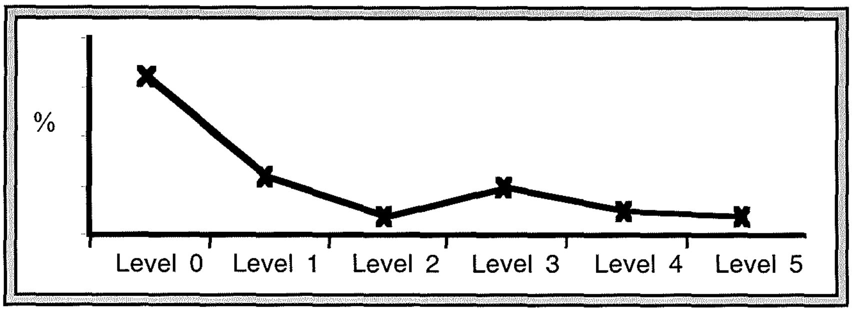


Figure 6.2 An Illustration of the Confidence Build-up for game 1 &2 with Year 1 and Game 2 with Year 2 After Each Round.

With game 1 and year 2, a different pattern is observed:

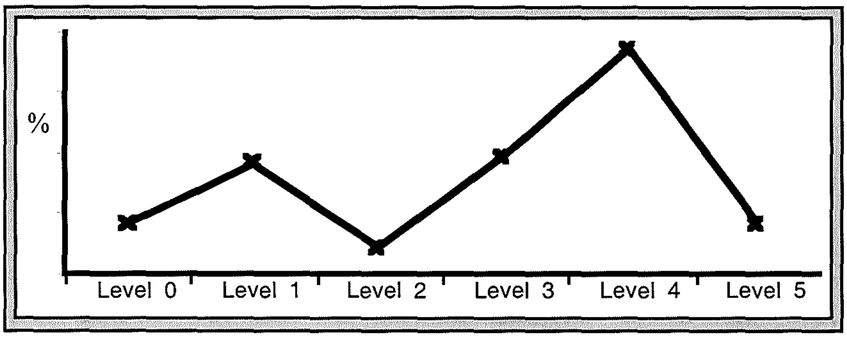


Figure 6.3 An Illustration of the Confidence Build-up for game 1 with Year 2 After Each Round.

This might suggest an element of over-confidence of year 2 pupils as they start game 1. This pattern of confidence reverts to that seen for year 1 after year 2 experienced the difficulty of the first game.

Again a face value inspection of the year 2 results indicates a close relation to the year 1 results. Nonetheless, the number of pupils with higher confidences (for example, 'I know it and I can prove it') seem to decline to less than half that observed during game 1. In all the year groups' results, there is a tendency by most pupils to place themselves, in terms of the confidence levels, mainly around uncertain positions of confidences, particularly during rounds 3 to 6. Needless to say, it was noted that not all pupils who indicated having a high level of confidence could describe the rule correctly.

The 'bumpy' build up of confidence can be seen when looking at game 1 for both year groups added together (table 6.7).

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	107	48	20	41	39	25
Round 2	53	58	38	51	51	29
Round 3	48	52	27	50	69	34
Round 4	48	48	27	52	71	34
Round 5	51	45	28	51	71	34
Round 6	52	45	28	50	70	35

Table 6.7 Year 1 and 2 Game 1 Confidence Level Results

This can be illustrated graphically (figure 6.4)

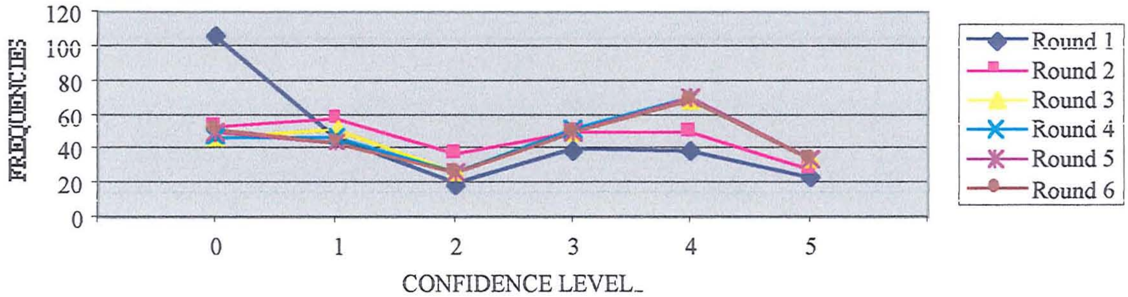


Figure 6.4 Graph of Year 1 and 2 Game 1 Combined Confidence Results

A similar table of results and graphical representation is obtained for game 2 (table 6.8 and figure 6.5).

Rounds	CONFIDENCE LEVEL FREQUENCIES					
	Level 0	Level I	Level II	Level III	Level IV	Level V
Round 1	193	38	11	21	12	5
Round 2	121	42	19	51	33	14
Round 3	110	38	23	50	45	14
Round 4	95	41	30	49	52	13
Round 5	98	34	33	51	49	15
Round 6	73	38	33	59	58	19

Table 6.8 Year 1 and 2 Game 2 Confidence Level Results

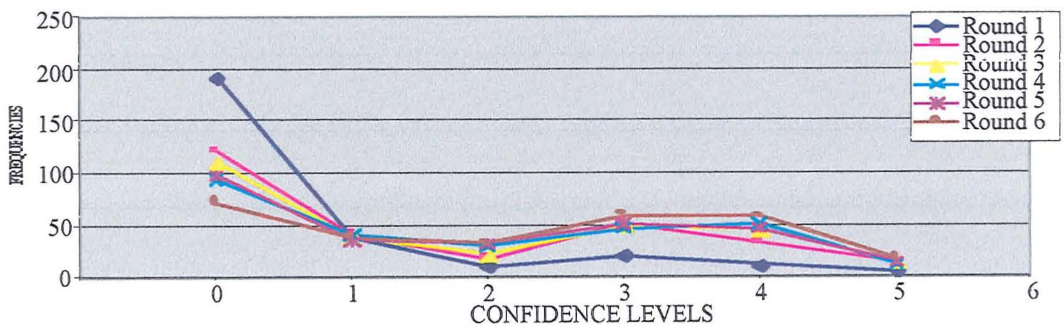


Figure 6.5 Graph of Year 1 and 2 Game 2 Combined Confidence Level Results

6.11 Summary of the Findings

Observing the way the pupils took part, it was clear that initial unwillingness to commit themselves often moved to over-confidence which then developed into a tendency to question their line of thought or ask for more information. However, the general trend concerning confidence building by pupils during their play of Eloosis provided a strong suggestion that problem solving does not follow a linear type of thought process.

In spite of the 'bumpy' process, pupils showed a lot of enthusiasm in playing the game. The game play sparked much debate amongst members of each group. The researcher observed in many of the instances that the enthusiasm from players came, not as a result of enjoying peer interaction only, but also from the demands placed on their cognitive involvement during play. Many came up with wonderful suggestions for the rule of the game when they thought they had it. However, the rejections from the chiefs on some of the suggestions made did not appear to deter the majority of the pupils from trying out new lines of thought.

As was expected, the pupils demonstrated a lot of interest in playing the game Eloosis. Overall, apart from over-confidence in year 2 at the outset, the two year groups tend to show the same patterns of behaviour. This is consistent with the idea that, in cognitive terms, they are at similar developmental levels when faced with this kind of problem.

6.12 Questionnaire/Test Results

The questionnaire/test responses were recorded and presented in the table shown in appendix M. The coding and interpretation of the response values are described as well (Appendix M). In addition, the frequencies of the responses were converted into percentages and tabled as shown by appendix N. The responses to the questionnaire/test came from all pupils who took part in the Eloosis game, including the chiefs (N=330). The questions from the questionnaire/test discussed are shown in figures 6.6, 6.7, 6.8 and 6.9. For each question, two percentages are given. The first is the percentage for year 1 and the second is the percentage for year 2.

[Note that in all the figures 6.6, 6.7, 6.8 and 6.9, the first number in percentage is the year 1 result and the second number in percentage is the year 2 result.]

1.6 How do you describe yourself? (*Tick all the boxes that apply to you*)

27/21 I learn better on my own.	55/68 I learn better when sharing ideas with others.
11/22 I like solving challenging activities.	16/10 I like solving easy activities.
49/55 I like to take part during group discussions	30/36 I like listening to others talk during group discussions

Figure 6.6 Item 1.6 of Section 1 of the Test

2.1 Which of the following are the problems that you had when working out the chief's rule in groups? (*Tick as many boxes as you wish*).

29/13 The time for playing the game was not enough.	45/48 The instructions for playing the game were not easy to understand.
42/46 The chief's rule was difficult to work out.	33/30 I did not discuss my ideas with other members of the group.
35/24 Other reasons (explain)	________________________

Figure 6.7 Item 2.1 of Section 2 of the Test

2.2 How did you work out the chief's rule? (*Explain*) __________ * *

2.3 Which of the following did you apply to work out the chief's rule? (*Tick any **TWO** boxes that apply to you*).

48/40 By guess work.	47/44 Observing the pattern of cards accepted by the dealer from others.
40/39 Observing the pattern of cards accepted by dealer from me.	45/42 Observing the pattern of cards rejected.
25/9 Anything else (*Write it down here*)	________________________

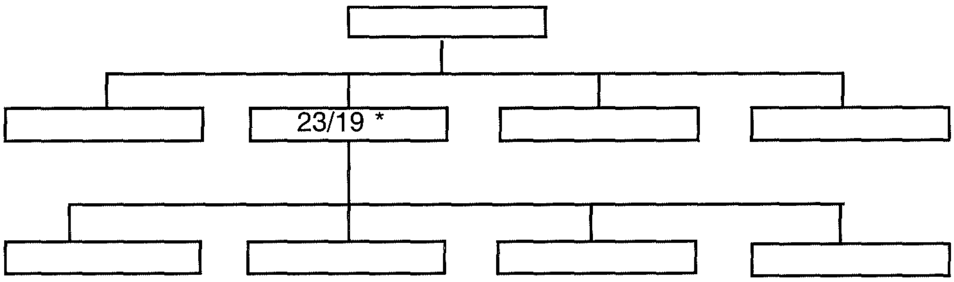
Figure 6.8 Items 2.2 and 2.3 of Section 2 of the Test

[* * This question was included to start the pupils thinking. The results were not analysed.]

The table below gives information about a family, from grandparents to grandchildren. It is the year 2000.

Grandmother Still alive in the year 2000	Aunt 10 years older than uncle 2	Uncle 1 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than uncle 1	Uncle 2 2 years younger than mother	Potso In 1990, her age was one-fifth of the age of her aunt.
Bodo In 1985, his age was half the age of Potso	Pako 2 years younger than Bodo	Vanessa 2 years younger than Pako

3.1 From the information given in the table, complete the family tree diagram below, starting with grandmother.



3.2 What other piece of information would you need about Vanessa to work out the **age of her grandmother** in the **year 2000**?

13/5 *

Figure 6.9 Items 3.1 and 3.2 of Section 3 of the Test

[* The figures indicate the percentages of year 1/year 2 pupils who responded to the items 3.1 and 3.2 correctly.]

The null hypothesis assumed in this case is:

> *"The pupils' level of educational attainment, age and gender are unrelated to their performance on a test that measures their self descriptions of how they think they can learn science better, their preferred methods of solving problems, solving a genealogical problem".*

Chi-square as a contingency test (Appendix K) was used to evaluate the null hypothesis. A determination of the existence of a difference between the choices made by the pupils at different years of study over their self descriptions and preferred methods of problem solving using raw data indicated that no obvious pattern emerged (Appendices O). The success on item 3.1 produced a statistically non-significant differences between the performances of each year of study (Appendix O). The frequence of the responses to item 3.2 were too small for the chi-square calculations to be done on them (see figure

6.12). Thus, in the genealogical item performance comparison, no statistically significant differences were found between year groups. The results sustained the null hypothesis proposed for this test.

Further comparisons were made between the following:

- pupils' self descriptions (item 1.6) related to their preferred ways of working out the chief's rule (item 2.3).
- pupils' gender (item 1.3) related to their self descriptions (item 1.6).
- Pupils' gender (item 1.3) related to the pupils' success on items 3.1 and 3.2.
- pupils' age (item 1.2) related to their self descriptions (item 1.6).
- pupils' age (item 1.2) related to their success on items 3.1 and 3.2.

The chi-square as a contingency test used in some cases to make the comparison. Items 2.1 and 2.2 turned out to be asking for the same information provided in item 2.3, and were considered a repeat and were therefore not analysed. The values (in percentages) are presented in tables 6.10, 6.11, 6.12 and 6.13. The values for table 6.9 were presented as raw figures since it was not possible to convert them to percentages. The numbers in brackets ( ) for tables 6.10, 6.11, 6.12 and 6.13 show the total number of pupils in that category. The chi-square test was calculated using raw data in tables 6.12 and 6.13. Grouping was used to satisfy the conditions for the use of the chi-square test.

	Q2.3 Preferred Methods				
Q 1.6 Self description	Guess work	Cards accepted by me	Other methods	Cards accepted by others	Cards rejected from all
Learn better on my own	9	16	4	18	13
Solving challenging activities	5	14	5	12	10
Take part in group discussions	29	37	13	39	33
Sharing ideas with others	42	32	14	40	28
Solving easy activities	8	8	3	9	6
Listen to others during group discussions	19	20	8	20	13

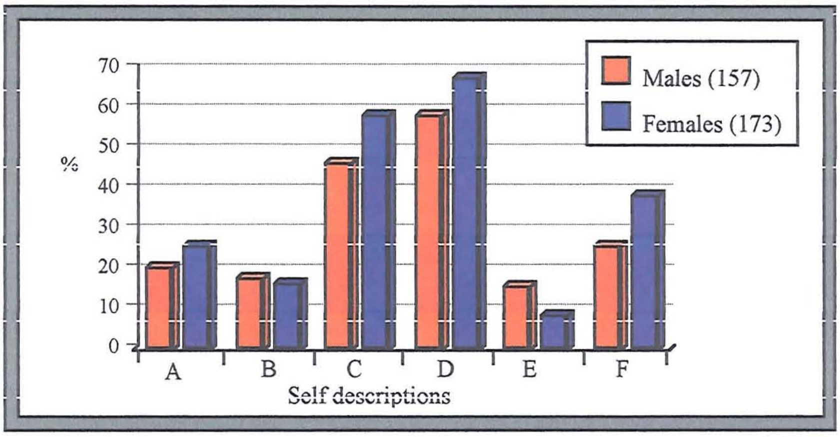
Table 6.9 Year 1 and 2 Self Description (1.6) Against Preferred Method (2.3)

The results of the comparison are presented in table 6.9. No obvious pattern emerged from the data. It appears that there is no clear link between the pupils' self-descriptions and the strategies they applied towards working out the chief's rule.

Gender	Q 1.6 Self description (values in %					
	Learn better on my own	Solving challenging activities	Take part in group discussions	Sharing ideas with others	Solving easy activities	Listen to others during group discussions
Males (157)	21	18	47	59	16	26
Females (173)	26	17	59	68	9	39

Table 6.10 Year 1 and 2 Gender (1.3) Against Self Description (1.6)

The results are presented on table 6.10 and a face value inspection of the frequencies revealed that there was no discernible link between gender difference and the way pupils described themselves as learners. The results were further represented by figure 6.10.



A - learn better on my own	B -like solving challenging activities
C- like to take part in group discussions	D -learn better when sharing ideas with others
E -like solving easy activities	F - like listening to others talk in discussions

Figure 6.10 Year 1 and 2 Gender (1.3) Against Self Description (1.6)

The results indicate that 50% or more of the total sample from both sexes preferred to describe themselves as 'interested in taking part in group discussions' and also 'learn better when sharing ideas with others' (figure 6.10)

Age	Q 1.6 Self description values in %					
	Learn better on my own	Solving challenging activities	Take part in group discussions	Sharing ideas with others	Solving easy activities	Listen to others during group discussions
13+14 yrs (65)	32	11	62	92	15	26
15 Years (126)	18	18	44	64	11	34
16+ Years (139)	24	21	59	63	12	36

Table 6.11 Year 1 and 2 Age (1.2) Against Self Description (1.6)

The relationship between the pupils' ages and their self description as learners are presented on table 6.11. Similarly, no distinctive pattern could be established to describe a possible link between the categories.

	Successful completion of family tree (Q3.1) values in %			
Age	Mother in correct place	Mother wrongly placed	Success in Q3.2	χ2
13+14 Years (65)	31	69	43*	
15 Years (126)	21	79	9*	2.9(2)
16+ Years (139)	21	79	9*	(n.s.)

Table 6.12 Year 1 and 2 Age (1.2) Against Success in Q 3.1 and Q 3.2

[* These values were not included in the chi-square calculations]

The relationship between pupils' successes in placing 'mother' at the correct box in the family tree and their age differences are presented on table 6.12. Again no discernible difference was observed. This was consistent with the observation made within year groups. Noticeable, however, in these results is the emergence of a pattern linking the success on item 3.1 and the success on item 3.2. Roughly 50% of the pupils who successfully placed 'mother' in the correct box responded correctly to item 3.2. in both year groups (figure 6.11).

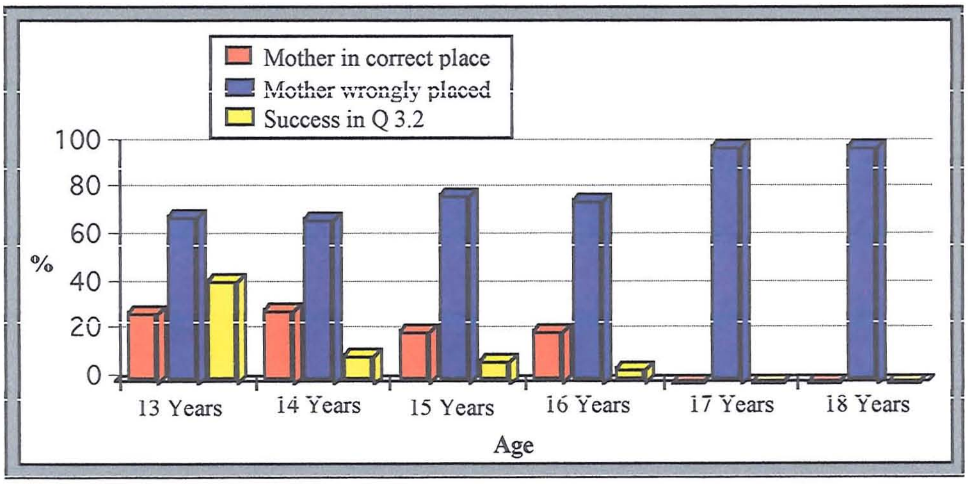


Figure 6.11 Year 1 and 2 Age (1.2) Against Success in items 3.1 and 3.2

Gender	Successful completion of family tree (Q3.1.1) values in % Mother in correct place	Mother wrongly placed	Success in Q3.2	x2 (df)
Males (157)	22	78	8*	0.1(1)
Females (173)	20	80	10*	(n.s.)

Table 6.13 Year 1 and 2 Gender (1.3) Against Success in Q 3.1 and Q 3.2

[* These values were not included in the chi-square calculations]

The results of the determination of a relationship between the pupils' gender and their success on items 3.1 and 3.2 are shown by table 6.13 and graph 6.12.

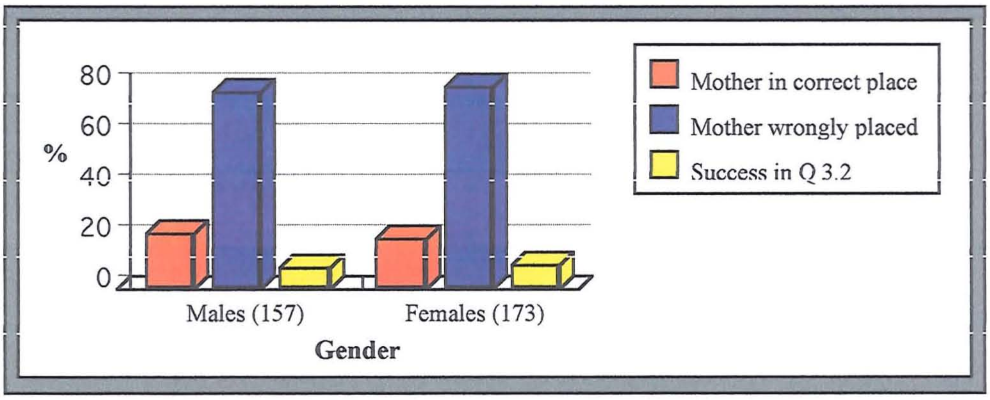


Figure 6.12 Year 1 and 2 Gender (1.3) Against Success in item 3.1 and 3.2

It was also noted from figures 6.11 and 6.12, that majority of the pupils were not successful in working out the solution to item 3.1 or placing 'mother' in the correct box of the family tree diagram. Approximately 20% of the total sample population place 'mother' in the correct box and nearly half of this portion managed to work out the correct solution to item 3.2. A possible explanation for this failure by the majority of the pupils to successfully find the solution to the item 3.2 may be attributed to the 'noise' or the amount of information the pupils had to manipulate at a single time.

However, it has not been easy to establish the exact cause of this failure. Some pupils may have perceived the question too demanding cognitively and not made efforts to work it out, while others may have simply been lazy to even read the question. It is also possible that some pupils read the question and even tried to figure out its solution, but gave in when they realised that its context was not familiar or had no meaning to them.

6.13 Conclusions

It was obvious that the pupils had great enthusiasm in playing Eloosis. It was very clear that the pupils had overwhelming inclinations towards group work and sharing of ideas during problem solving. However, no apparent pattern emerged at all from the data that indicated any significant difference between year one and year two pupils on solving the genealogical items. Indeed, there is an overall lack of success. In fact a higher percentage of younger pupils responded correctly to item 3.2 compared to their older counterparts. The results might have arisen from two possible reasons:

(1) The test was inappropriate or perhaps too hard for them.
(2) The skill of 'seeing' critical information or a critical experiment has not been achieved by pupils for developmental reasons.

The test may have been difficult because it was the first trial test. Consequently, the following measures were taken:

(1) Teaching units were developed to investigate further the developmental nature of the experimental approach.
(2) The test used in the first experiment was improved by way of restructuring the items and the nature of responding to some of them.
(3) It was decided to explore further the use of Eloosis as a *teaching tool* rather than as an investigating instrument in the second part of the study.

CHAPTER SEVEN

EXPERIMENT TWO - BOTSWANA SAMPLE

7.1 Introduction

As a result of the outcomes of experiment one, it is clear that pupils derived a lot of interest from working as a group and sharing ideas. It was also noted from the results that the majority of pupils, at the initial stages of a problem solving situation, were keen and cognitively challenged to work out and arrive at solutions. This enthusiasm, however, deteriorated perhaps as they began to doubt their cognitive readiness.

This part of the study, therefore, is intended to investigate further possible answers to the question raised from experiment one. *If the ability to see experiments as a way of asking questions (including the use of control experiments), is developmental, is it possible to accelerate the development of this skill by using appropriate teaching*?

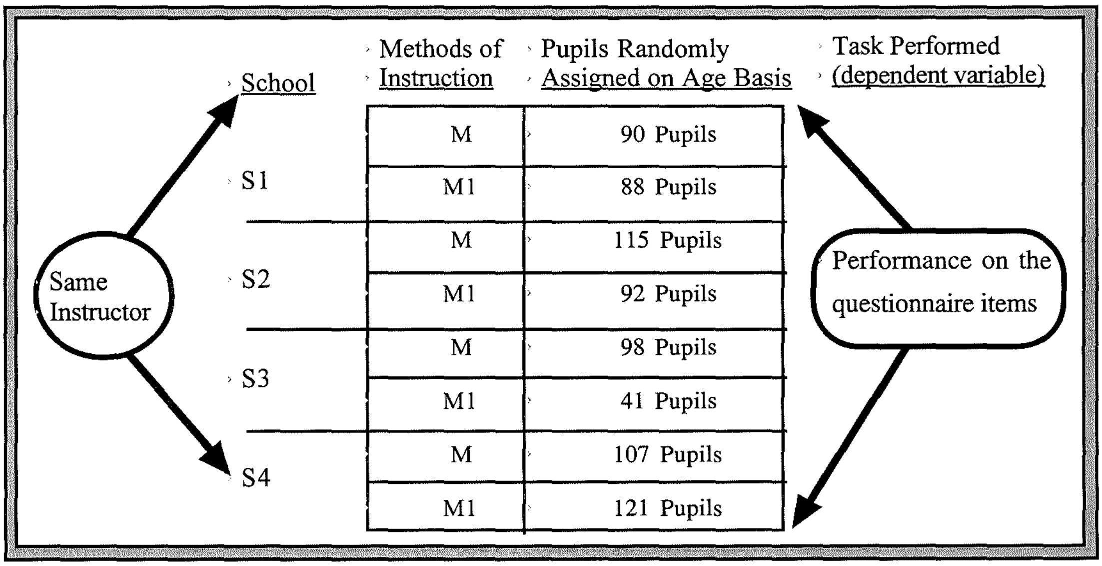
7.2 Research Design

Based on the results of the first experiment, the following assumptions were made:

- ◇ *There is (are) no significant difference(s) between genders, ages and levels of educational attainment among junior secondary school pupils in identifying a solution to a problem through the experimental approach.*
- ◇ *There is (are) no significant difference(s) between genders, ages and levels of educational attainment among junior secondary school pupils in determining a critical piece of information during scientific investigation activities.*

The experimental design was planned to investigate these assumptions by using the same age group of pupils from Botswana as those selected for the experiment one. The sample group was divided into two sections: the experimental and control groups. The experimental group was involved in some activities meant to develop the experimental approach strategies. The control group was never exposed to these activities but underwent normal school learning together with the experimental group.

Teaching units (Appendix D) based on the contents of the Botswana's three-year junior secondary integrated science syllabus were devised (Appendix B). Instructions on Eloosis used as a teaching tool were designed as well. To evaluate the effects of the teaching units and Eloosis, two questionnaires/tests were constructed, one for the experimental group and the other for the control group. These questionnaires/tests were administered to the two groups on the same day under the same instructions by the science teachers who volunteered to help in this project from each of the schools selected. In addition some pupils selected from the sample groups were interviewed.



Note: M - the conventional methods of teaching in the schools.
M1 - the intervention method (using teaching units and Eloosis).

Figure 7.1 A Research Design showing Schools, Instructional Methods, and Ability Levels Controlled to Meet the Project Aims.

To minimise factors such as variation in teaching styles, experience and others, that may produce an unbalanced delivery of the instructions on the teaching units and the Eloosis, the experimental groups were instructed by the same person at the same time of the day and under the same classroom conditions. The figure 7.1 illustrate the research design for this project.

7.3 Sample Population and Organisation

A sample of 752 pupils were randomly chosen from four of the five schools in Molepolole (Botswana) used during the first experiment. The sample comprised of 342 experimental group pupils and 410 control group pupils. The sample selection system used during the first experiment was utilised. The organisation of the sample used is illustrated by table 7.1.

Year Groups	Units Done	No. of Expnt'l Group Evaluated	No. of Control Group Evaluated	Total Evaluated
Year 1	3, 4, 5, 7	95	93	188
Year 2	1, 2, 3, 4, 5, 7	155	202	357
Year 3	1, 2, 4, 5, 6, 7	92	115	207
Totals		342	410	752

Note: One year 2 experimental group was reported on school duty and did not respond to the questionnaire items.

Table 7.1 Sample Organisation.

Schools were given strict instructions to select control group pupils from classes that did not participate in the activities of the first experiment. The activities for the study were planned to be conducted within three months (See table 7.2).

Months in 2001	Weeks	Visit schools to make schedules	Units Teaching	Eloosis	Questionnaire Administration	Questionnaire Collection
July	Week 1	✓				
	Week 2		✓			
	Week 3		✓	✓		
	Week 4		✓		✓	
August	Week 1		✓	✓		✓
September	Week 1		✓	✓		
	Week 2		✓		✓	
	Week 3		✓	✓		✓
	Week 4				✓	
October	Week 1					✓

Table 7.2 Schedule for School Visits

Each group (both experimental and control) was a class consisting of a balanced number of girls and boys (~35-45 pupils) who studied integrated science and was characterised by a wide range of abilities amongst the pupils. Each experimental group had two sessions (1 hour 30 minutes each) of units teaching and Eloosis.

A year group, for example, in the first session, would get instructions on two teaching units followed by a discussion on how each sub-group worked out solutions to the problems. The average time taken to work on each unit was 30 minutes. In the second session, the group continued to work on a third teaching unit and Eloosis, followed by a few minutes of discussions. The group would then be administered with a questionnaire/test a week later together with the control group from the same school.

7.4 A Description of the Research Instruments Used

Teaching Units

The titles and the main objective(s) of each teaching units are now described. A full description of the units is in Appendix D.

Unit 1 - Using The Right Metal (*based on topics covered by years 2 & 3*).

- Pupils were expected to use information provided on some characteristics of selected metals to choose the best metal for each described purpose.
- The tasks required pupils to identify the critical information and design a critical experiment in order to provide a scientifically viable choice of metal.

Unit 2 - Trees and Cars (*based on topics covered by years 2 & 3*)

- Pupils were expected to manipulate and use the information given about trees and cars to determine whether the claims by the newspaper were credible.
- The activities required pupils to debate in a group and generate possible ideas that would justify their reasons for or against the newspaper claims.

Unit 3 - Food and Health (*based on topics covered by years 1, 2 & 3*)

- Pupils were asked to use the information provided on the kinds of food required by the human body and their functions in the human body to prescribe a healthy diet for individuals at different ages. The activities also asked pupils to identify a crucial part of the diet besides those described.
- The tasks required pupils to identify the critical piece of information necessary to provide a reliable solution to a problem.

Unit 4 - Shadows (*based on topics covered by years 1, 2 & 3*)

- Pupils were expected to use information they gained from school science lessons to design a critical experiment that would provide a scientific explanation for the shadow phenomena. The nature of the apparatus to be used was described to them.
- The tasks required pupils to use an experiment as a source of information and identify the critical piece of information necessary for the design of the experiment.

Unit 5 - Ecosystem (*based on topics covered by years 1, 2 & 3*)

- Pupils were expected to use knowledge gained from school science lessons to provide a possible scientific explanations for the observed increase in rats and rabbit populations. Some of the background information on the conditions in the rats and rabbits habitat was provided.

- The activities required pupils to identify critical piece(s) of information necessary for the possible scientific explanation to the problem.

Unit 6 - Speed of Sound versus Speed of Light in Air (*based on topics covered by years 2 & 3*)

- Pupils were asked to discuss in groups their colleagues' explanations of Modisa's predicament and use their knowledge of how sound and light travel to generate a scientifically plausible explanation.
- The tasks designed required pupils to identify a critical piece of information for a scientifically plausible conclusion.

Unit 7 - How Does Sound Energy Travel? (*based on topics covered by years 1, 2 &3*)

- Pupils were asked to discuss in a group statements made by their class mates regarding how sound energy travels. They were to use knowledge they gained from school science lessons to plan and design experiments to support their explanation.
- The tasks required pupils to design critical experiments and identify the critical factor for the result of the experiment to be more reliable.

The activities from each of the teaching units were designed to develop the strategies or skills necessary for pupils to see the experiments as ways of asking questions in problem solving situations. This involved pupils working as a group to generate possible solutions to a problem, plan and design experiments to test what they (pupils) perceive as a critical piece of information and make conclusions that are scientifically viable.

Figure 7.2 illustrates one of the teaching units (unit 4) that pupils were given instructions on. To work on these units, the class was divided into small groups of 4 to 5 pupils. Each small group was requested to select one member to write down their answers on the answer sheet provided (Appendix D).

Unit 4

Shadows

Have you ever wondered why your shadow sometimes looks shorter and other times taller than your normal height? Neo and Bosele have a problem with their shadows. Here is how they try to explain to one another why their shadows sometimes appear shorter and sometimes taller.

NEO:	(*Looking at his shadow on the wall*) Bosele look at my shadow I am a giant. Gggrrrrrr (stretching out his arms). Look at your shadow it is so short. This means that I am taller than you.
BOSELE:	Neo you know very well that you are shorter than me, I am 1.5 metres tall and you are 1.1 metres tall. This is just your eyes deceiving you. If you move to where I am you will see that I am telling the truth.
NEO:	(*Standing next to Bosele*) Aahh! You are right, look at my shadow now .. it is even shorter than yours. Why ?
BOSELE:	(*Grimming*) It depends on where you are inside the house.

Try to help Neo understand what is happening.

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

Task 1: What More Information Do I Need

(1) Would Neo's shadow appear on a vertical wall if he was standing outside the house near the wall with the sun directly above him?

(2) If Neo was taller than Bosele, would his shadow be shorter than that of Bosele when standing next to each other with the sun directly behind them?

(3) There are certain things that are necessary for a shadow to be produced or formed. What are these things? Discuss these things and list as many of them as possible on the answer sheet.

Task 2: Making Neo Understand

(4) You are given the following items to use to design one experiment in order to show how the height of a shadow changes:- a large sheet of white card, a large ball of bostik, a candle, a metre rule, and a ruler. Discuss what this experiment should be. When you have agreed, write down in 3 or 4 sentences the experiment you would carry out. You can draw diagrams to show how you would arrange the items in the experiment.

Figure 7.2 Unit 4 - Shadows

To sustain pupils' interests and motivation during unit activities, the units were devised such that their contexts were related to the pupils' everyday experiences. It was hoped that through group discussions, pupils would generate useful ideas to work out possible solutions to the problems contained in the units. It was expected that, by comparing their answers, pupils would appreciate each others' ideas, acknowledge the various methods used to attain possible solutions to a problem and realise the importance of exchanging notes in order to verify their results.

On completion of the unit exercises, the class was engaged in a discussion focused mainly on the authenticity of the approaches used by the different groups, followed eventually by the instructor providing the correct answers to the questions where necessary. Pupils were requested to remain in the same group throughout the sessions on teaching units in order to get acquainted with each others ways of presenting arguments and thinking things through.

Card Game (Eloosis) Used as a Teaching Tool

The game was played in the same manner as in the first part of the study. A small group of 6 pupils were selected as players with the rest of the class carefully observing the play. The cards accepted were displayed in front of the whole class throughout the play. The researcher assumed the role of the chief. A simple rule was chosen by the chief for the game to last a shorter period of time.

At the end of the game, pupils were engaged in discussions geared towards establishing the link between the game played and how scientists investigates solutions to natural phenomena. The guidelines outlined in chapter six relating the activity of the game to the scientific method of enquiry were applied during this exercise. A checklist, filled in by the researcher, was constructed to provide information on how the pupils played the game (see figure 7.3 and appendix E).

Checklist for Eloosis

Name of School: ______________________________

1. Did the class grasp the general concept of experimentation or asking questions?

☐ Yes ☐ No ☐ Some

2. Did the pupils have any concept of criticality (an experiment with an unambiguous answer?

☐ Yes ☐ No ☐ Some

3. What was the ability of the pupils who managed to grasp the above?

☐ Below average ☐ Average ☐ Above average

4. How much time did the dialogue or the discussions with the whole class take before the above signs were shown? __________ minutes

Figure 7.3 A Checklist for Eloosis Used as a Teaching Tool

7.5 Questionnaires/Tests

Two questionnaires/tests were developed to test further the extent to which Botswana school pupils (13-15 year olds) are able to identify critical pieces of information necessary to work out solutions to problems and plan and design critical experiments to test their line of thought. The theoretical information on the construction of questionnaire items are discussed in appendix F. Questionnaires/tests were designed for the experimental group and the control group.

The Experimental Group Questionnaire/Test

Items for this questionnaire/test required pupils to provide their personal information, their opinions on how they think they can learn science better, their general opinions about the units they worked on, their feelings about working in groups and to demonstrate the thinking skills they gain from science lessons and units.

An Evaluation Exercise

Please complete this questionnaire about your studies in science as honestly as possible. Do not write your name.

Name of School:____________________________________

(1) How old are you? *(Write your age in the box)* ☐

(2) *(Tick one box).* boy ☐ or girl ☐

(3) In what form are you? *(Tick in the correct box)* Form 1 ☐ Form 2 ☐ Form 3 ☐

We would like to know your opinions about how you think you can learn science better.

Here is an example of how to answer the following questions:

If you had to describe "a racing car" you could do it like this:

Quick	✓						Slow
Important			✓				Unimportant
Safe					✓		Dangerous

The positions of the ticks between the word pairs shows that you considered it s very quick, slightly more important than important and quite dangerous.

[Use this method of ticking to answer the items (4) and (5)]

(4) **I can learn science better**

on my own	☐ ☐ ☐ ☐ ☐ ☐	in a group
through solving difficult activities	☐ ☐ ☐ ☐ ☐ ☐	through solving easy activities
through reading science books	☐ ☐ ☐ ☐ ☐ ☐	without reading science books
through science experiments	☐ ☐ ☐ ☐ ☐ ☐	without doing science experiments
by relating it to events of daily life	☐ ☐ ☐ ☐ ☐ ☐	by not relating it to events of daily life

(5) **What are your general opinions about the Units you did?**

Boring	□ □ □ □ □ □	Interesting
Easy to work out solutions to	□ □ □ □ □ □	Difficult to work out solutions to
Related science to events of daily life	□ □ □ □ □ □	Did not relate science to events of daily life
Made me like science even more	□ □ □ □ □ □	Made me hate science even more
Improved my thinking skills	□ □ □ □ □ □	Did not improve my thinking skills
I enjoyed doing most of them	□ □ □ □ □ □	I hated doing most of them

(6) **What are your feelings about working as a group?**
(Tick the boxes to show your opinions)

	strongly agree	agree	disagree	strongly disagree
I found the discussions boring	□	□	□	□
I enjoyed working with members of my group	□	□	□	□
Most of the ideas from other members of the group were NOT helpful	□	□	□	□
Most of the ideas came from one person	□	□	□	□
Working as a group made it easier for us to get answers to the Units	□	□	□	□
I did NOT respect ideas from others since they are always wrong.	□	□	□	□

We would like you to apply the thinking skills you used with the Units to find answers to questions 7, 8, 9 and 10.

(7) A local cattle farmer has 500 cattle. The cattle are grazed outside everyday for 9 hours and then spend 15 hours inside the kraal. The cattle farmer has been asked by a local vegetable farmer to supply 500 kg of kraal manure every week for a year. The vegetable farmer has agreed to collect the manure using her truck.

Before agreeing to supply kraal manure, LIST UP TO FOUR things that the cattle farmer should know.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Which **ONE** of the things you listed is MOST IMPORTANT in determining whether the cattle farmer will be able to supply enough manure? ______ *(Write the number).*

(8) Tebogo has been studying global warming and wonders how scientists know what is actually the truth about global warming. Her friends suggest several ways to find the answers. These are listed in the shaded box.

A	Read Scientific books
B	Talk to experts like University professors
C	Carry out experiments to test the idea of global warming
D	Collect as much information as possible about global warming
E	Assume global warming is true and act accordingly
F	Use intelligent guesswork
G	Look at information which has already been gathered through research
H	Accept what majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below. The letter which comes first is the most important and the letter which comes last is the least important for you.

□ □ □ □ □ □ □ □

Most important — Least important

(9) Here are some statements which are known to be true by experiment:

(a) The substance sodium fluoride contains the elements sodium and fluorine only
(b) A solution of sodium fluoride in pure water conducts electricity well
(c) The products obtained when electricity is passed through the sodium fluoride solution in water are hydrogen and oxygen

Look at these statements, which of the following is true? *(Tick the box next to the true statement)*

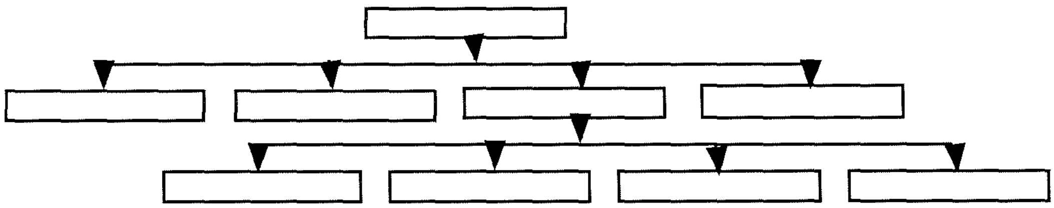
(1) Sodium fluoride contains hydrogen and oxygen ☐
(2) Water contains hydrogen and oxygen only ☐
(3) Hydrogen and oxygen are everywhere ☐
(4) Water contains hydrogen and oxygen ☐

In ONE sentence, describe the experiment which should be carried out to be sure that your answer is correct. ____

(10) The table below gives information about a family, from grandmother to grandchildren. It is the year 2 000.

Grandmother Still alive in the year 2 000	**Aunt** 10 years younger than uncle 2	**Uncle 1** 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than Uncle 1.	**Uncle 2** 2 years younger than mother.	**Potso** In 1990, her age was one-fifth the age of her Aunt
Bodo In 1985, his age was half the age of Potso	**Pako** 2 years younger than Bodo	**Vanessa** 2 years younger than Pako

Use the information given in the table to complete the family tree diagram below, with grandmother at the top.



What other piece of information would you need about Vanessa to work out the age of her grandmother in the year 2 000? ____

The Control Group Questionnaire/Test

The items for this questionnaire/test were the same as the items in the experimental questionnaire/test except that the control group was supposed to base their opinions on the effects of the science lessons offered at the schools rather than the effects of the units (see figure 7.5).

(5) **What are your general opinions about science activities you do during your science lessons?**

Boring	☐ ☐ ☐ ☐ ☐ ☐	Interesting
Easy to work out solutions to	☐ ☐ ☐ ☐ ☐ ☐	Difficult to work out solutions to
Relate science to events of daily life	☐ ☐ ☐ ☐ ☐ ☐	Do not relate science to events of daily life
Make me like science even more	☐ ☐ ☐ ☐ ☐ ☐	Make me hate science even more
Improve my thinking skills	☐ ☐ ☐ ☐ ☐ ☐	Do not improve my thinking skills
I enjoy doing most of them	☐ ☐ ☐ ☐ ☐ ☐	I hate doing most of them

(6) **What are your feelings about working as a group?**
(Tick the boxes to show your opinions)

	strongly agree	agree	disagree	strongly disagree
I find the discussions boring	☐	☐	☐	☐
I enjoy working with members of my group	☐	☐	☐	☐
Most of the ideas from other members of the group are NOT helpful	☐	☐	☐	☐
Most of the ideas come from one person	☐	☐	☐	☐
Working as a group make it easier for us to get answers to the Units	☐	☐	☐	☐
I do NOT respect ideas from others since they are always wrong.	☐	☐	☐	☐

The maximum time needed to complete responding to each questionnaire was 20 minutes. The questionnaires were administered to the groups by teachers who volunteered to help from each school.

7.6 Interview

It was felt that more information could be obtained from interviewing a few pupils concerning their perception on school science experiments and the role these experiments play in scientific investigations. A sample of 21 pupils from three of the four schools used in the study were selected from each year group (see table 7.3).

School	Year 1	Year 2	Year 3
A	2 boys, 1 girl	1 boy, 2 girls	2 boys, 1 girl
B	-	1 boy, 2 girls	1 boy, 2 girls
C	-	2 boys, 1 girl (group 1) 1 boy, 2 girls (group 2)	-

Table 7.3 Composition of Interview Sample Group

The criteria used to select pupils for the interview was based on the ability to express oneself verbally. The pupils were interviewed in groups of three. The different year groups were interviewed separately to avoid possible intimidation by older and more experienced pupils.

The interview responses were noted by the researcher during the interview by writing down conceded points. The interview consisted of 23 questions in an unstructured form (see figure 7.6).

Interview Items - Botswana Sample

1. Do you do science at school?
2. Do you like it? How much compared to other subject that you do at school?
3. What do you usually do during science lessons that interests you?
4. Tell me the things that you hate/love most about science lessons?
5. Why do you hate/love them?
6. Do you do experiments during your science lessons?
7. How often do you do experiments in you school?
8. If you do NOT do experiments, would you like to do them as part of your science activities?
9. Why do you think the teacher asks you to do experiments?
10. How does working with others during experiments help you?
11. Do you like doing these experiments?
12. If YES, what is it that you like most about doing experiments?
13. If NOT, what do you dislike most about doing experiments?
14. Why do you think your teacher always asks you to work in groups during experiments?
15. Would you say schools are right to expect pupils to carry out experiments ? Why ?
16. What skills have you gained so far from carrying out experiments ? How do you use these skills in your daily life ?
17. Do you think people would understand how most things work if they have not done science at school? Why?
18. In your opinion, have results from experiments helped you to develop better ways of understanding your environment? Give examples.
19. Are some experiments better than others in giving you answers ?
20. Are experiments which go as expected more useful than the ones which do not? Why ?
21. Do you think science always provides right answers about things ?
22. How can we be sure that we have the right answers ?
23. What do you think science is trying to teach us ?

Figure 7.4 Interview Questions for Botswana Sample

The purposes of the interviews were to test the validity of the questionnaire and to gain richer insights. During the interview, each of the three pupils were allowed a chance to express their views concerning the questions asked.

7.7 Analysis, Interpretation and Discussion of Experiment Two Results

The raw data (in frequencies) obtained from the responses of the two questionnaires were recorded as shown by appendices H & I. These results were interpreted and presented as percentages. The chi-square test was used to analyse the results (Appendix K). In the analyses, the results from the control group were compared with those from the experimental group and the expected results from the larger population of 13-15+ year of old pupils in Botswana.

7.8 Results of Items 4, 5 & 6.

The chi-square was calculated using sets of six frequencies but, for clarity some frequencies were grouped. Item 4 responses were interpreted as follows: For example, part (a) of the item is shown below.

	1	2	3	4	5	6	
on my own	☐	☐	☐	☐	☐	☐	in a group

Frequencies for boxes 1 and 2 were combined to represent the opinion '*I can learn science better on my own*'. Frequencies for boxes 3 and 4 were combined as well to represent a neutral opinion whilst frequencies for boxes 5 and 6 were combined to represent the opinion '*I can learn science better in a group*'. The same interpretation was used with other parts of item 4.

Item 5 responses were interpreted as follows: For example, part (a) of the item is shown below.

	1	2	3	4	5	6	
Boring	☐	☐	☐	☐	☐	☐	interesting

The frequencies for boxes 1 and 2 were combined to represent the opinion 'boring' and frequencies for boxes 3 and 4 were combined as well to represent a neutral opinion. Frequencies for boxes 5 and 6 were combined to represent the opinion 'interesting'. This interpretation was repeated with other parts of item 5.

Item 6 responses were interpreted such that frequencies for '*strongly agree*' (1) and '*agree*' (2) were combined to represent the opinion '*agree*' and the frequencies for the '*disagree*' (3) and '*strongly disagree*' (4) were combined to represent the opinion '*disagree*'.

Experimental and Control Group Responses by Year of Study

The opinions of both control and experimental groups on their learning strategies in science, scientific activities including the units and working as a group during problem solving were examined. This was done by investigating the differences between the control group performance and the experimental group performance on items 4, 5 and 6 of the questionnaires within a year of study.

The frequency values obtained were analysed using the chi-square as a goodness of fit test. These frequencies were then converted to percentages to provide a better picture in the tables. The distribution of pupils with each category were as follows: $N_{experimental\ 1}=94$; $N_{experimental\ 2}=156$; $N_{experimental\ 3}=92$; $N_{control\ 1}=93$; $N_{control\ 2}=202$; $({}_{control\ 3}=115$. The subscript numbers 1, 2, and 3 represent year groups.

The outcomes of the chi-square (χ^2) tests are shown by tables 7.4, 7.5 and 7.6. The following should be noted about the tables:

- The values under each year group show the chi-square value and the letters in brackets ( ) next to the chi-square values indicate the degree of freedom (df).
- The fourth column contains the measure of the level of significance of the chi-square value under each year of study.
- The level of significance denoted by (n.s.) indicates a non-significant difference.
- The last columns on the right hand side of the tables indicate the category favoured by the positive side of the statements.
- The symbols E and C represents experimental and control respectively.
- The symbol (-) denotes a situation where the comparison is not significant.

Item 4. I can learn science better	chi-square (χ^2)				
	year 1	year 2	year 3	sig.	most favoured
on my own ... in a group	3.3(2)	15.8(2)	7.0(1)	n.s. - 1% - 1%	-/E/E
by solving difficult /by solving easy activities	9.1(2)	2.0(2)	19.0(2)	5% - n.s. - 1%	C/-/E
by reading/without reading science books	3.9(1)	4.3(1)	1.2(1)	n.s. - 5% - n.s.	-/E/-
through/without science experiments	3.5(1)	0.4(1)	1.4(1)	n.s. - n.s. - n.s.	-/-/-
by relating/not relating it to daily life	0(1)	12.3(2)	1.4(1)	n.s. - 1% - n.s.	-/E/-

Table 7.4 Comparison of Experimental and Control Groups' Perceptions of How they Can Learn Science Better by Year of Study

Item 5. What are your general opinions about the Units or science activities?	chi-square (χ^2) year 1	year 2	year 3	sig. level	most favoured
Boring ... Interesting	0.1(2)	3.3(2)	15.1(1)	n.s. - n.s. - 1%	-/-/E
Easy/Difficult to work out solutions	13.1(2)	20.8(2)	17.3(2)	1% - 1% - 1%	C/C/E
Related/Did not relate science to daily life	2.7(2)	9.0(2)	7.9(1)	n.s. - 5% - 1%	-/E/E
Made/Did not make me like science more	0(1)	0.6(1)	0.1(1)	n.s. - n.s. - n.s.	-/-/-
Improved/Did not improve my thinking skills	4.4(1)	0(1)	4.1(1)	5% - n.s. - 5%	E/-/C
Enjoyed/Did not enjoy doing most of them	0.9(1)	7.3(2)	6.8(1)	n.s. - 5% - 1%	-/E/E

Table 7.5 Comparison of Experimental and Control Groups' Opinions About Science Activities by Year of Study

Item 6. What are your feelings about group work?	chi-square (χ^2) year 1	year 2	year 3	sig. level	most favoured
I found the discussions boring	2.7(1)	1.8(1)	2.1(1)	n.s. - n.s. - n.s.	-/-/-
I enjoyed working with members of my group	1.4(1)	0(1)	0.3(1)	n.s. - n.s. - n.s.	-/-/-
Most ideas from other members were NOT helpful	0.3(1)	0.2(1)	1.7(1)	n.s. - n.s. - n.s.	-/-/-
Most of the ideas came from one person	1.1(1)	2.2(1)	0.7(1)	n.s. - n.s. - n.s.	-/-/-
Working as a group made it easier to get answers	16.5(1)	0.3(1)	3.2(1)	1% - n.s. - n.s.	-/-/-
I did NOT respect ideas from others - always wrong	0(1)	1.3(1)	4.9(1)	n.s. - n.s. - 5%	-/-/E

Table 7.6 Comparison of Experimental and Control Groups' Feelings About Working as a Group by year of Study

It can be clearly seen that the experimental group's opinions about how they thought they can learn science better and working as a group are often higher than the opinions of the control groups. The differences are mostly significant with year 2 and 3. Only in the cases of 'learning science by solving difficult activities' (table 7.4) and 'science is difficult to work out solutions to' (table 7.5) did the control group consistently held more positive opinions about these aspects of science and the differences were highly significant in each case particularly with year 1 and 2. The control group, year 1 category, strongly felt that working as a group enhanced solving difficult tasks in science.

Nevertheless, the opinions of each group showed very little or insignificant differences regarding their strong positive opinions on the benefits of working as a group (table 7.6). However, noticeable in this case, is the highly significant difference in favour of the experimental group that indicates a strong support for respecting ideas from other members of the group. This is consistent with the strong views held about group work by each group.

Control Group Only by Year of Study

The differences between performances of the control group pupils from different years of study were investigated. This was meant to determine whether there were any differences amongst year 1, year 2 and year 3 pupils regarding their responses to items 7, 8, 9 and 10 which could be termed developmental. The results were presented in a table form (Appendix Q) and the chi-square as a contingency test was used to compare the frequency pattern across the three year groups to see whether there is any evidence of developmental effect. The values of the chi-square test are shown by tables 7.7, 7.8 and 7.9.

Item 4. I can learn science better	χ^2	df	sig.	most favoured
on my own/in a group	28.0	4	1%	year 3
by solving difficult/easy activities	2.0	4	n.s.	-
by reading/without reading science books	9.6	4	5%	year 3
through/without science experiments	13.6	2	1%	year 3
by relating/not relating it to daily life	11.2	2	1%	year 3

Table 7.7 Comparison of Years 1, 2 &3 Control Groups' Perceptions of How they Can Learn Science Better

Item 5. What are your general opinions about the science activities?	χ^2	df	sig.	most favoured
Boring/Interesting	0.6	4	n.s.	-
Easy/Difficult to work out solutions	5.9	4	n.s.	-
Related/Did not relate science to daily life	8.9	4	n.s.	-
Made/Did not make me like science more	4.3	4	n.s.	-
Improved/Did not improve my thinking skills	14.5	2	1%	year 3
Enjoyed/Did not enjoy doing most of them	1.6	2	n.s.	-

Table 7.8 Comparison of Years 1, 2 & 3 Control Groups' Opinions About Science Activities

Item 6. What are your feelings about group work?	χ^2	df	sig.	most favoured
I found the discussions boring	10.7	2	1%	year 3
I enjoyed working with members of my group	7.0	2	5%	year 3
Most ideas from other members were NOT helpful	11.8	2	1%	year 3
Most of the ideas came from one person	15.6	2	1%	year 3
Working as a group made it easier to get answers	0.8	2	n.s.	-
I did NOT respect ideas from others - always wrong	1.5	2	n.s.	-

Table 7.9 Comparison of Years 1, 2 & 3 Control Groups' Feelings About Working as a Group

The developmental pattern is clearly seen from the results of comparing year groups' performances within the control group. The year 3 pupils show significant differences in the positiveness of their opinions regarding their preferred learning strategies for science and working as a group. Interesting to note is the lack of differences of opinion with respect to the impact their school science activities have had on them (table 7.8). However, strong opinions were expressed by all pupils about how working on science activities had improved their thinking skills. The differences between the year groups were highly significant. This showed a clear developmental effect.

Control Group and Experimental group (Combined) by Gender

The comparison between the performance of all the males (N_{males}=360) and females ($N_{females}$=392) (control and experimental groups combined) from all year groups on the items 4, 5 and 6 were investigated and the chi-square as a contingency test was used to test the differences (Appendix Q). This was meant to determine the possibility of the differences in the responses to these items occurring as a result of pupils maturing with age within the same gender group.

Item 4. I can learn science better	χ^2	df	sig.	most favoured
on my own/in a group	4.0	2	n.s.	-
by solving difficult/easy activities	0.9	2	n.s.	-
by reading/ without reading science books	4.1	1	5%	girls
through/without science experiments	4.3	1	5%	girls
by relating/not relating it to daily life	0.5	1	n.s.	-

Table 7.10 Comparison of Males and Females Perceptions of How they can Learn Science Better (combined experimental and control groups)

Item 5. What are your general opinions about the Units and science activities?	χ^2	df	sig.	most favoured
Boring/Interesting	7.4	1	1%	girls
Easy/Difficult to work out solutions	2.2	2	n.s.	-
Related/Did not relate science to daily life	3.4	1	n.s.	-
Made/Did not make me like science more	5.2	1	5%	girls
Improved/Did not improve my thinking skills	3.2	1	n.s.	-
Enjoyed/Did not enjoy doing most of them	6.5	1	5%	girls

Table 7.11 Comparison of Males and Females Opinions About Scientific Activities (combined experimental and control groups)

Item 6. What are your feelings about group work?	χ^2	df	sig.	most favoured
I found the discussions boring	12.6	1	1%	girls
I enjoyed working with members of my group	11.1	1	1%	girls
Most ideas from other members were NOT helpful	5.7	1	5%	girls
Most of the ideas came from one person	2.8	1	n.s.	-
Working as a group made it easier to get answers	5.9	1	5%	girls
I did NOT respect ideas from others - always wrong	2.0	1	n.s.	-

Table 7.12 Comparison of Males and Females Feelings About Working as a Group (combined experimental and control groups)

A comparison between boys and girls levels of opinions clearly produced interesting results. The girls held highly significant positive views about how they thought they can learn science, working in groups during scientific activities and the impact of school science activities on their general attitude towards science. This could be attributed to the fact that girls are biologically and socially more developed at these ages. Nonetheless, both boys and girls, equally show respect for group work and sharing of ideas amongst group members to solve difficult scientific problems.

A study in Scotland conducted by Skryabina (2000) reported that boys at S2 level (age ~13+) were significantly more interested than girls in studying science applications in life, how science can help in life and in solving every day problems. Girls at S2 are reported in the study to enjoy mostly doing practical work, solving problems, learning about the human body and how science can make our lives healthier. However, with this group of pupils, both boys and girls showed the same levels of interest in items relating science to every day life (Appendices P & Q).

It is clearly from the results on pupils' opinions about science and its impact on their thinking that the intensity of the positiveness of the opinions increases with age. These observations are consistent with the theoretical views expressed by Piaget and discussed earlier (chapter 4). Can any form of intervention accelerates this state of affair? Shayer and Adey, discussed in chapter 5, are strong advocates of this notion. A further investigation using test items was done to examine the possible differences developed by the use of teaching units and Eloosis. The next section discusses the results from this investigation.

7.9 Results of Items 7, 8, 9 and 10.

Items 7, 8, 9 and 10 were designed to test pupils' ability to apply successfully skills they learned from solving problems in school science lessons (in the case of control and experimental groups) and from working on units designed by the researcher (in the case of the experimental group). The responses to these items were interpreted as follows:

Item 7: From a list of up to four things that the pupils have named (7a), only one of them was critically important for the cattle farmer to know before agreeing to supply manure every week for the whole year. Pupils were to indicate this critical thing by writing down its number from the list (7b). The notation (0) indicates 'incorrect' response and the notation (1) indicates 'correct' response to the item. No list or no number were interpreted as incorrect responses. The analysis of this item excludes part (a) which is the list of things to remember by the farmer. Only part (b) is analysed.

Item 8: Pupils were to respond to the item by arranging the suggested answers in their order of importance, starting with the most important. In the opinions of a group of experts, it was expected that pupils would rate C the most important followed by D, and finally G. The boxes on the rating scale were assigned a number from 1 to 8, starting with the box on the left side. For example, if any of the three letters rated most important was placed in the first box, it would be coded by the number (1). Therefore, each letter could possibly be awarded any code number from (1) to (8).

Item 9: The first task of the item (9a) required the pupils to select from the four statements listed one that they considered true. A wrong response or no response were coded by a mark of (0) and a correct response was coded by a mark of (1). The second part of the item (9b) asked the pupils to describe an experiment that verifies the answer to 9(a). The marks awarded for a full response to the item were based on four key words: *hydrogen and oxygen*, *combine*, *pure* and *test for water*. Therefore, a wrong response meant (0) code, any one of the key words present was awarded the code (1), any two of the key words were awarded the code (2), any three key words present were awarded the code (3) and all four present were awarded the code (4).

Item 10: The first part of the item (10a) required the pupils to complete the family tree diagram using the information provided in the table. A response where 'mother' was placed in the wrong box or 'no response' situation were awarded the code (0) and a response with 'mother' placed in the correct box was awarded the code (1). In this case, if 'mother' was placed in the correct box, the code (1) would be awarded regardless of how the rest of the boxes were completed. The second part of the item (10b) required the pupils to respond by either 'Vanessa's date of birth' or 'Vanessa's age'. The (0) code was awarded for wrong response or no response. The code of (1) was awarded for the correct response. However, a few pupils were able to say combine hydrogen and oxygen.

The results of the questionnaire/test items 7, 8, 9 and 10 were converted into percentages and presented by tables 7.13, 7.14, 7.15, 7.16 and 7.17. The chi-square as a goodness of fit test was used on raw data to show if frequency distributions between experimental and control differed.

Experimental and Control Groups Responses by Year of Study

This part of the experiment two was intended to determine any difference in performance between the experimental and control groups which would suggests that the Units were effective.

Item 7b		correct (1)	wrong (0)	$\chi2$	sig. level	more favoured
Year 1	Experimental	6	94	-	-	-
	Control	4	96			
Year 2	Experimental	12	88	-	-	-
	Control	8	92			
Year 3	Experimental	13	87	0.5	n.s.	-
	Control	16	84			

[Due to the frequency values for correct responses being smaller than the set limit for the calculations of chi-square (Appendix...) it is not possible to calculate chi-square for year 1 and 2 because they break conditions for the use of chi-square]

Table 7.13 Experimental and Control Groups Results for Item 7b by Year of Study

It appears that there are no significant differences between the performances of the experimental and control groups at all years of study. However, there seems to be clear evidence from the results of a developmental effect. This is demonstrated by the gradual increase in the number of correct responses from year 1 to year 3 pupils in both control and experimental groups (table 7.13) although it is not possible to calculate chi-square.

Item 8C		good (1-3)	satisfactory (4-5)	not good (6-8)	$\chi2$	sig. level	favoured
year 1	Experimental	70	25	5	10(1)	1%	experim't
	Control	53	25	22			
Year 2	Experimental	64	19	17	6.3	5%	experim't
	Control	57	28	15			
Year 3	Experimental	56	27	17	1.6(1)	n.s	-
	Control	63	30	7			
Item 8D							
year 1	Experimental	60	31	10	1.9	n.s	-
	Control	52	35	13			
Year 2	Experimental	61	26	13	2.1	n.s	-
	Control	63	28	9			
Year 3	Experimental	74	21	5	1.6(1)	n.s	-
	Control	67	28	5			
Item 8G							
year 1	Experimental	25	24	51	5	n.s	-
	Control	32	29	39			
Year 2	Experimental	25	46	29	2.4	n.s	-
	Control	31	40	29			
Year 3	Experimental	58	25	17	16.3	1%	experim't
	Control	38	44	18			

Table 7.14 Experimental and Control Groups Results for Item 8 by Year of Study

It can be observed from table 7.14 that the differences in performances between the experimental group and the control group pupils are generally non-significant except in item 8C (year 1 and year 2) and item 8G (year 3). In all the three cases where the differences were significant, the experimental group scored much higher than control group. This could be attributed to the effect of the teaching units and Eloosis.

However, the choice C 'carrying out experiments to test the idea of global warming' was more popular with the year 1 and 2 pupils. Their view is positive but their achievement on the 'manure', the 'sodium fluoride' and the 'genealogical' items is very low. The option D 'collect as much information as possible about global warming' may be developmental and more positively placed by the pupils, but produced no significant differences between the experimental and control groups. The option G 'look at information which has been gathered through research' seems strongly developmental (at year 3) when combining the good positions and the satisfactory positions of G.

Overall, both groups do not demonstrate clearly their conceptual understanding of experiments as ways of asking questions in scientific enquiry. Their fascination with experiments is clearly not a guarantee for understanding the purpose and function of experiments. However, those who worked on the units (experimental group) are more in favour of using experiments (8C) to question phenomena. This could be an indication that the units had an impact.

Item 9a		wrong (1-3)	correct (4)	$\chi 2$	sig. level	more favoured
Year 1	Experimental	41	59	0.7(1)	n.s.	-
	Control	35	65			
Year 2	Experimental	44	56	0.2(1)	n.s.	-
	Control	46	54			
Year 3	Experimental	35	65	1.5(1)	n.s.	-
	Control	26	74			

Table 7.15 Experimental and Control Groups Results for Item 9a by Year of Study

Table 7.15 shows that there is no significant difference between experimental and control groups. The higher success of year 3 may be a developmental effect The number of pupils who responded correctly to item 9b was very small for any statistical analysis to be carried out. This is why no discussions are done on the results from this part of the item (Appendix P).

Item 10a		mother (1)	wrong (0)	$\chi 2$	sig. level	more favoured
Year 1	Experimental	27	73	0	n.s	-
	Control	27	73			
Year 2	Experimental	24	76	0.7	n.s	-
	Control	27	73			
Year 3	Experimental	24	76	0	n.s	-
	Control	24	76			

Table 7.16 Experimental and Control Group Results for Item 10a by Year of Study

Item 10b		date of birth/age (1)	wrong (0)	$\chi 2$	sig. level	more favoured
Year 1	Experimental	11	89	1.3	n.s	-
	Control	8	92			
Year 2	Experimental	23	77	2.3	n.s	-
	Control	18	82			
Year 3	Experimental	23	77	0.5	n.s	-
	Control	20	80			

Table 7.17 Experimental and Control Group Results for Item 10b by Year of Study

Interestingly, pupils again performed badly on the item 10a and 10b. The majority of the pupils were able to complete the family tree diagram but ignored the critical position of 'mother' on the diagram. There is no significant differences between the responses from the experimental and control groups on both parts of the item. An explanation to this failure by the pupils could be attributed to the amount of information (noise) contained in the item and the fact that the pupils are culturally not familiar with the concept of family tree diagrams. However, higher correct responses from year 2 and year 3 pupils may be due to experience and exposure to more science concepts.

To further investigate the developmental effect on the pupils' performance, responses from the control group only were compared by year of study. The results are discussed below.

Control Group Only by Year of Study

The results from the control group were grouped by year of study to investigate any difference between the year groups that might suggest a developmental trend. The raw frequency values were analysed using the chi-square as a contingency test. These were then converted to percentages and presented in tables 7.18, 7.19, 7.20, 7.21 and 7.22.

Item 7b	correct (1)	wrong (0)	$\chi 2$	sig. level	more favoured
control 1	4	94			
control 2	8	92	8.3	5%	year 3
control 3	16	84			

Table 7.18 Control Group Results for Item 7b by Year of Study

The pupils' responses to this item clearly indicate the developmental effect as more correct responses were recorded moving from year 1 to year 3.

Item 8C	good (1-3)	satisfactory (4-5)	not good (6-8)	$\chi 2$	sig. level	more favoured
control 1	53	25	22			
control 2	57	28	15	7.6	n.s	-
control 3	63	30	7			
Item 8D						
control 1	52	35	13			
control 2	63	28	9	2.7(2)	n.s	-
control 3	67	28	5			
Item 8G						
control 1	32	29	39			
control 2	31	40	29	11.3	5%	year 3
control 3	38	44	18			

Table 7.19 Control Group Results for Item 8 by Year of Study

The effect on performance in this item is clearly developmental but the differences between the year groups are not significant except for responses to 8G. More year 3 pupils scored higher than the year 1 and 2 pupils who performed equally in placing option G (looking at information which has already been gathered through research) in the first three boxes.

Item 9a	wrong (1-3)	correct (4)	$\chi2$	sig. level	more favoured
control 1	35	65			
control 2	46	54	10.9(2)	1%	Year 3
control 3	26	74			

Table 7.20 Control Group Results for Item 9a by Year of Study

The differences in performances between the year groups in item 9(a) (the sodium fluoride problem) is highly significant in favour of the year 3 pupils. The effect of development is seen between year 2 and 3. However, it is surprising to see year 1 pupils scoring higher than year 2 in this item. The reasons for this are not known.

Item 10a	mother (1)	wrong (0)	$\chi2$	sig. level	more favoured
control 1	27	73			
control 2	27	73	0.3	n.s	-
control 3	24	76			

Table 7.21 Control Group Results for Item 10a by Year of Study

Item 10b	age (1)	wrong (0)	$\chi2$	sig. level	more favoured
control 1	8	92			
control 2	18	82	7	5%	year 2 & 3
control 3	20	80			

Table 7.22 Control Group Results for Item 10b by Year of Study

The difference in performance between the year groups on item 10a is not significant. However, there is a clearly developmental effect on the pupils' responses to item 10b which produced differences that are significant. The results of item 10b are therefore consistent with expectations of the study. An investigation of the gender effect on pupils' performance was also carried out and the results are discussed below.

Experimental and Control Group Results (Combined) by Gender

The results from the experimental and control groups were combined as one sample results since not much difference was observed between them. These results were used to investigate the effect of maturation on the ability to see the place of experimentation in pupils that may have occurred in each gender group due to learning school science. The data obtained from pupils' responses to test items 7, 8, 9 and 10 was analysed using the chi-square as a contingency test to establish any differences in performance between genders. The results were presented by tables 7.23, 7.24, 7.25 and 7.26 as percentages for clarity.

Item 7b	Gender Group	correct (1)	wrong (0)	$\chi 2$	sig. level	more favoured
	Boys	9	91	0.5(1)	n.s	-
	Girls	10	90			

Table 7.23 Combined Sample Data for Item 7b by Gender

Item 8	Gender Group	good (1-3)	satisfactory (4-5)	not good (6-8)	$\chi 2$	sig. level	favoured
C	Boys	60	25	15	0.4(2)	n.s	-
	Girls	61	26	13			
D	Boys	59	32	9	4.2(2)	n.s	-
	Girls	65	25	10			
G	Boys	30	37	33	3.0(2)	n.s	-
	Girls	37	36	27			
E	Boys	11	24	65	1.2(2)	n.s	-
	Girls	10	28	62			

Table 7.24 Combined Sample Data for Item 8 by Gender

Item 9a	Gender Group	1&2 correct	all wrong	$\chi 2$	sig. level	more favoured
	Boys	31	69	10.8(1)	1%	girls
	Girls	42	58			

Table 7.25 Combined Sample Data for Item 9a by Gender

Item 10	Gender Group	age (1)	wrong (0)	$\chi 2$	sig. level	more favoured
(a)	Boys	23	77	1.6(1)	n.s	-
	Girls	27	73			
		mother (1)	wrong (0)			
(b)	Boys	17	83	0.5(1)	n.s	-
	Girls	19	81			

Table 7.26 Combined Sample Data for Item 10 by Gender

As expected, there are few significant differences between male and female pupils concerning their performance on the test items. The only case where gender had an effect was on the item 9(a).

Overall there is generally no difference between gender groups in the ability to see experiments as ways of asking questions in scientific enquiry. The highly significant difference observed in item 9(a) could be a factor of girls maturing faster than boys and thus able to produce longer chains of reasoning.

Experimental and Control Groups (combined) Results by Pupils' Ages

The combined data was used to determine if there is any difference between the pupils' ages and the development of the ability to see the place and nature of experimentation in scientific enquiry. Again the data obtained from the pupils' responses to items 7, 8, 9 and 10 was analysed using chi-square as a contingency test to determine any differences in performance between pupils at different age levels. The frequencies of some age groups were combine because analysing them separately would have broken the rule for chi-square calculations. The results of the analysis were presented by table 7.27.

Item 7b	Age Groups	correct (1)	wrong (0)		$\chi 2$	sig. level	favoured
	13-14 years	8	92				
	15 years	6	94		4.9(2)	n.s	-
	16+ years	12	88				
Item 8		good (1-3)	Satisfactory (4-5)	not good (6-8)			
C	13-14 years	61	23	16			
	15 years	50	30	20	5.6(4)	n.s	-
	16+ years	59	28	13			
D	13-14 years	58	33	9			
	15 years	57	31	12			
	16+ years	66	26	8	4.1(2)	n.s	-
G	13-14 years	23	35	42			
	15 years	30	40	30	11.5(4)	5%	16+ years
	16+ years	37	36	27			
Item 9b		correct (1&2)	all wrong (0)				
	13-14 years	49	51				
	15 years	42	58		12.2(2)	1%	13-14 yrs
	16+ years	33	67				
Item 10		mother (1)	wrong (0)				
(a)	13-14 years	34	66				
	15 years	24	76		3.1(2)	n.s	-
	16+ years	26	74				
		age (1)	wrong (0)				
(b)	13-14 years	16	84				
	15 years	19	81		0.4(2)	n.s	-
	16+ years	18	82				

Table 7.27 Combined Sample Data for Items 7, 8, 9 and 10 by Age

It can be clearly seen from the data obtained on the performances of the combined control and experimental groups that there are few instances of differences in performance between the year groups being significant. These significant cases are observed in the responses to item 8G and 9(b). There is also clear evidence of the differences being developmental. Considering the results of table 7.27, only item 8G and 9(b) show a clear developmental effect.

In the Botswana's education system placing of pupils in different levels of study by age is still flexible. This may account for the differences between comparison by year of study and by pupils' ages. Most consistent with this observation is the results for item 10a, which is based on no specific subject (see tables 7.8, 7.14, 7.19 and 7.20). However, the evidence obtained from the pupils' responses to the test items clearly indicate that the ability to see an experiment as a way of asking questions during problem solving cannot be homogeneously accelerated through a single teaching approach. The fact that individual learners have unique ways of receiving and interpreting information presented to them is testimony to this observation.

7.10 The Interview Results

An attempt was made to obtain more information on pupils' conceptualisation of the place and nature of experimentation in scientific enquiry. Pupils whom the schools considered high achievers in integrated science were selected by their science teachers. For the purpose of this project, three pupils per year of study from each school were used.

The first group of the interview questions were designed to investigate further the pupils' interests in science as a subject (i.e. to get them talking). The other group of questions were designed to determine whether pupils comprehend the purposes of experiments they carry out during their science lessons. In addition, pupils were asked to provide their opinions on why they are asked to work in groups when carrying out experiments.

The final part of the interview required pupils to express their perception of how the effects of experimental results help to shape their conceptual knowledge of every day events. These questions were asked in the order they are presented in table 7.5. Each question asked was circulated amongst the respondents for the interviewer to obtain a concerted response.

AREA OF INTEREST	QUESTIONS
Pupils' Interest in Science (Just to get them talking)	Do you do science at school? Do you like it? How much compared to other subject that you do at school? What do you usually do during science lessons that interests you? Tell me the things that you hate/love most about science lessons? Why do you hate/love them?
Place of Experiments in Pupils' Science	Do you do experiments during your science lessons? How often do you do experiments in you school? If you do NOT do experiments, would you like to do them as part of your science activities? Why do you think the teacher asks you to do experiments? Do you like doing these experiments? What is it that you like/dislike most about doing experiments?
Group work During Experiments	Why do you think your teacher always asks you to work in groups during experiments? How does working with others during experiments help you?
Effects of Experimental Results on Pupils' Daily Life Events	Would you use experiments to solve problems you encounter at home? Give examples Do you think people who went to school understand things better than those who did not? Why? In your opinion, have results from experiments helped you to develop better ways of understanding your environment? Give examples. Do you think doing experiments is a waste of time? Do you think science would be interesting with or without doing experiments? How has experimenting helped people improve their lives? Should we believe 100% in results from any experiment? If not why?

Figure 7.5 Classification of Interview Questions

Common Responses to the Interview Questions

The responses from the interview questions were recorded by carefully selecting common ideas in the students responses and writing them down in the researcher's own words. The results were analysed and discussed as follows:

Do you do science at school?

100% of the pupils interviewed said yes to the question.

Do you like it?

95% of the interviewed pupils said yes to the question and the remaining 5% responded by saying that they sometimes do not like science particularly when learning difficult or uninteresting topics or topics that are unrelated to their every day life.

How much compared to other subjects that you do at school?

When asked to use a scale of 1 to 5, 1 being 'most like' and 5 being 'least like', 48% of the pupils rated their like for science 1, 28% rated it 2, 10% rated it 3, another 10% rated it 4 and only 4% of the pupils rated it 5.

What do you usually do during science lessons that interests you?

All the pupils asked said spontaneously "carrying out experiments". However, when probed for more information, some pupils said they were also interested in watching video shows on nature conservation, family life, and the human body. The common reasons for having interest in these part of science revolved around the relevance of the knowledge gained to their everyday experiences.

Tell me the things that you hate/love most about science lessons?

Amongst the many responses given, the majority of the pupils regarded the writing of lengthy notes and the difficult language used to describe concepts as the things they hated about science lessons. However, as expected, all the pupils said they loved working in groups and handling scientific apparatus. The pupils resented writing lengthy notes during science lessons mainly because it is tiring and they loved group work primarily because it offers them the opportunity to share ideas.

Do you do experiments during your science lessons? How often?

The response to this question was a 100% yes and this rendered the next question of "If you do not do experiments, would you like to do them as part of your science activities?" redundant. Nonetheless, a majority of the pupils, particularly year 2s and 3s were quick to point out that the frequency with which they are engaged in experimental activities depended on the topic.

Why do you think the teacher asks you to do experiments?

As expected, pupils gave responses which reflected their perception rather than the perception of their teacher. They perceive science experiments as activities designed to enhance better understanding of concepts, to enable them to experience science in action and to have a chance to handle and manipulate science apparatus. A few pupils, however, were able to state that teachers asked them to carry out experiments in order to prove things true. These naive perceptions are consistent with what the literature says about pupils' concept of scientific experiments conducted in schools.

Do you like doing these experiments?

80% of the pupils thought that the experiments were necessary, but failed to substantiate their position when asked for a reason why they thought doing experiments was necessary. About 19% of the pupils interviewed felt that some experiments they have done in science were not necessary. When asked to explain themselves, the pupils said that some of the experiments they carried out in science lessons either did not produce results or something went wrong and they had to abandon them.

Why do you think your teacher always asks you to work in groups during experiments?

The responses alluded to the notions of sharing ideas, helping each other to understand instructions and shortage of apparatus. When asked to explain the benefits of working in groups during experiments, there were no reasonable responses given. The interviewer's probing questions and hints prompted some pupils to mention arriving at better conclusions as one of the benefits.

The questions on the effects of experimental results on pupils' every day experience generated the following responses: 100% of the pupils asked felt that they could use knowledge gained from school experiments to solve problems encountered at home. Years 1s and 2s could not provide example of such problems but, some year 3 pupils mentioned the filtering of water containing undissolved impurities and subsequent boiling of the water to make it safe for drinking. All pupils interviewed considered education vital for increasing one's ability to think and develop better skills for doing things but 74% failed to explain how knowledge gained from experimenting in school science could help them improve their lives. In fact 33% of the pupils felt that we should believe fully in experimental results because scientists who carried out those experiments are intelligent and everything they do is true. However, 67% of the pupils interviewed felt that nobody should believe in the results obtained from scientific experiments out rightly because scientists can be fallible.

7.11 Summary of Findings from Experiment Two

If indeed schools teach pupils to acquire the skill of experimenting and its place in scientific enquiry, the message is clearly not getting through to the pupils or the pupils are simply not ready cognitively. The results from the test responses, particularly item 8 and 9 do denotes this contention. A few instances of the developmental effect suggest that as pupils get more exposure to science content and grow in maturity, significant signs of differences in the ability to see experiments as ways of questioning during scientific enquiry increases.

The information processing model suggests that individuals can learn to group isolated units of information (chunking) in order to increase the amount of information to be recalled. However, this process does not happen automatically and certain frames of thoughts ought to have been developed which are dependent on the individual's experiences. Therefore, the inability to conceptualise the place and nature of experimentation in scientific enquiry by lower secondary school pupils could be an indication that their cognitive ability with regard to this concept is not yet fully developed or has not yet developed in some pupils. It is also clear that the teaching units and Eloosis had had their impact on some pupils. In some cases the effects were significant and in other instances the effects were insignificant. It would be interesting to see what the effects of a prolonged use of the units and Eloosis would yield.

A further investigation was carried out to establish the generalisability of this findings using lower secondary school pupils from a different country.

CHAPTER EIGHT

EXPERIMENT THREE - SCOTLAND SAMPLE

8.1. Introduction

The results from experiment one are consistent with the view that the way of asking questions in scientific investigations is developmental although the limitations of the test instrument have already been noted. Subsequently, the analyses of experiment two results reveal that the use of appropriate teaching seemed to generate very limited improvement in this skill. Although in a few cases there was significant differences between the experimental and control groups which was due the effect of the units and Eloosis teaching, generally the difference in performance between year groups was not significant. The data strongly suggested that a developmental factor was at work. It was now appropriate to investigate the effects of culture and the differences in educational approaches on the conceptualisation of the place and nature of experimentation in scientific enquiry by early secondary school pupils.

8.2. Sample Population

To achieve this, a group of 741 pupils (12-14 year olds) was selected randomly from four Scottish schools. The schools will be known as school 1, 2, 3 and 4 for the purposes of this project. Permission was sort from schools to have access to their pupils (Appendix T).It was hoped that due to the differences in cultural practices and educational approaches, Scotland pupils will provide results that either confirm or nullify those from the Botswana group. Again schools had the prerogative of selecting the pupils for the study from S1, S2 and S3. Table 8.1 presents the composition of the Scotland sample.

School	S1(12 years)	S2 (13 years)	S3 (14 years)	Total
1	32	71	39	**142**
2	40	71	29	**140**
3	49	59	36	**144**
4	103	109	103	**315**
Total	**224**	**310**	**207**	**741**

Table 8.1 A Scotland Sample Group who Responded to Questionnaire/Test

An additional group of pupils was used to play Eloosis. A total of 120 pupils were selected randomly from school 5. (see table 8.2).

School	S1 (12 years)	S2 (13 years)	S3 (14 years)	S4 (15 years)	Total
5	40	29	36	15	**120**

Table 8.2 A Scotland Sample Group who Participated in the Eloosis

8.3. Experimental Instruments

To generate data for the purpose of experiment three, the questionnaire/test used with the Botswana control sample group was modified to meet the Scottish pupils contextual knowledge. The card game Eloosis was also used as a teaching tool with a checklist designed to elicit more information from the pupils regarding their perception on experimentation in scientific investigations. This part of the study was not meant to compare Botswana schools with the Scotland schools.

The Questionnaire/Test (Scotland Sample)

The purpose for this instrument was to determine if the developmental pattern observed with the Botswana group regarding experimentation in scientific investigations could be observed in a different cultural and educational setting. The original version of the questionnaire/test used with the Botswana group was slightly modified and certain items removed for the exercise. Items 5 and 6 were omitted since not much information could be derived from them which could fulfil the purpose of this part of the study.

These modifications produced a questionnaire/test for Scotland sample group containing eight items. Items 7, 8, 9 and 10 were therefore renumbered to become 5, 6, 7 and 8 respectively. The Botswana names used in the genealogical item 10 and item 8 of the Botswana version were changed to Scottish names. In item 7 of the Botswana version, the word 'kraal' was replaced with the word 'barn' which the Scottish pupils were more familiar with (see questionnaire/test used with the Scotland group below).

An Evaluation Exercise

Please complete this questionnaire about your studies in science as honestly as possible.

Your Name: ____________________ Name of School: ____________________

(1) How old are you? *(Write your age in years)* ☐

(2) *(Tick one box).* boy ☐ or girl ☐

(3) In what year are you? *(Tick in the correct box)* *First* year ☐ Second year ☐ Third year ☐

We would like to know your opinions about how you think you can learn science better.

Here is an example of how to answer the following questions:

If you had to describe "a racing car" you could do it like this:

Quick	✓						Slow	The positions of the ticks between the word pairs shows that you considered it s very quick, slightly more important than important and quite dangerous.
Important			✓				Unimportant	
Safe					✓		Dangerous	

[Use this method of ticking to answer the item (4)]

(4) **I can learn science better**

on my own	□ □ □ □ □ □	in a group
through solving difficult activities	□ □ □ □ □ □	through solving easy activities
through reading science books	□ □ □ □ □ □	without reading science books
through science experiments	□ □ □ □ □ □	without doing science experiments
by relating it to events of daily life	□ □ □ □ □ □	by not relating it to events of daily life

We would like you to apply the thinking skills you used with the Units to find answers to questions 7, 8, 9 and 10.

(5) A local cattle farmer has 500 cattle. The cattle are grazed outside everyday for 9 hours and then spend 15 hours inside the barns. The cattle farmer has been asked by a local vegetable farmer to supply 0.5 tones (500 kg) of manure from the barns every week for a year. The vegetable farmer has agreed to collect the manure using her truck.

Before agreeing to supply manure, LIST UP TO FOUR things that the cattle farmer should know.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Which **ONE** of the things you listed is MOST IMPORTANT in determining whether the cattle farmer will be able to supply enough manure? _____ *(Write the number).*

(6) Fiona has been studying global warming and wonders how scientists know what is actually the truth about global warming. Her friends suggest several ways to find the answers. These are listed in the shaded box.

A	Read Scientific books
B	Talk to experts like University professors
C	Carry out experiments to test the idea of global warming
D	Collect as much information as possible about global warming
E	Assume global warming is true and act accordingly
F	Use intelligent guesswork
G	Look at information which has already been gathered through research
H	Accept what majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below. The letter which comes first is the <u>most</u> important and the letter which comes last is the least important for you.

□ □ □ □ □ □ □ □

Most important — Least important

(7) Here are some statements which are known to be true by experiment:

(a) The substance sodium fluoride contains the elements sodium and fluorine only
(b) A solution of sodium fluoride in pure water conducts electricity well
(c) The products obtained when electricity is passed through the sodium fluoride solution in water are hydrogen and oxygen

Look at these statements, which of the following is true? *(Tick the box next to the true statement)*

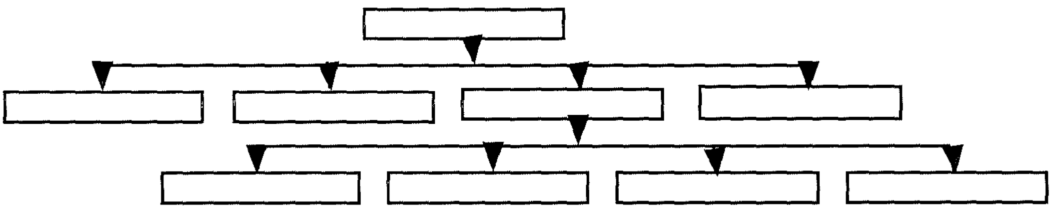
(1) Sodium fluoride contains hydrogen and oxygen ☐
(2) Water contains hydrogen and oxygen only ☐
(3) Hydrogen and oxygen are everywhere ☐
(4) Water contains hydrogen and oxygen ☐

In ONE sentence, describe the experiment which should be carried out to be sure that your answer is correct. ______________________________

(8) The table below gives information about a family, from grandmother to grandchildren. It is the year 2 000.

Grandmother Still alive in the year 2 000	**Aunt** 10 years younger than uncle 2	**Uncle 1** 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than Uncle 1.	**Uncle 2** 2 years younger than mother.	**Potso** In 1990, her age was one-fifth the age of her Aunt
Bodo In 1985, his age was half the age of Potso	**Pako** 2 years younger than Bodo	**Vanessa** 2 years younger than Pako

Use the information given in the table to complete the family tree diagram below, with grandmother at the top.



What other piece of information would you need about Vanessa to work out the age of her grandmother in the year 2 000? ______________________________

The questionnaire/test and the instructions for administering it were mailed to the schools for the teachers to administer to the pupils. Pupils were allowed 15 minutes to finish the questionnaire/test. The questionnaire/test was returned to the researcher by mail.

Eloosis as a Teaching Tool (Scotland Sample)

The purposes of using Eloosis were the same as with the Botswana sample. However, a teacher assumed the role of the chief during play of the game. Due to the small number of pupils per class, all members of the class formed one group of players. There was enough time to use four rules, similar in the nature of their complexity to those used with the Botswana pupils, with all the groups.

These sessions of playing Eloosis were followed afterwards by discussions guided by the questions in the checklist (see figure 8.1). The teacher used the questions in the checklist following the order they are presented to get the pupils talking. The researcher ensured that the same questions were asked in that order to all the groups of pupils involved by reminding the teacher whenever necessary and recorded the pupils' responses.

Checklist For Eloosis (Scotland Sample)

Name of School ____________________ Year group ____ No. of Pupils ____

1. How many enjoyed the game?.. ☐

2. How many considered the game easy?... ☐

3. What do you think the game taught you? ______________________________

4. Did you sometimes think you had the answer, then the next card made you changed your mind? How many?......................... ☐

5. When you thought you had it, did you try a card which you thought I would want or reverse? How many?............... ☐ rejected cards ☐ accepted cards

6. Which is better? .... ☐ rejected cards ☐ accepted cards

7. Which gives you better certainty?.................................... ☐ rejected cards ☐ accepted cards

8. How does the game relate to how science tries to find answers? ______________________________

9. Why do you conduct experiment in science lessons? __________________

10 What is science trying to teach us? ______________________________

11 Are some experiments better than others? What makes a good experiment? ___

12 Are results from experiments always right? __________________________

13 How can we be certain of answers we get from experiments? _____________

[Note: These items were used as a guide for the discussions - some probing questions were also used to elicit more information from pupils]

Figure 8.1 Eloosis checklist (Scotland Sample)

8.4 Interpretation, Analysis and Discussion of Experiment Three Results

The coded scores of the responses from the questionnaire/test were presented as shown by appendices R. The scoring and grouping of categories within an item was done as described in experiment two (see section 7.8). The data was analysed using the chi-square as a contingency test. Pupils' perceptions recorded during discussions of Eloosis were analysed (see appendix S, table 8.17 and figure 8.2).

8.5 Results of the Questionnaire/Test (Scotland Sample)

A total of 741 pupils responded to the questionnaire/test. In the analysis, the performance by each year group was compared with other year groups to determine any differences brought about by maturation and educational attainment level. A further investigation was done to establish the existence of possible differences between the Scotland and the Botswana sample groups within each year group.

Scotland Sample Group by Year of Study

The distribution of pupils by year of study was described as follows: N_{S1}=224, N_{S2}=310 and N_{S3} = 207, where S_1 is year 1, S_2 is year 2 and S_3 is year 3. The results of this investigation were presented as percentages (tables 8.3 - 8.7.

Item 4a	own (1-2)	both (3-4)	group (5-6)	$\chi2$	sig. level	most favoured
Year 1	19	28	53			
Year 2	21	43	36	23.3(4)	1%	year 1
Year 3	24	34	42			
Item 4b	Solve difficult activities (1-2)	both (3-4)	solve easy activities (5-6)	$\chi2$	sig. level	most favoured
Year 1	36	44	20			
Year 2	34	50	16	4.5(4)	n.s.	-
Year 3	30	54	16			
Item 4c	read science books (1-2)	both (3-4)	not read science books (5-6)	$\chi2$	sig. level	most favoured
Year 1	52	35	13			
Year 2	54	32	14	6.1(4)	n.s	-
Year 3	43	40	27			
Item 4d	through science experiments (1-2)	both (3-4)	no science experiments (5-6)	$\chi2$	sig. level	most favoured
Year 1	77	16	7			
Year 2	75	19	6	2.5(2)	n.s.	-
Year 3	79	14	7			
Item 4e	relate to events of daily life (1-2)	both (3-4)	not relate to events of daily life (5-6)	$\chi2$	sig. level	most favoured
Year 1	41	44	15			
Year 2	46	45	8	7.8(2)	n.s.	-
Year 3	46	46	8			

Table 8.3 Item 4 Results by Year of Study

Pupils' responses to item 4 produced no significant differences in performance between different year groups except in part (a) (see table 8.3). Over 50% of the year 1 pupils felt that they could learn science better in a group. With this group, year 3 pupils' opinions concerning how they thought they can learn science, were moderately lower in optimism than those of the year 1 and 2 pupils. Not much information was obtained from the data concerning the effect of maturation on the responses to this item.

Item 5b	correct (1)	wrong (0)	χ^2	sig. level	most favoured
Year 1	15	85			
Year 2	25	75	9.7(2)	1%	year 2
Year 3	17	83			

Table 8.4 Item 5b Results by Year of Study

This item corresponds to item 7b for the Botswana sample questionnaire/test. It can be clearly seen from the results that more year 2 pupils responded correctly to this item (25%). The developmental effect is evident between year 1 and 2 performances. This had produced differences that were highly significant. The higher percentage of correct responses by year 2 compared to that of year 3 could be attributed to the fact that year 3 pupils self-selected their choice of science subject to study.

Item 6C	good (1-3)	satisfactory (4-5)	not good (6-8)	χ^2	sig. level	most favoured
Year 1	57	27	16			
Year 2	48	39	13	9.3(4)	n.s	-
Year 3	48	37	15			
yr 1&2	-	-	-	7.2(2)	5%	year 1
Item 6D						
Year 1	58	33	9			
Year 2	65	28	7	3.5(2)	n.s.	-
Year 3	66	26	8			
Item 6G						
Year 1	48	36	16			
Year 2	50	36	14	0.8(4)	n.s.	-
Year 3	50	35	16			

Table 8.5 Item 6 Results by Year of Study

This item corresponds to item 8 for the Botswana questionnaire/test. There are no significant differences between responses from the different year groups. The moderately significant difference observed at placing option C in the first three boxes became significant at 5% level when the response frequencies from year 1 and 2 were combined and compared with those of year 3. Despite more than 50% of the pupils placing the options D and G in the first three boxes, no significant differences in terms of performance caused by the developmental effect were observed. However, at face value there is evidence that the older pupils responded correctly to 6D and 6G.

Item 7a	correct (1)	wrong (0)	χ^2	sig. level	most favoured
Year 1	54	46			
Year 2	59	41	8.8(2)	5%	year 2
Year 3	45	55			
Item 7b	1&2 correct	all wrong	χ^2	sig. level	most favoured
Year 1	8	92			
Year 2	3	97	*	-	-
Year 3	3	97			

Table 8.6 Item 7 Results by Year of Study

[* Correct responses to item 7(b) were too small for the chi-square calculations to be carried out on them]

Despite the differences in year groups' responses being significant, still year 3 pupils broke the developmental pattern observed between year 1 and 2 by scoring lower in item 7(a). Item 7b response frequencies were too small for any statistical comparison to be made.

Item 8a	mother (1)	wrong (0)	χ^2	sig. level	most favoured
Year 1	23	77			
Year 2	41	59	20.7(2)	1%	year 2
Year 3	31	69			
Item 8b	age (1)	wrong (0)	χ^2	sig. level	most favoured
Year 1	22	78			
Year 2	34	66	8.1(2)	5%	year 2
Year 3	30	70			

Table 8.7 Item 8 Results by Year of Study

This item corresponds to item 10 for the Botswana sample questionnaire/test. Contrary to the Botswana results on this item, particularly item 8a, the difference between the year groups's responses are significant in favour of the year 2 pupils. Again the developmental effect is observed between year 1 and 2 pupils. Responses to item 8b clearly indicate this same pattern where year 1 and 2 pupils demonstrate the developmental effect. However, the results from year 2 and 3 in both parts of item 8 do not differ badly.

There are clear indications that the performance of the Botswana sample group on certain item differs greatly to that of the Scotland sample group. A further investigation was conducted to compare the same year groups from the two samples on their performances to all the items used with the Scotland sample group. The intentions of the exercise were to explore the possible effect of the cultural differences and the different educational approaches. The results are discussed below.

Botswana and Scotland Sample Groups Comparison by Year of Study

The results from each year group in the Botswana control sample (N=410) were compared with the results of their counterparts from the Scotland sample (N=741) (see tables 8.8 - 8.16). The chi-square as a contingency test was used to analyse the existence of any difference in performance on all questionnaire/test items. The label '*year 1-bot*', for example, represents year 1 pupils in the Botswana sample and similarly, the label '*year 1-scot*' represents year 1 pupils in the Scotland sample.

Item 4a	own (1-2)	both (3-4)	group (5-6)	$\chi 2$	sig. level.	more favoured
year 1 -bot.	27	20	53			
year 1-scot.	19	28	53	3.7(2)	n.s.	-
year 2-bot.	27	23	50			
year 2-scot.	21	43	36	18.9(2)	1%	year 2 - bot
year 3-bot.	6	17	77			
year 3-scot.	24	34	42	38(1)	1%	year 3 -bot

Table 8.8 Item 4a Results of Scotland and Botswana Samples by Year of Study

Item 4b	solve difficult activities (1-2)	both (3-4)	solve easy activities (5-6)	$\chi 2$	sig. level.	more favoured
year 1 -bot.	51	27	22			
year 1-scot.	36	44	20	6.2(2)	5%	year 1 - bot
year 2-bot.	53	23	24			
year 2-scot.	34	50	16	31.1(2)	1%	year 2 - bot
year 3-bot.	47	31	22			
year 3-scot.	30	54	16	15.3(2)	1%	year 3 - bot

Table 8.9 Item 4b Results of Scotland and Botswana Samples by Year of Study

Item 4c	read science books (1-2)	both (3-4)	not read science books (5-6)	$\chi 2$	sig. level.	more favoured
year 1 -bot.	73	22	5			
year 1-scot.	52	35	13	11(1)	1%	year 1 - bot
year 2-bot.	79	18	3			
year 2-scot.	54	32	14	29.7(1)	1%	year 2 - bot
year 3-bot.	90	8	2			
year 3-scot.	43	40	27	68.7(1)	1%	year 3 - bot

Table 8.10 Item 4c Results of Scotland and Botswana Samples by Year of Study

Item 4d	through science experiments (1-2)	both (3-4)	no science experiments (5-6)	$\chi2$	sig. level.	more favoured
year 1 -bot.	71	20	9			
year 1-scot.	77	16	7	1.1(1)	n.s.	-
year 2-bot.	78	19	3			
year 2-scot.	75	19	6	0.4(1)	n.s.	-
year 3-bot.	89	8	3			
year 3-scot.	79	14	7	4.7(1)	5%	year 3 - bot

Table 8.11 Item 4d Results of Scotland and Botswana Samples by Year of Study

Item 4e	relate to events of daily life (1-2)	both (3-4)	not relate to events of daily life (5-6)	$\chi2$	sig. level.	more favoured
year 1 -bot.	53	40	7			
year 1-scot.	41	44	15	4.9(1)	n.s	-
year 2-bot.	57	31	12			
year 2-scot.	46	45	8	9.8(1)	1%	year 2 - bot
year 3-bot.	75	22	3			
year 3-scot.	46	46	8	22.6(1)	1%	year 3 - bot

Table 8.12 Item 4e Results of Scotland and Botswana Samples by Year of Study

In cases where the differences are significant, the Botswana pupils were more positive than their Scotland counterparts. The groups are genuinely consistent in their preferences to learning science better. Possible causes of the differences in pupils' preferences in item 4c can be attributed to the fact that Scotland pupils are not provided with science textbooks like the Botswana pupils. In item 4d, both groups show similar and strong preferences in learning science through experiments with the Botswana group showing a slightly greater maturation effect. In all the year groups this move is not significant. This confirms the similarity in the pupils' recognition of the importance of the use of scientific experiments to learn science better.

In item 4e, a comparison of the years groups from the two samples indicates that year 1 pupils were not different in their responses. Overall, the Botswana pupils showed a constant move from the perception that better learning of science is '*by not relating it to events of daily life*' to a more positive perception. The major differences are evident with year 2 and 3 pupils who showed a very high significant difference in their preferences and the strength of the differences grew with maturation or years of exposure to science education.

Item 5b	correct (1)	wrong (0)	χ^2	sig. level.	most favoured
year 1 -bot.	4	94			
year 1-scot.	15	85	6.9(1)	1%	year 1 - scot
year 2-bot.	8	92			
year 2-scot.	25	75	22(1)	1%	year 2 - scot
year 3-bot.	16	84			
year 3-scot.	17	83	0.1(1)	n.s	-

Table 8.13 Item 5b Results of Scotland and Botswana Samples by Year of Study

The Botswana pupils started with a low percentage of correct responses and steadily caught up with the Scotland pupils at year three. This is difficult to explain, but the syllabus differences, styles of teaching, culture and the use of CASE materials could have contributed to the Scotland pupils' ability to identify the critical piece of information at years 1 and 2 levels.

Item 6C	good (1-3)	satisfactory (4-5)	not good (6-8)	χ^2	sig. level.	more favoured
year 1 -bot.	53	25	22			
year 1-scot.	57	27	16	1.3(2)	n.s	-
year 2-bot.	57	28	15			
year 2-scot.	48	39	13	5.4(2)	n.s	-
year 3-bot.	63	30	7			
year 3-scot.	48	37	15	6.2(1)	5%	year 3 - bot
Item 6D						
year 1 -bot.	52	35	13			
year 1-scot.	58	33	9	1.4(1)	n.s	-
year 2-bot.	63	28	9			
year 2-scot.	65	28	7	1.0(1)	n.s	-
year 3-bot.	67	28	5			
year 3-scot.	66	26	8	1.5(1)	n.s	-
Item 6G						
year 1 -bot.	32	29	39			
year 1-scot.	48	36	16	19.4(2)	1%	year 1 - scot
year 2-bot.	31	40	29			
year 2-scot.	50	36	14	24.7(2)	1%	year 2 - scot
year 3-bot.	38	44	18			
year 3-scot.	50	35	16	3.6(2)	n.s	-

Table 8.14 Item 6 Results of Scotland and Botswana Samples by Year of Study

A comparison of the two groups revealed that they started off from the same level of performance, but at year 2 the Botswana group considered 'carrying out experiments to test the idea of global warming' the most important source of evidence than their Scotland counterparts. These differences, however, are not significant. It is also not clear what the possible causes of these differences are.

Item 7a	correct (1)	wrong (0)	χ2	sig. level.	more favoured
year 1 -bot.	58	42			
year 1-scot.	54	46	0.5(1)	n.s	-
year 2-bot.	50	50			
year 2-scot.	59	41	3.8(1)	5%	year 2 - scot
year 3-bot.	60	40			
year 3-scot.	45	55	6.3(1)	5%	year 3 - bot
Item 7b	1&2 correct	all wrong	χ2	sig. level.	more favoured
year 1 -bot.	0	100			
year 1-scot.	8	92	breaks rule		-
year 2-bot.	1	99			
year 2-scot.	3	97	breaks rule		-
year 3-bot.	3	97			
year 3-scot.	3	97	breaks rule		-

Table 8.15 Item 7 Results of Scotland and Botswana Samples by Year of Study

It can be clearly seen from the data that the Scotland year 2 pupils performed better than their Botswana counterparts on item 7a, and the Botswana year 3 pupils performed better than the Scotland pupils. The differences are significant. The results of item 7b clearly indicate that very few pupils from each group could provide a scientific description of the experiment necessary to prove that water contains hydrogen and oxygen. The figures were just too low for statistical analysis.

Item 8a	mother (1)	wrong (0)	χ2	sig. level.	more favoured
year 1 -bot.	27	73			
year 1-scot.	23	77	0.6(1)	n.s	-
year 2-bot.	27	73			
year 2-scot.	41	59	10.5(1)	1%	year 2 - scot
year 3-bot.	24	76			
year 3-scot.	31	69	1.6(1)	n.s	year 3 - scot
Item 8b	age (1)	wrong (0)	χ2	sig. level.	more favoured
year 1 -bot.	8	92			
year 1-scot.	22	78	9.8(1)	1%	year 1 - scot
year 2-bot.	18	82			
year 2-scot.	34	66	14.2(1)	1%	year 2 - scot
year 3-bot.	20	80			
year 3-scot.	30	70	4.1(1)	5%	year 3 - scot

Table 8.16 Item 8b Results of Scotland and Botswana Samples by Year of Study

The results of the comparison of the responses to item 8a reveals that the Scotland pupils' performance at year 2 had risen but was not retained at year 3. This observation is confirmed by the high significance of the differences in performance between the year 2 groups. Possible reasons for this difference in attainment between year 2 groups could be accredited to curriculum chance or the CASE effect or even cultural effect.

Results of item 8b show that the Scotland group is consistently better than the Botswana group. The differences at year 1 and 2 are highly significant and moderately significant at year 3. This is due to the fact that the Botswana group, even though, had lower scores at year 1 and 2, were able to reduce the margin at year 3. Possible reasons for the differences at year 1 and 2 could be due to cultural effect or could also be due to CASE intervention materials.

8.6 Results of Eloosis as a Teaching Tool

The answers obtained from the pupils during the discussions following the play of Eloosis were recorded and analysed as shown by table 8.17 and figure 8.2. The frequencies of the pupils' responses to questions raised during the discussions were converted to percentages. The population distribution by year of study were as follows: N_{S1}=40, N_{S2}=29, N_{S3}=36 and N_{S4}=15. The symbols (r) and (a) next to the question numbers represent respectively the rejected and accepted cards cases in each question (see figure 8.1). The responses to questions 3, 8, 9, 10, 11, 12 and 13 are presented in appendix S. The coding used in figure 8.2 are explained below.

Key to Questions
Q1. - How many enjoyed the game?
Q2. - How many considered the game easy?
Q4. - Did you sometimes think you had the answer, then the next card played changed your mind?
Q5a - When you thought you had it, did you try a card which you thought I would want ?
Q5r - When you thought you had it, did you try a card which you thought I would reject?
Q6a - How many think that "the card I want" is better?
Q6r - How many think that "the card I rejected" is better?
Q7a - How many think that "the card I want" gives you better certainty?
Q7r - How many think that "the card I rejected" gives you better certainty?

The results of questions 1, 2, 4, 5, 6 and 7 are presented by the graph in figure 8.2. A large gap in between the bars on the chart indicate that 0% responses.

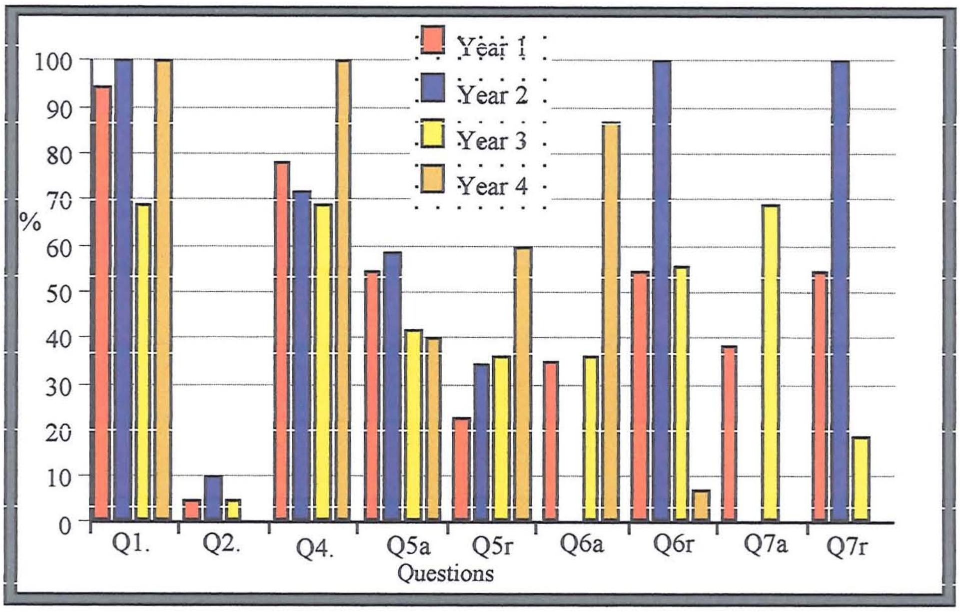


Figure 8.2 Pupils' Responses (in %) to the Checklist Questions 1, 2, 4, 5, 6 & 7

Despite the difficult nature of the game, pupils overwhelmly indicated that they enjoyed playing the game as was the case with Botswana pupils. However, further investigations revealed that pupils' enjoyment of the game did not necessarily mean they understood the processes involved in working out the chief's rule. The results of item 4, 5, 6 and 7 clearly demonstrate the uncertainty in pupils' thought processes. Amazingly over 80% of year 4 pupils, contrary to the lower year groups perceptions, considered accepted cards as the main source of evidence that they relied upon to work out the chief's rule and almost completely claimed to have disregarded the pattern from rejected cards.

Year Group	No. of Rules Used	Methods used to work out chief's rule
1	4	Guess work; Work what is in the chief's head; observe rejected and accepted cards; look for pattern.
2	4	Test thoughts by playing cards; repeating play of same type of card persistently; learning from previous mistakes.
3	4	Observing patterns; making intelligent guesses; Testing ideas through card playing; working as a group.
4	3	Testing things out

[Note: This question was asked during question 3 in the checklist to solici t more information from pupils]

Table 8.17 Pupils' Responses to the Question 'How did you work out the chief's rule?'

The responses provided by the pupils on the method they used to work out the chief's rule clearly manifest a trial and error approach by all. The pupils could not spell out clearly the critical information that they had to hold onto to work out the rule. The pattern of thought observed with the Scotland group is similar to that observed with the Botswana group. To determine the pupils' perception regarding '*what message they gained from the game*' and '*how the message relate to the way scientists try to find answers to phenomena'*, more questions were answered. The responses to these questions are discussed below.

8.7 Discussions of the Responses to Questions 3, 8, 9, 10, 11, 12 and 13

These questions are part of the discussion activities done after playing Eloosis and are presented by figure 8.3.

Question No.	Questions
3	What do you think the game taught you?
8	How does the game relate to how science tries to find answers?
9	Why do we conduct experiments in science lessons?
10	What is science trying to teach us
11	Are some experiments better than other? What makes a good experiment?
12	Are answers from experiments always right?
13	How can you be certain of the answer from an experiment?

Figure 8.3 Questions 3, 8, 9, 10, 11 and 12 Used in the Eloosis Checklist

Generally, pupils vaguely related Eloosis to experimenting in scientific investigations. Through the use of some probing questions and providing clues by the teacher, some answers were obtained. It can be seen clearly from the responses given by the pupils (Appendix...) that some are based on common knowledge which is not necessarily scientific. The majority of the pupils in all the year groups strongly felt that the process of scientific enquiry is logical and follows a set of sequential steps. This perception is consistent with the role of technicians, described earlier, who are required to follow a set of instructions to conduct an experiment.

It is not surprising therefore, to see from the results that neither could the pupils state the purpose(s) of experiments correctly nor state attributes of a good experiment. Could this be a reflection of how the pupils are taught in schools or merely lack of knowledge. Surprisingly, the pupils were able to recognise that not all experiments provide the best answers. However, they could not explain scientifically how they could differentiate between good and bad experimental results. Neither could they describe how they could verify an experimental result.

It is obvious that if some of the school science aims are to develop skills necessary for experimenting in scientific investigations, as stated in majority of school science curricula (i.e. plan and design experiments, decide on variables to manipulate during the experiment, make conclusions that are scientifically sound and so on), then, either the schools are using the wrong approaches or simply the pupils are not ready cognitively.

CHAPTER NINE

SUMMARY AND CONCLUSIONS

9.1 Summary of Purpose of the Research

The overall aim of this project is concerned with the ability of lower secondary level pupils to conceptualise the use of an experiment as a way of asking critical questions during investigations in their science lessons. This aim produced five questions to which the project attempted to provide possible answers. The overall conclusions will be drawn from these questions:

(1) Do pupils at lower secondary level appreciate the inclusion of experiments in science learning?

(2) Can these pupils identify a critical piece of information necessary for providing a credible solution to a problem?

(3) Do lower secondary level pupils have the ability to conceptualise or see experiments as ways of asking critical questions in scientific investigations?

(4) Can the development of the experimenting skill in those pupils at lower secondary level who have not yet developed it be accelerated through appropriate teaching?

(5) Can lower secondary pupils from completely different teaching and cultural backgrounds demonstrate similar performances in terms of seeing the experiment as a way of asking critical questions in scientific investigations?

To answer these questions, three experiments were conducted with samples from lower secondary level pupils.

9.2 Overall Conclusions

Experiment One

This experiment was designed to provide answers to questions (2) and (3). Based on the outcome of the results, the answers to the questions (2) and (3) appear to be negative. This result is not surprising given that the skills involved in identifying a critical piece of information and in scientific experimentation are highly abstract and that these pupils are in the transitional stage of formal operations as described by Piaget (1967). It is also noted that the test material used was limited in terms of time pupils were exposed to them and in terms of their style which may have been different from what the pupils are normally used to. Nevertheless, the outcome are negative, indeed surprisingly so.

Experiment Two

In this experiment, an attempt was made to seek answers to question (1) and (4) and reexamine questions (2) and (3). Given that results of experiment one indicate that the ability to see an experiment as a way of asking critical questions in scientific investigations may be developmental, there was a need to determine if this ability could be accelerated through appropriate teaching as suggested by the CASE theory. Only in some instances do the experimental group show better response frequencies than the control group. The general outcome clearly show that the teaching approaches used appear to have not accelerated the development of the ability to see experiments as a way of questioning critically in scientific investigations. If there was any acceleration to this effect it was not homogeneous. This findings are consistent with the criticisms raised by Bliss (1995) and Leo and Galloway (1996).

The Nuffield Science syllabuses in England were based partly on Bruner's discovery learning approach (his hypothetical mode) which has strong connection with the scientific way of enquiry., with its emphasis on the empirical. Syllabuses had to be modified radically when it became clear that pupils could not cope with this approach. It is possible that pupils had not yet reached the developmental stage where this view of the place of the experimental was accessible. This is consistent with the findings here.

However, it is surprising to see the pupils showing strong appreciation for the inclusion of experiments as part of their science activities despite their lack of knowledge on the purpose of experiments. It became clear later that pupils were confusing experiments with practical work or situations where they follow a set of instructions to confirm answers to a teacher designed problem. It is very clear that pupil perceptions of the place of experiments is very different from the stated intentions of curriculum planners.

Experiment Three

In this experiment, attempts were focused on providing answers to question (4) and (5). The answer to question (4) in this case would help to determine if the results of experiment two are generalisable. Answers to question (5) in this case were used to establish if the different teaching and cultural environments had any effect on the ability to see experiments as critical questions to scientific investigations. There was also a repeat attempt to generate more answers to question (1).

As expected the results to this experiment show that there are no significant differences between the two groups with respect to question (4). It appears that it is generally true that the ability to see experiments as ways of asking questions in scientific investigations is developmental and cannot either be homogeneously accelerated nor influenced by the differences in the pupils' learning environment. However, in instances where the problem being investigated is based on conceptual knowledge independent of any disciplines studied at schools, but familiar to the pupils, significant differences brought about by the different cultural and teaching environment are seen.

Generally, all pupils at junior secondary level regard experiments as their main attractions to learning science at schools. This finding is consistent with the results from other research (Skryabina, 2000); Woolnough, 1991).

9.3 Final Conclusions

Identifying a critical piece of information necessary for use in exploring possible solutions to problem in scientific investigations appears to be highly complex and, therefore, fairly inaccessible with pupils at lower secondary level. This limitation, therefore, renders the ability to see experiments as means of asking questions during problem solving in science inaccessible as well. Despite this cognitive inability, curriculum designers and policy makers suggest that schools should find means of developing these skills. This then brings in the questions like: Do teachers possess the knowledge and the skills of experimenting to effectively pass them on to the pupils? Should the emphasis on the development of experimental skills be on doing it as the scientists do or something else?

9.4 Limitations of the Study

This has been a ground breaking study particularly at the level of lower secondary science education. It was not easy, therefore, to find literature describing previous research work with respect to the development of the ability to see experiments as ways of asking questions during scientific investigations.

It would have been interesting and probably even more rewarding to have used the teaching units and Eloosis with a selected group of pupils from year 1 to the last year of their lower secondary science education had time permitted. Such a longitudinal study approach might have provided useful information and insights about the development of the ability to conceptualise the place and nature of experimentation in scientific enquiry.
It was not easy to determine efforts made by the school science teachers to help their pupils achieve the set objectives on the development of the experimenting skills.

9.5 Final Summary

A final summary of the answers from the investigations on the five questions above is in figure 9.1 below

Questions	Comments base on the results of the experiments
(1) Do pupils at lower secondary level appreciate the inclusion of experiments in science learning?	The perceptions are different
(2) Can these pupils identify a critical piece of information necessary for providing a credible solution to a problem?	The answer turned out to be 'NO'
(3) Do lower secondary level pupils have the ability to conceptualise or see experiments as ways of asking critical questions in scientific investigations?	The answer turned out to be 'NO'
(4) Can the development of the experimenting skill in those pupils at lower secondary level who have not yet developed it be accelerated through appropriate teaching?	It is limited to a few pupils
(5) Can lower secondary pupils from completely different teaching and cultural backgrounds demonstrate similar performances in terms of seeing the experiment as a way of asking critical questions in scientific investigations?	Yes, and the performance was equally not too successful

Figure 9.1 Final Comments of the Findings from the Three Experiments

9.6 Future Work

In light of these limitations, the researcher intends to carry out further work to provide more insights into this project. The following pieces of work could be carried out to extend the present work:

- ◇ *A longitudinal study of a group of pupils from their first year of lower secondary science education to the end of their upper secondary science education to determine the extent to which experimenting skills development could be accelerated by appropriate teaching or if its is exclusively developmental.*
- ◇ *An investigation of the approaches used in lower secondary school to develop the skills associated with experimenting to establish their effectiveness and limitations.*
- ◇ *A comparison study on the relationship between the number of reasoning steps and the ability to conceptualise the place and nature of experimentation in scientific enquiry.*
- ◇ *It could also be interesting to study the possible effects of working memory space on the development of the ability to identify critical piece of information necessary for problem solving in science and the development of the ability to see experiments as ways of asking questions in scientific enquiry activities.*

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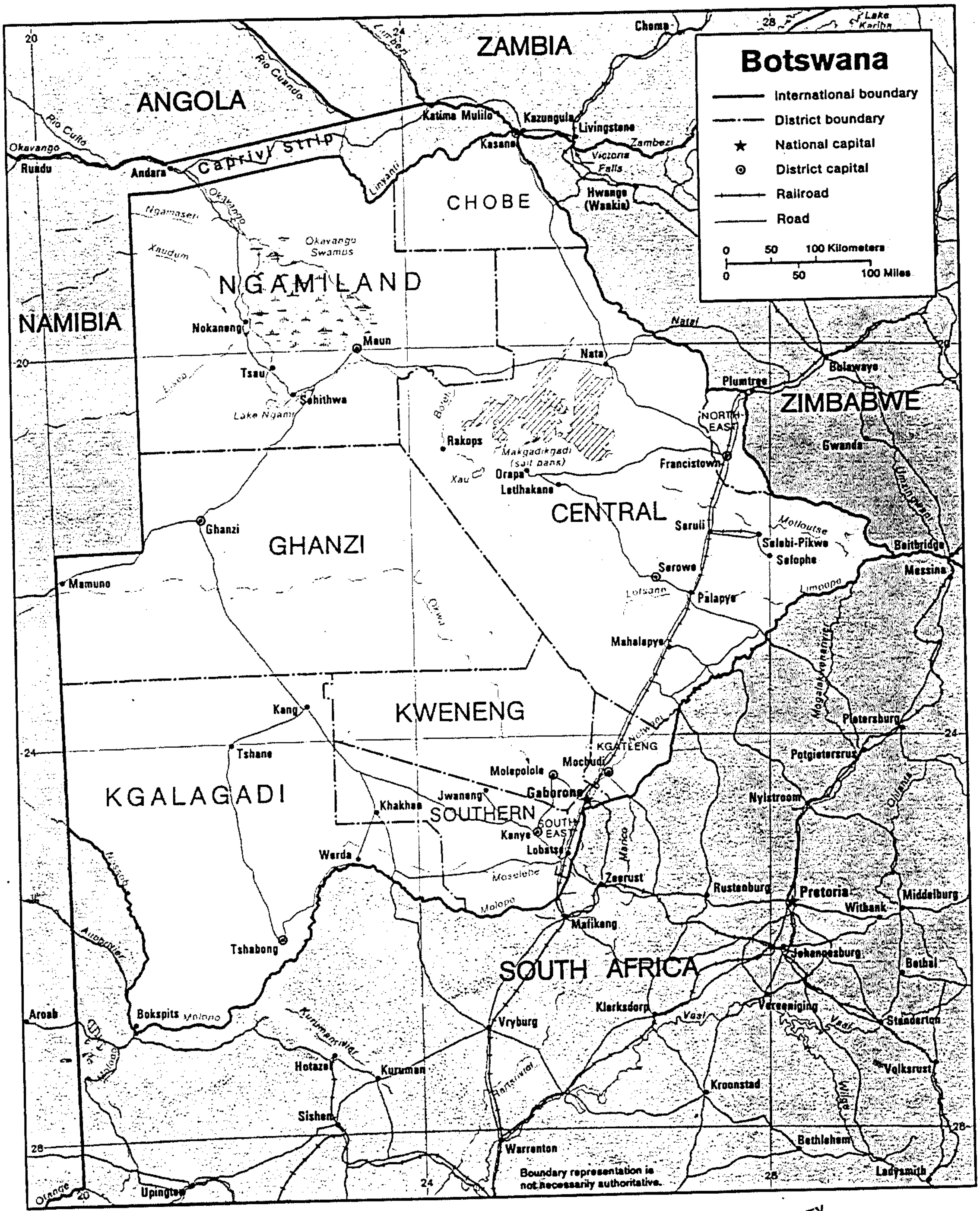
Appendices

Appendix A

Map of the Republic of Botswana



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Appendix B

Botswana Three-Year Junior Secondary Science Syllabus Content and Module 1 of the syllabus

Botswana Three-Year Junior Secondary Science Syllabus

Year 1

Module 1: The Scientific Method and Precautions

Unit 1.1 How Scientists Work (*10 periods*)

Topics: Doing science; Applications of science in everyday life; Safety; First aid.

Unit 1.2 Making Measurements (*10 periods*)

Topics: Reading scales of measuring instruments; Measuring length; Measuring area; Measuring mass; Density; Measuring temperature; Measuring time.

Module 2: Water

Unit 2.1 What is matter (*10 periods*)

Topics: Understanding matter; States of matter; Changes of state of matter.

Unit 2.2 Living Matter (*10 periods*)

Topics: Characteristics of life; Classification of living things; Plant and animal cells; Cells, tissues, organs and systems in plants and animals.

Module 3: Family Life Education

Unit 3.1 Human Growth and Development (*10 periods*)

Topics: Physical development and puberty; Parts of the reproductive system

Unit 3.2 Family Planning (*5 periods*)

Topics: Methods of birth control

Unit 3.3 Sexual Behaviour Problems (*10 periods*)

Topics: Teenage pregnancy; Sexually transmitted diseases and HIV/AIDS

Module 4: Water

Unit 4.1 Water in Botswana (*15 periods*)

Topics: Sources of water; Uses of water; Storage and conservation of water

Module 6: Energy

Unit 6.1 Forms of Energy and Energy Changes (*10 periods*)

Topics: Sources of energy; Energy changes; Conservation of energy

Unit 6.2 Sound Energy (*15 periods*)

Topics: The sound we hear; The ear; Ear defects and deafness; Applications of sound

Module 7: Healthy Living

Unit 7.1 Personal Hygiene (*5 periods*)

Topics: Keeping clean; Caring for teeth

Unit 7.2 Nutrition (*10 periods*)

Topics: Food, nutrition and their sources; Food poisoning; Preservation, storage and food handling; Digestion

Unit 7.3 Transporting Substances in the human Body (*10 periods*)

Topics: What is blood; The heart and circulatory problems

Unit 7.4 Drugs (*5 periods*)

Topics: Drugs use, misuse and abuse

Module 8: Our Environment

Unit 8.1 Energy Flow (*15 periods*)

Topics: Photosynthesis; Respiration; Transport of food, water and nutrients in plants

Year 2

Module 2: Matter

Unit 2.3 Air (*10 periods*)

Topics: Components of air; Properties of air; Preparation, properties and uses of carbon dioxide and oxygen

Module 3: Family Life Education

Unit 3.4 Human Reproduction (*10 periods*)

Topics: Pregnancy; Child care

Module 4: Water

Unit 4.2 Water as a Universal Solvent (*15 periods*)

Topics: Dissolving; Hard and soft water; Making water safe for use

Module 5: Forces

Unit 5.1 Investigating Forces (*20 periods*)

Topics: Types of forces; Effects of forces; Friction force; Measuring force

Module 6: Energy

Unit 6.3 Light Energy (*15 periods*)

Topics: Sources; Properties of light; Splitting white light; The eye; Eye defects, blindness, and diseases; Applications of light

Unit 6.4 Heat Energy (*10 periods*)

Topics: Sources and effects of heat; Methods of heat transfer and applications; Temperature regulation

Module 7: Healthy Living

Unit 7.5 Communicable Diseases (*10 periods*)

Topics: Causes of infectious diseases; How infections are spread; Preventing infections

Module 8: Our Environment

Unit 8.2 Ecosystems (*15 periods*)

Topics: Characteristics of ecosystems; Food chains, food webs, food pyramids, producers and consumers; Adaptation; Nutrient cycles

Unit 8.3 Sexual Reproduction in Flowering Plants (*10 periods*)

Topics: Reproductive parts of a flower; Pollination and fertilisation; Seed dispersal

Module 9: Communication

Unit 9.1 Communication in animals (*10 periods*)

Topics: Communicating by using senses; Nervous system; hormones

Module 10: Science in the Home

Unit 10.1 The House and Surroundings (*5 periods*)

Topics: Building materials; Ventilation; Insulation; Sanitation

Year 3

Module 2: Matter

Unit 2.4 The Building Blocks of Matter (*15 periods*)

Topics: Atoms, elements, mixtures, molecules and compounds; Physical and chemical changes; Purification techniques; Chemical reactions

Unit 2.5 Acids and Bases (*10 periods*)

Topics: Properties and examples of acids and bases; Chemical reactions of acids and bases

Unit 2.6 Metals and Non-metals (*10 periods*)

Topics: Properties, uses and examples; Reactions of metals with non-metals; Rocks, minerals and ores; Mining

Module 5: Forces

Unit 5.2 Machines (*10 periods*)

Topics: Simple machines; Skeletal system

Module 6 Energy

Unit 6.5 Electrical Energy (*10 periods*)

Topics: Sources of electricity; Circuits, voltage, current and resistance; Effects of electricity; Using electrical appliances and power consumption

Module 8: Our Environment

Unit 8.4 Managing Natural Resources (*15 periods*)

Topics: Conserving natural resources; Pollution

Unit 8.5 Solar System (*5 periods*)

Topics: Stars and planets; Motion of planets; The moon

Module 9: Communication

Unit 9.2 Electronic Communication (*15 periods*)

Topics: Electronic devices

Module 10: Science in the Home

Unit 10.3 Chemicals in the Home (*10 periods*)

Topics: Common household chemicals; Simple household chemical reactions

FORM 1

MODULE 1: THE SCIENTIFIC METHOD AND PRECAUTIONS

UNIT 1.1 – HOW SCIENTISTS WORK (10 periods)

Topics	*General Objectives*	Specific Objectives
	The students should be able to:	*The students should be able to:*
Doing science	1.1.1 acquire basic process skills to carry out investigations using scientific method and develop an interest in science.	1.1.1.1 explain what science is. 1.1.1.2 discuss how science affects our everyday life. 1.1.1.3 observe people with science-related careers in their working environments (use of video cassettes and guidance materials recommended). 1.1.1.4 demonstrate the following process skills suitable for simple investigations: observing, comparing, classifying, measuring, interpreting, analysing, inferring, predicting, formulating hypothesis, controlling variables, experimenting, (designing and carrying out procedures), problem solving and communicating in daily life situations. 1.1.1.5 infer correctly relations of variables from experimental results presented in tables, graphs, observations. 1.1.1.6 make reasonable conclusions on the basis of available experimental results.
Applications of science in everyday life	1.1.2 appreciate applications of science skills in everyday life.	1.1.2.1 carry out an investigation on any problem in daily life which lends itself to experimentation involving the use of simple laboratory apparatus. 1.1.2.2 carry out a scientific investigation over a longer period of time using a theme related to daily life science situations.
Safety awareness	1.1.3 acquire basic knowledge, skills and techniques needed to work safely in the laboratory.	1.1.3.1 describe what safety is and what a safe place is. 1.1.3.2 state common hazards in the laboratory. 1.1.3.3 list safety rules applicable in the laboratory. 1.1.3.4 demonstrate safe behaviour in a laboratory.
First aid	1.1.4 acquire basic first aid skills in handling common injuries or minor accidents.	1.1.4.1 define first aid. 1.1.4.2 demonstrate some simple first aid techniques: treating bites, burns, shock, poisoning and controlling bleeding.

UNIT 1.2 – MAKING MEASUREMENTS (10 periods)		
Topics	*General Objectives*	*Specific Objectives*
Reading scales of measuring instruments	1.2.1 acquire skills in reading scales of instruments using divisions and sub-divisions of standard units of the metric system.	1.2.1.1 accurately read the scale of a measuring instrument to its smallest division.
Measuring length	1.2.2 perform estimations and accurate measurements of length.	1.2.2.1 estimate length of common objects to the nearest centimetre. 1.2.2.2 carry out experiments using rulers and metre rules to measure lengths to the nearest millimetre. 1.2.2.3 convert given measurements in traditional and non standard units into metres.
Measuring area	1.2.3 perform estimations and accurate measurements of area.	1.2.3.1 estimate the area of any common shape. 1.2.3.2 determine area of an irregular object such as a leaf. 1.2.3.3. design suitable methods for measuring areas in daily life situation.
Measuring mass	1.2.4 perform estimations and accurate measurements of mass.	1.2.4.1 estimate mass of common objects. 1.2.4.2 read the scales of a triple beam balance or a lever arm balance to the nearest gram. 1.2.4.3 design suitable methods for measuring mass in daily life situations.
Measuring volume	1.2.5 perform estimations and accurate measurements of volume.	1.2.5.1 estimate volume of a liquid or an object. 1.2.5.2 read the scales of a measuring cylinder (thinking of the following: level surface, meniscus, parallax error) to the nearest cubic centimetre (cm^3). 1.2.5.3 design suitable methods for measuring volume in daily life situations given a variety of objects and suitable measuring devices . 1.2.5.4 carry out accurate measurements of irregular objects floating and sinking using displacement cans and measuring cylinders.
Density	1.2.6 be aware of the relationship between mass and volume.	1.2.6.1 define density as mass per cubic centimetre of that substance. 1.2.6.2 compare masses of different substances of the same volume. 1.2.6.3 determine densities of different substances.
Measuring temperature	1.2.7 perform estimations and accurate measurements of temperature.	1.2.7.1 estimate temperature. 1.2.7.2 state that temperature is the degree of hotness/coldness. 1.2.7.3 read the scales of a laboratory thermometer to the nearest degrees Celsius (°C). 1.2.7.4 read the scales of a clinical thermometer to the nearest 1/10 °C.
Measuring time	1.2.8 perform estimations and accurate measurements of time.	1.2.8.1 estimate time to the nearest minute. 1.2.8.2 read the scales of a stop watch or a stop clock to the nearest second (s). 1.2.8.3 design suitable methods for measuring time.

Appendix C

Eloosis Instructions to the Chiefs

INSTRUCTIONS FOR THE CHIEFS

1. BEFORE THE START OF THE GAME, you should have:

i) A group of players to work with,

ii) Your RULE (known to you only)

iii) Two (2) packs of playing cards.

2. AT START OF THE GAME, do the following:

i) Shuffle the cards and issue/deal them out until they are all gone. (It does not matter even if some player have one card more than others).

ii) Inform the players that any card accepted must remain on the table face-up. Any rejected card must be returned to the player's hand and can be played later, if seen necessary by player.

3. DURING ONE ROUND OF PLAY, do the following:

i) Ask a player to your left hand side to start the play by placing his/her card face-up on the table. This card should either be accepted or rejected by you, then play passes on to the next player.

ii) Each player must in turn select one card from his/her hand and place it face-up in line with those already on the table.

iii) Your rule must be used to decide which cards to accept and not to accept. You must strictly follow the rule throughout the game.

iv) When all players have had a chance to play the game once, This marks the end of a round. Stop the play and allow the players to fill in the progress assessment form.

4. Start the NEXT ROUND of play by repeating steps 2 and 3

5. Let the play continue using the same rule until ROUND SIX.

6. The NEXT SESSION of play starts with a new rule and the play follows all the steps above.

Appendix D

Teaching Units, Answer Sheets, Interview Questions and Table of Metals and their Behaviours

Unit 1

Using the Right Metal

Uses of Metals

Have you ever thought of the kind of material that most things are made from? We use wood, grass, brick, stone and various metals to make our houses. Cars, trains, tractors, tools that we use at home and electrical wires are all made of metal. It is important to note that different metals are used for different purposes. This is because different metals behave in different ways. For example, a metal like aluminium does not rust, melts at around 660 ^{0}C and can be made into thin sheets. A large amount of aluminium is quite light for its size. We say aluminium has a *lower density* compared with most metals. Unfortunately, aluminium bends easily and therefore is too weak to carry heavy loads..

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

Part 1: Choosing the Right Metal for the Job.

(1) This is how you start. Work as a group and discuss the kind of behaviour which is required of a metal for each of the following jobs. *(Write your agreed answers on the answer sheet provided).*

Jobs

(a) Main structure and body of a car.

(b) Wires for the electrical wiring of a house.

(c) Filament for a light bulb.

Jobs to be Done	What the Metal Should be Like
(a) Car structure and body	The metal should be strong, have a high density, and not react with water. Large amounts are needed.
(b) Wires for electricity	
(c) Filament for light bulb	

What to do next.

(2) Now that you have agreed on the kind of behaviours, ask for a table of metals and use it to choose the best metal for each job. You can even suggest a good second choice. Use the space provided on the answer sheet to write down your agreed choices.

[When you have finished with this part, ask for part 2.]

Unit 1

Using the Right Metal

Part 2: The Problem

A light bulb filament is made from a very thin coil of metal that allows electric current to flow through with difficulty. This makes the filament to heat up as electrical current passes through it and produce light.

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

(3) Discuss which behaviour of the metal you have chosen makes it the best one for light bulb filaments? *(Write your agreed answer on your answer sheet)*

(4) Given the following items:

- **3 cells**

- **connecting wires**

- **a switch**

- **thin wires of same thickness made from the different metals**

- **a bulb**

Step 1

You have time to do one experiment to find out which metal is best for making light bulb filaments. Discuss what this experiment should be. *(Remember you can only use the materials listed above to carry out the experiment)*

Step 2

When you have agreed, write down in 3 or 4 sentences the experiment you would carry out and how this would show you which metal is best to make light bulb filaments. *(Use your anser sheet to write down your agreed answers. You may want to draw a diagram of the experiment).*

Unit 2

Trees and Cars

A local leader was talking to a group of village people about the dangers of cutting down trees without replacing them. He said that the importance of having trees around was that they absorb most of the carbon dioxide from the air. He further said that too much carbon dioxide in the air traps heat and this may cause an increase in global temperature.

To make the people understand the seriousness of what he was talking about, he gave them an example that he picked from a well known USA news paper. The example is given in the box below.

> "One tree can use up about 6 kg of carbon dioxide per year or enough to offset pollution produced by driving one car for 40 000 km

Is this statement true?

> INSTRUCTIONS
> You will be working in a small group.
> Discuss the possible answers to the questions below.
> One member of the group should write down the agreed answers on the answer sheet.

Part 1: Is The Statement True?

You teacher has asked you to find out if this statement is really true. To start your task, you teacher has given you the following information to use :

- The car uses petrol
- 1 litre of petrol has a mass of 700 g (0.7 kg)
- On average the car covers a distance of 10 km on 0.7 kg of petrol.
- 1 kg of petrol produces 3.4 kg of carbon dioxide

Use the information above to calculate the following: *(Work as a group to do the calculations)*

(1) Mass of petrol used by car over the distance of 40 000 km.

(2) Mass of carbon dioxide produced over the distance of 40 000 km.

(3) The actual number of trees needed to use up all the carbon dioxide produced by the car driving 40 000 km.

Part 2:

(4) Look at the calculations in question (3) above, the newspaper statement is wrong about the number of trees that can use up 6 kg of carbon dioxide in a year. Would the statement in the box above be true if it were from a book? Discuss this and write down your agreed answer on your answer sheet.

(5) Do you think the local leader's opinions were all correct? Discuss this and write down your agreed answer on the answer sheet.

(6) It is possible that the newspaper is correct in its conclusion but has the wrong figure for the amount of carbon dioxide absorbed per year. Discuss how you might check if the figure 6 kg is correct? Write your agreed answer on the answer sheet.

Unit 3

Food for Health

Everyone needs to eat the right kind of things. Neo's little brother Nnana has a diet sheet. The information in the sheet tells Neo's mother what Nnana should eat in the morning, during the day and in the evening. He needs special food because he is a very tiny baby. Have you ever thought of what the rest of us need for our breakfast, lunch and supper?

We need to eat different kinds of food to be healthy. We need carbohydrates, fats, proteins, vitamins, and minerals in the food we eat each day. These kinds food or nutrients have special functions in our body and can be obtained from different sources of foods as shown by the table below.

Kind of food	What it Does in Our Body	Sources of the Food
Carbohydrates	provide our body with energy quickly	flour, sugar, maize, sorghum,potatoes, etc.
Fat	provide our body with energy as well, but slowly	butter, margarine, cooking oil, etc.
Protein	build our body muscles, nails, and hair	meat, fish, eggs, etc.
Vitamins	help in building healthy body cells	fresh fruits, fresh vegetables, milk, liver, fish, etc.

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

Part 1: How Do We Decide What Kind Of Food We Need

(1) Look at the information in the table above. Discuss in your group which of the kinds of food listed in the table is most important and which is least important in the diet of the people below. **For example, a football player would need a lot of proteins** *(most important)* **to build his muscle for strength** *(reason for most important)* **and less fats** *(least important)*. (Remember, our bodies need all these kinds of food to be healthy). Write your agreed answers on the answer sheet and give ONE reason for your choice.

(a) a lady model

(b) an old lady

(c) a teenage boy

(d) a baby

(2) Eating too much of ONE kind of food affects our body health. Also NOT eating certain kinds of food can affect our body health. Most importantly, our bodies have to remove the undigested food materials to be healthy.

Which other important piece of information would you need to know about your diet besides it providing your body with energy, building your body cells and protecting your body against deficiency diseases? Discuss this and write your agreed answer on the answer sheet.

[When you are finished with this part, ask for part 2]

Unit 3

Food for Health

Part 2: How Much Do Our Bodies Need Daily

Now that we know what kind of food different people need, let us look at how much of these kinds of food different people need in their diets each day. Experiments show that the different amounts of food that each person needs depend on the person's age and gender.

The table below shows amounts of different kinds of food that people should have in their diet everyday.

200 g polished rice:	containing 8g protein; 97g carbohydrate; 1g fat; 2g fibre; no vitamins
150 g beef:	containing 26g protein; 0g carbohydrate; 36g fat; 5g fibre; no vitamins
1 apple:	containing 4g protein; 10g carbohydrate; 1g fat; 5g fibre; vitamins
250 g milk:	containing 8g protein; 10g carbohydrate; 10g fat: 0g fibre; vitamins
200 g soft porridge:	containing 12g protein; 132g carbohydrate; 18g fat; 10g fibre; vitamins

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

(3) Neo (a boy who is 11 years old), has his daily diet the same as that of Karabo (a girl who is also 11 years old). How is this going to affect Neo's health? Discuss this in your group and write down what you think would happen to Neo on the answer sheet.

(4) One of the reasons why Neo needs more of the proteins, fats and carbohydrates has to do with him being male. What do you think is the main reason for males to require more food than females?

(5) Neo ate the following foods in ONE day:

Age		Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)
10 - 11 years	Boy	57	76	285	30
	Girl	51	68	255	25
15 years	Boy	72	96	360	30
	Girl	53	72	265	30
Grown-ups	Male	72	97	360	30
	Female	54	72	270	30

(a) Work out the total masses of each of the following: *(Use the answer sheet to write down your agreed answers).*

Carbohydrate
Protein
Fat
fibre (roughage)

(b) A diet which contains all of the different kinds of food (nutrients) in the right amounts is said to be a balanced diet. Looking at the amounts you got in (a), is Neo's diet a balanced?

(c) What would you have to do to Neo's diet to make sure that it contains the necessary kinds of food in the right amounts? Discuss this and write your agreed answer on the answer sheet.

Unit 4

Shadows

Have you ever wondered why your shadow sometimes looks shorter and other times taller than your normal height? Neo and Bosele have a problem with their shadows. Here is how they try to explain to one another why their shadows sometimes appear shorter and sometimes taller.

NEO:	(*Looking at his shadow on the wall*) Bosele look at my shadow I am a gaint. Gggrrrrrrr (stretching out his arms). Look at your shadow it so short. This means that I am taller than you.
BOSELE:	Neo you know very well that you are shorter than me, I am 1.5 metres tall and you are 1.1 metres tall. This is just your eyes deceiving you. If you move to where I am you will see that I am telling the truth.
NEO:	(*Standing next to Bosele*) Aahh! You are right, look at my shadow now .. it is even shorter than yours. Why ?
BOSELE:	(*Griming with delight*) It depends on where you are inside the house.

Try to help Neo understand what is happening.

INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

Task 1: What More Information Do I Need

(1) Would Neo's shadow appear on a vertical wall if he was standing outside the house near the wall with the sun directly above him?

(2) If Neo was taller than Bosele, would his shadow be shorter than that of Bosele when standing next to each other with the sun directly behind them?

(3) There are certain things that are necessary for a shadow to be produced or formed. What are these things? Discuss these things and list as many of them as possible on the answer sheet.

Task 2: Making Neo Understand

(4) You are given the following items to use to design one experiment in order to show how the height of a shadow changes:- a large sheet of white card, a large ball of bostik, a candle, a metre rule, and a ruler. Discuss what this experiment should be. When you have agreed, write down in 3 or 4 sentences the experiment you would carry out. You can draw diagrams to show how you would arrange the items in the experiment.

Unit 5

Ecosystem

An ecosystem is describes as "a community of plants and animals living in a certain area, including the soil and other non-living materials". An ecosystem can be as small as a water-filled hole in a forest tree or as big as the forest itself. In a perfect ecosystem, all things found in it depend on each other to survive - this is called a balanced ecosystem. For example, plants depend on animals for manure and carbon dioxide, whilst animals depend on plants for food and oxygen. Note that the number of organisms in a perfect ecosystem does not change. A change in the climate and human interference has caused most of the ecosystems to change and some to disappear completely. Let us look at how ecosystems change.

> INSTRUCTIONS
> You will be working in a small group.
> Discuss the possible answers to the questions below.
> One member of the group should write down the agreed answers on the answer sheet.

Modisa is a 13 year old boy. During one of the school holidays he went to his father's cattle post for two weeks. He saw rabbits and rats in the forest around his cattle post. His father said to him, "I have seen quite a lot in the past two years". Modisa wanted to know what would increase the number of rats and rabbits. His father said, "I do not know, my son, maybe they have to increased their rates of reproducing ".

(1) Is Modisa's father correct in suggesting that "maybe rats and rabbits have to increase their rates of reproducing" in order for them to increase in number? Discuss this and write your agreed answer on the answer sheet.

(2) Discuss in your group THREE major possible reasons for increase in the number of rats and rabbits, and indicate whether the reasons are due to changes in climate or human interferences. One reason has been given for you. See if you can think of three more. *(Write down your agreed answers on the answer sheet).*

Reason	**Cause**
Good rains in the two years	Change in climate

(3) Modisa then suggested to his father to get advice from the Agriculture people concerning what could cause the number of rats and rabbits to increase.

What should Modisa's father need to do first before meeting with the Agriculture people? Discuss this and write your agreed answer on the answer sheet.

(4) What kind of things would you have to do to be sure your answers to question (3) are the right ones? Discuss this and write your agreed answers on the answer sheet.

Unit 6

Speed of Sound Versus Speed of Light in Air

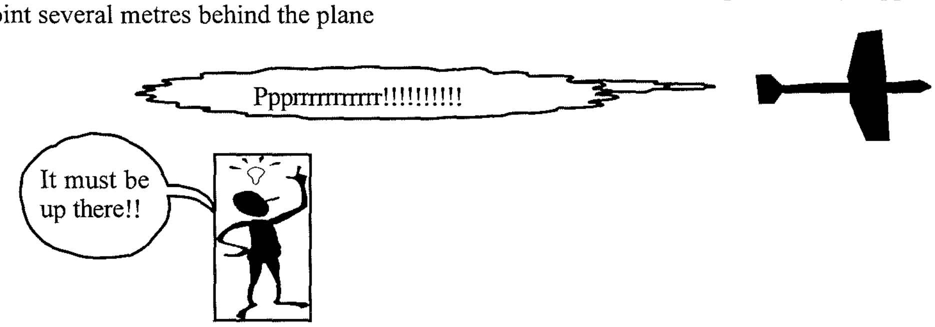
What Science Say

Science describe both **sound** and **light** as forms of wave motion. Sound is produced by things which **move or vibrate**. Like when a skin drum is struck with a drumstick, it moves to and fro. Light is produced by things that are **very hot**, like a burning piece of wood. Experiments show that sound travels with a speed of 340 m/s at sea level.

What Happened to Modisa

Modisa, a thirteen-year old boy, made some interesting observations as he was sitting under a tree at his father's cattle post. He saw his father chopping down a dry tree trunk some 680 metres away from where he was sitting. As he observed carefully, he became very confused. He could not understand why the sound of the chopping axe and the act of chopping did not happen at the same time.

As he was thinking about this, he immediately remembered something similar to this: the plane that passes over their cattle post every Wednesday afternoon. The sound from the plane always appears to come from a point several metres behind the plane



INSTRUCTIONS You will be working in a small group. Discuss the possible answers to the questions below. One member of the group should write down the agreed answers on the answer sheet.

Three students were asked to explain why Modisa saw the chopping first before hearing the sound from the chopping. They suggested the following:

Student A:	Modisa probably has a hearing problem and therefore could not hear quickly enough.
Student B:	I think the sound from the chopping had its speed reduced by the trees and the air as it travelled towards Modisa.
Student C:	I personally think the sound just took a longer time to reach Modisa as it had to travel a longer distance.

(1) Calculate the amount of time taken by the sound made by the chopping axe to reach Modisa.

$$\textbf{Remember: Time} = \frac{\textbf{distance}}{\textbf{speed}}$$

(2) From the calculations in (1), what reason would you give to Modisa to explain why the sound from chopping did not happen at the same time as seeing the chopping. Give your agreed answer in ONE sentence on your answer sheet.

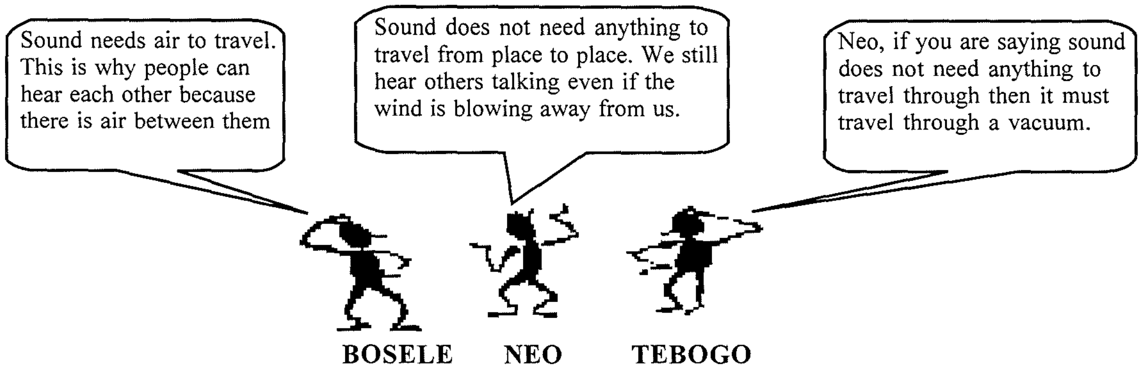
(3) Can you suggest ONE other situation where we see light first and hear sound after a few seconds? Discuss this and write your agreed answer on the answer sheet

(4) What other piece of information would you need to know to be sure that your answer in (2) is reasonable?

Unit 7

How Does Sound Energy Travel?

[The extract is taken from a textbook for Botswana Junior Secondary School science]



INSTRUCTIONS
You will be working in a small group.
Discuss the possible answers to the questions below.
One member of the group should write down the agreed answers on the answer sheet.

Part 1

(1) As a group discuss the three statements made by Bosele, Neo and Tebogo about how sound travels.

Who do you think has a better idea of how sound reaches us from its source?

Part 2

A group of students wish to carry out a set of experiments in their classroom to find out the following:

(a) If sound really need air to travel from place to place, and
(b) If sound can travel through other materials other than air.

(2) Think of an experiment the students could carry out in order to find out if sound can travel through water. Discuss this and write in ONE sentence on the answer sheet, the kind of experiment you have agreed on.

(3) Think of a second experiment that the students can carry out in order to find out if sound really needs air to travel from place to place. Discuss this and write in ONE sentence on the answer sheet, the kind of experiment you have agreed on.

(4) What is the most important thing that the students in (3) need to do in order to make sure that the result of their experiment is accurate? Discuss this and write your agreed answer on the answer sheet.

Unit 1

Using the Right Metal
ANSWER SHEET

Group Number __________ Name of School ________________________

Form ________

Part 1: Choosing the Right Metal for the Job.

Use this table to answer questions (1) & (2)

Jobs to be Done	What the Metal Should be Like	Best Metal
(a) Car structure and body	The metal should be strong, have a high density, not reactin water, needed in large amounts.	
(b) Wires for electricity		
(c) Filament for light bulb		

Part 2: The Problem

(3) Behaviour of metal chosen. ______________________________________

(4) The experiment.

____

____

____

____

____

____

____

____

____

Unit 2

Trees and Cars

ANSWER SHEET

Group Number ___________Name of School ____________________________

Form _________

Part 1: Is the Statement True?

(1) Mass of petrol used by car over a distance of 40 000 km = ______ kg

(2) Mass of carbon dioxide produced over a distance of 40 000 km = ______ kg

(3) The actual number of trees needed to use up the carbon dioxide = ____ trees

Part 2:

(4) The statement would be

____

(5) The local leader's opinions are

____

____

(6) ____

____

____

____

____

____

____

Unit 3

Food for Health
ANSWER SHEET

Group Number ___________ Name of School ______________________________

Form _________

Part 1: How Do We Decide What Kind of Food We Need

(1)	Most important	Least important	Reason for most important
(a) A lady model	_____________	_____________	_____________
(b) An old lady	_____________	_____________	_____________
(c) Teenage boy	_____________	_____________	_____________
(d) A baby	_____________	_____________	_____________

(2) ____

____

____

Part 2: How Much Do Our Bodies Need Daily.

(3)

____

____

(4) Males require more food than females because

____

____

(5) (a) The total mass of

carbohydrates = _______________ g

proteins = _______________ g

fats = _______________ g

fibres (roughage) = _______________ g

(b) Neo's diet is ____

(c) ____

Unit 4

Shadows
ANSWER SHEET

Group Number __________ Name of School ______________________________

Form ________

Task 1: What More Information Do I Need

(1) YES/NO

(2) YES/NO

(3)

____

____

____

Task 2: Making Neo Understand

(4) The description of the experiment.

____

____

____

____

____

____

Unit 5

Ecosystem
ANSWER SHEET

Group Number __________ Name of School ______________________________

Form ________

(1) Modisa's father is

____

(2) The first one has been done for you.

Reason	**Cause**
Good rains in the two years offers plenty of food	Change in climate
______________________________________	______________
______________________________________	______________
______________________________________	______________

(3)

____

____

____

____

(4) Things to do

____

____

____

____

Unit 6

Speed of Sound versus Speed of Light

ANSWER SHEET

Group Number __________Name of School ______________________________

Form ________

(1) I think the suggestion by student _____ is correct.

(2) Time take by sound from the chopping to reach Modisa is ___________ seconds

(3) Reason

____

____

(4)

____

(5) The other piece of information is

____

____

Unit 7

How Does Sound Energy Travel

ANSWER SHEET

Group Number ___________Name of School _______________________________

Form _________

Part 1:

(1) __________________ has a better idea of how sound reaches us from its source.

Part 2:

(2)

____

____

____

____

____

(3)

____

____

____

____

____

(4)

____

____

Interview Items (Botswana)

1. Do you do science at school?
2. Do you like it? How much compared to other subject that you do at school?
3. What do you usually do during science lessons that interests you?
4. Tell me the things that you hate/love most about science lessons?
5. Why do you hate/love them?
6. Do you do experiments during your science lessons?
7. How often do you do experiments in you school?
8. If you do NOT do experiments, would you like to do them as part of your science activities?
9. Why do you think the teacher asks you to do experiments?
10. How does working with others during experiments help you?
11. Do you like doing these experiments?
12. If YES, what is it that you like most about doing experiments?
13. If NOT, what do you dislike most about doing experiments?
14. Why do you think your teacher always asks you to work in groups during experiments?
15. Would you say schools are right to expect pupils to carry out experiments ? Why ?
16. What skills have you gained so far from carrying out experiments ? How do you use these skills in your daily life ?
17. Do you think people would understand how most things work if they have not done science at school? Why?
18. In your opinion, have results from experiments helped you to develop better ways of understanding your environment? Give examples.
19. Are some experiments better than others in giving you answers ?
20. Are experiments which go as expected more useful than ones which do not? Why ?
21. Do you think science always provides right answers about things ?
22. How can we be sure that we have the right answers ?
23. What do you think science is trying to teach us ?

TABLES

Table 1: Some metals and some of their behaviours.

Metal	Melting Point (°C)	Boiling Point (°C)	Density (g cm^{3})	Conductivity* (microhm^{-1} cm^{-1})	Reaction With			Strength **	% in Earth's Crust
					Cold Water	Acid	Damp Air		
A	839	1484	1.55	0.22	Fast	Fast	Slow	Low	3.4
B	1083	2567	8.96	0.59	Nil	Nil	Nil	High	0.01
C	1064	2807	19.30	0.42	Nil	Nil	Nil	High	5×10^{-7}
D	1535	2750	7.87	0.10	Nil	Slow	Slight	Very high	4.7
E	328	1740	11.35	0.05	Nil	Slight	Nil	Low	2×10^{-3}
F	649	1090	1.74	0.22	Slow	Fast	Slow	Medium	1.94
G	64	774	0.86	0.14	Fast	Fast	Fast	Very low	2.40
H	232	2270	7.31	0.09	Nil	Slow	Nil	Low	6×10^{-4}
I	1660	3287	4.54	0.02	Nil	Slight	Nil	High	0.58
J	3410	5660	19.30	0.18	Nil	Nil	Nil	Very high	6×10^{-3}

KEY:

* The higher the value the higher the ability of the metal to allow electric current to pass through it.

"NIL" means 'No obvious reaction can be seen occurring'

** Is based on the bending and stretching behaviour of the metals

Appendix E

Experiment 1, 2 and 3 Eloosis Checklists

Progress Assement Form for the Game Eloosis

Group Number: ☐

ROUND ONE

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

	(*Tick here*)
I have no real idea, so I have just made a guess.	☐
I cannot be sure, but I think I have it	☐
I am almost sure, but I would like some more information	☐
I really believe I have it	☐
I know it and I can prove it	☐

The next card I would play to prove it would be (*Name it*) ____________________

****

ROUND TWO

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

	(*Tick here*)
I have no real idea, so I have just made a guess.	☐
I cannot be sure, but I think I have it	☐
I am almost sure, but I would like some more information	☐
I really believe I have it	☐
I know it and I can prove it	☐

The next card I would play to prove it would be (Name it) ____________________

****

ROUND THREE

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

	(*Tick here*)
I have no real idea, so I have just made a guess.	☐
I cannot be sure, but I think I have it	☐
I am almost sure, but I would like some more information	☐
I really believe I have it	☐
I know it and I can prove it	☐

The next card I would play to prove it would be (*Name it*) ____________________

ROUND FOUR

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

(*Tick here*)

I have no real idea, so I have just made a guess. ☐
I cannot be sure, but I think I have it ☐
I am almost sure, but I would like some more information ☐
I really believe I have it ☐
I know it and I can prove it ☐
The next card I would play to prove it would be (*Name it*) ____________

****

ROUND FIVE

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

(*Tick here*)

I have no real idea, so I have just made a guess. ☐
I cannot be sure, but I think I have it ☐
I am almost sure, but I would like some more information ☐
I really believe I have it ☐
I know it and I can prove it ☐
The next card I would play to prove it would be (*Name it*) ____________

****

ROUND SIX

- Have you worked out the pattern? (*Tick the box that applies to you*) ☐ Yes ☐ No
- What is the pattern? (*Describe it*) ____________________
- How confident are you? (*Put a tick in the box that applies to you*)

(*Tick here*)

I have no real idea, so I have just made a guess. ☐
I cannot be sure, but I think I have it ☐
I am almost sure, but I would like some more information ☐
I really believe I have it ☐
I know it and I can prove it ☐
The next card I would play to prove it would be (Name it) ____________

Checklist for Eloosis Used as a Teaching Tool (Botswana)

Name of School: ______________________________

1. Did the class grasp the general concept of experimentation or asking questions?

   ☐ Yes ☐ No ☐ Some

2. Did the pupils have any concept of criticality (an experiment with an unambiguous answer?

   ☐ Yes ☐ No ☐ Some

3. What was the ability of the pupils who managed to grasp the above?

   ☐ Below average ☐ Average ☐ Above average

4. How much time did the dialogue or the discussions with the whole class take before the above signs were shown? __________ minutes

Checklist For Eloosis (Scotland)

Name of School ____________________________ Year group ____

1. How many enjoyed the game?.. ☐

2. How many considered the game easy?.. ☐

3. What do you think the game taught you? __________________________

4. Did you sometimes think you had the answer, then the next card made changed your mind? How many?............................ ☐

5. When you thought you had it, did you try a card which you thought I would want or reverse? How many?................. ☐ rejected cards ☐ accepted cards

6. Which is better? .... ☐ rejected cards ☐ accepted cards

7. Which gives you better certainty?.. ☐ rejected cards ☐ accepted cards

8. How does the game relate to how science tries to find answers? ____

9. Why do you conduct experiments in science lessons ___________________________

10. What is science trying to teach us? ______________________________________

11. Are some experiments better than others? What make a better experiment? ________

12. Are answers from experiments always right? _______________________________

13. How can we be certain of answers we get from experiments? ___________________

Guidelines for Eloosis Discussions After Playing

◇ [This guidelines are meant to help the pupils grasp the relationship between the processes they used to work out the chief's rule in Eloosis and the processes used in scientific investigations to explore solutions to problems.]

◇ The teacher has to lead the discussions by following these guideline points by way of asking questions in order to get the pupils talking.

◇ **Card Game**: Place the acceptable card on the table
Scientific Process: Collect data

◇ **Card Game**: Find a pattern in the accepted cards
Scientific Process: Search for regularities and postulate a rule, law or theory

◇ **Card Game**: Play the next card according to the pattern found
Scientific Process: Perform an experiment and predict the result

◇ **Card Game**: If card is not accepted, modify or discard the previous rule
Scientific Process: Alter or discard a rule in favour of new experimental evidence

◇ **Card Game**: Tell the rest of the players what the rule is
Scientific Process: Publish the results of the investigation

Source: (Ziegler, 1974)

Appendix F

The Theory for the Construction of Questionnaire

Construction of Questionnaires

Wiersma (1995) offers some guidance concerning the construction of items for questionnaires, especially those that do not relate to demographic information (Wiersma, 1995, chapter seven, page 179). A close inspection of the guide lines clearly elucidate the complexity of the skills and the care expected from those putting the items together. Wiersma, therefore, emphasises the need to pay careful attention to details. His contention is that poorly constructed and organised items "do not provide the necessary data" for a survey (Wiersma, 1995).

The rule of thumb regarding the construction of items for questionnaires, otherwise referred to as "the rule of parsimony" by Wiersma (1995) states:

Keep Things As Simple As Possible To Obtain The Necessary Data.

Weiss (1975) emphasises the importance of the items to reflect the objectives of the project, otherwise the data collected may not make sense or may prove difficult to analyse. Although both item formats can be used within a single questionnaire, research findings recommend that the proportion of selected-response items to that of open-ended items be much higher. Dillman (1978) associates the tendency by respondents to either return questionnaires with incomplete responses or not return the questionnaires at all, with the use of questionnaires containing items requiring respondents to express their opinions through writing a considerable number of sentences.

Wiersma (1995) on the other hand, favours the use of the Likert scale, commonly used in questionnaire surveys, as a format for most of the selected-response items. Mason and Bramble (1989) describe the Likert scale as a scale consisting of a statement which requires the respondents to indicate the degree of intensity on an attribute. However, a number of scaling techniques have been developed over the years which are meant to measure mainly attitudes, judgments, opinions, and many more traits not easily measured by tests.

However, there is also available a number of formats used to construct selected-response items, like, true or false, matching items, selecting from a range of responses to a single item a preferred number and many more. Wiersma (1995) do support the use of a wide variety of item formats to make the questionnaire attractive and stress the fact that items of the same format should be grouped together within a questionnaire, but care should also be taken to maintain a logical sequence of the items to capture the attention of the respondent. He also recommends that, in the case where open-ended items are included in the questionnaire, they should be placed at the end of the questionnaire or at the end of each group of items with same format (Dillman, 1978; Mason and Bramble, 1989; Wiersma, 1995).

To increase the response rate of the questionnaire or to increase the percentage of respondents returning the questionnaire, the attractiveness and the professional appearance of the questionnaire must be acceptable and maintained throughout the questionnaire (Clark and Boser 1989; Johnson *et al.* (1992). Tollefson *et al.* (1984) reports that a timed response to a questionnaire increases the response rate as long as the time allotted to the task of completing the questionnaire answering is realistic. This means that the time within which the respondent is supposed to finish responding to the questionnaire must match the average time required to completely finish responding to all the items.

Some of the arguments raised concerning the construction of questionnaires have been adhered to when constructing the questionnaire for this pilot project. In particular, the items are sequenced and grouped according to their formats. The items are constructed using simple and short sentences to reduce too much noise to the respondents. The instructions are easy to comprehend and contains fewer information. To further sustain the respondents' interests, the purpose for each section of the questionnaire is clearly described.

Appendix G

Experiment One Questionnaire/Test

Experiment One Questionnaire/test.

Please complete this questionnaire as honestly as possible. Your identity will remain confidential. Please do not write your name on this form.

Section 1

This section asks for some personal information about you.

1.1 Name of School: ______________________________

1.2 How old are you? (*Write in this box*) ☐ (years old).

1.3 Are you a ☐ boy or a ☐ girl? (*Tick on the right box*)

1.4 In what form are you? (*Tick on the right box*)

☐ Form 1 ☐ Form 2 ☐ Form 3

1.5 Which languages do you speak? (*Tick all the boxes that apply to you*)

☐ Setswana ☐ English ☐ Afrikaans ☐ Other (specify) _____

1.6 How do you describe yourself? (*Tick all the boxes that apply to you*)

☐ I learn better on my own.

☐ I learn better when sharing ideas with others.

☐ I like solving challenging activities.

☐ I like solving easy activities.

☐ I like to take part during group discussions.

☐ I like listening to others talk during group discussions.

Section 2

This section asks for some thinking skills you applied during the game to work out the chief's rule.

2.1 Which of the following are the problems that you had when working out the chief's rule in groups? (*Tick as many boxes as you wish*).

☐ The time for playing the game was not enough.

☐ The instructions for playing the game were not easy to understand.

☐ The chief's rule was difficult to work out.

☐ I did not discuss my ideas with other members of the group.

☐ Other reasons (explain) ______________________________

2.2 How did you work out the chief's rule? (*Explain*) ______________________________

Please Turn Over

2.3 Which of the following did you apply to work out the chief's rule? (*Tick any **TWO** boxes that apply to you*).

☐ By guess work.

☐ Observing the pattern of cards accepted by the dealer from others.

☐ Observing the pattern of cards accepted by dealer from me.

☐ Observing the pattern of cards rejected.

☐ Anything else (*Write it down here*) ______________________________

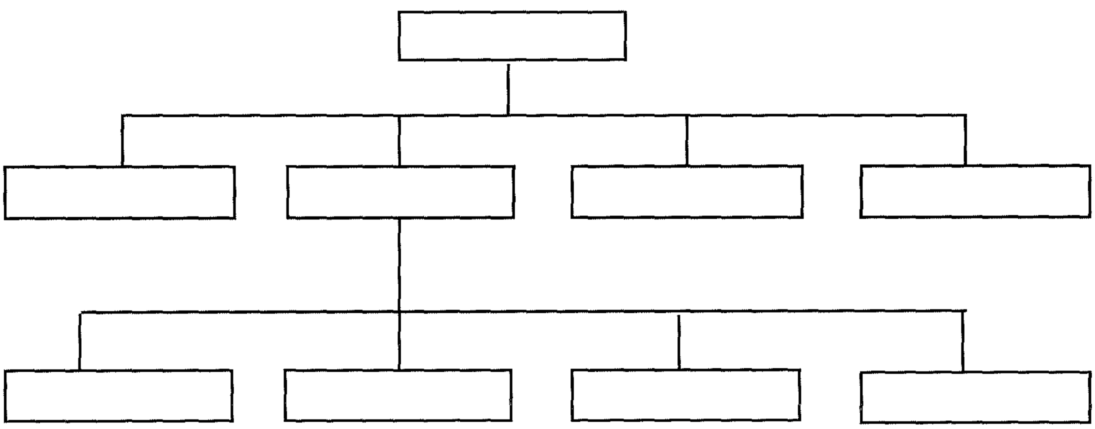
Section 3

This section asks you to apply the thinking skills you used to work out the chief's rule to solve the problem below.

The table below gives information about a family, from grandparents to grandchildren. It is the year 2000.

Grandmother **Still alive in the year 2000**	**Aunt** **10 years older than uncle 2**	**Uncle 1** **4 years younger than aunt**
Mother **In 1960, she was the same age as grandmother in 1927 and 4 years younger than uncle 1**	**Uncle 2** **2 years younger than mother**	**Potso** **In 1990, her age was one-fifth of the age of her aunt.**
Bodo **In 1985, his age was half the age of Potso**	**Pako** **2 years younger than Bodo**	**Vanessa** **2 years younger than Pako**

3.1 From the information given in the table, complete the family tree diagram below, starting with grandmother.



3.2 What other piece of information would you need about Vanessa to work out the **age of her grandmother** in the **year 2000**? ______________________________

Thank you for your time and co-operation.

Appendix H

Experiment Two (Control Group) Questionnaire/Test

Experiment Two Control Questionnaire/Test

Please complete this questionnaire about your studies in science as honestly as possible. Your identity will remain confidential. Do not write your name on this form. Use the number you were given at the beginning of the exercise to identify yourself.

Pupil Identity Number ________ Name of School:______________________________

(1) How old are you? *(Write your age in the box)* ☐

(2) Are you a: boy ☐ or girl ☐ *(Tick one box).*

(3) In what form are you? *(Tick in the correct box)* Form 1 ☐ Form 2 ☐ Form 3 ☐

We would like to know your opinions about how you think you can learn science better.

Here is an example of how to answer the following questions:

If you had to describe "a racing car" you could do it like this:

Quick	✓						Slow
Important			✓				Unimportant
Safe					✓		Dangerous

The positions of the ticks between the word pairs shows that you considered it s very quick, slightly more important than important and quite dangerous.

Use this method of ticking to answer the questions (4) and (5).

(4) **I can learn science better**

on my own	☐	☐	☐	☐	☐	☐	in a group
through solving difficult activities	☐	☐	☐	☐	☐	☐	through solving easy activities
through reading science books	☐	☐	☐	☐	☐	☐	without reading science books
through science experiments	☐	☐	☐	☐	☐	☐	without doing experiments
by relating it to events of daily life	☐	☐	☐	☐	☐	☐	not relating to events of daily life

(5) **What are your general opinions about science activities you do during your science lessons?**

Boring	☐	☐	☐	☐	☐	☐	Interesting
Easy to work out solutions to	☐	☐	☐	☐	☐	☐	Difficult to work out solutions to
Relate science to daily life events	☐	☐	☐	☐	☐	☐	Not relate it to daily life events
Make me like science even more	☐	☐	☐	☐	☐	☐	Make me hate science even more
Improve my thinking skills	☐	☐	☐	☐	☐	☐	Not improve my thinking skills
I enjoy doing most of them	☐	☐	☐	☐	☐	☐	I hate doing most of them

(6) **What are your feelings about working as a group?**
(Tick the boxes to show your opinions)

	Strongly agree	Agree	Disagree	Strongly disagree
I find the discussions boring	☐	☐	☐	☐
I enjoy working with members of my group	☐	☐	☐	☐
Most of the ideas from other members of the group are NOT helpful	☐	☐	☐	☐
Most of the ideas come from one person	☐	☐	☐	☐
Working as a group make it easier for us to understand activities	☐	☐	☐	☐
I do NOT respect ideas from others since they are always wrong.	☐	☐	☐	☐

We would like you to apply the skills you gained from science lessons to work out questions 7, 8, 9 and 10.

(7) A local cattle farmer has 500 cattle. The cattle are grazed outside everyday for 9 hours and then spend 15 hours inside the kraal. The cattle farmer has been asked by a local vegetable farmer to supply 0.5 tonnes (500 kg) of kraal manure every week for a year. The vegetable farmer has agreed to collect the manure using her truck.

(a) Before agreeing to supply kraal manure, LIST UP TO FOUR things that the cattle farmer should know.

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

(b) Which **ONE** of the things you listed is MOST IMPORTANT in determining whether the cattle farmer will be able to supply enough manure? _____ *(Write the number).*

(8) Tebogo has been studying global warming and wonders how scientists know what is actually the truth about global warming. Her friends suggest several ways to find the answers. These are listed in the shaded box.

A	Read Scientific books
B	Talk to experts like University professors
C	Carry out experiments to test the idea of global warming
D	Collect as much information as possible about global warming
E	Assume global warming is true and act accordingly
F	Use intelligent guesswork
G	Look at information which has already been gathered through research
H	Accept what majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below. The letter which comes first is the most important and the letter which comes last is the least important for you.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Most important — Least important

(9) Here are some statements which are known to be true by experiment:

(i) The substance sodium fluoride contains the elements sodium and fluorine only
(ii) A solution of sodium fluoride in pure water conducts electricity well
(iii) The products obtained when electricity is passed through the sodium fluoride solution in water are hydrogen and oxygen

(a) Look at these statements, which of the following is true? *(Tick the box next to the true statement)*

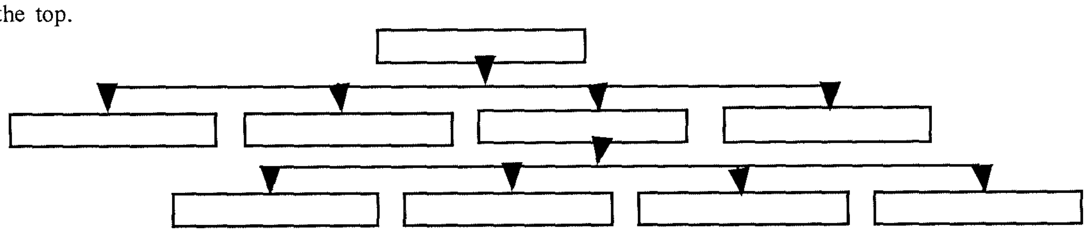
(1) Sodium fluoride contains hydrogen and oxygen ☐
(2) Water contains hydrogen and oxygen only ☐
(3) Hydrogen and oxygen are everywhere ☐
(4) Water contains hydrogen and oxygen ☐

(b) In ONE sentence, describe the experiment which should be carried out to be sure that your answer is correct.____

(10) The table below gives information about a family, from grandmother to grandchildren. It is the year 2 000.

Grandmother Still alive in the year 2 000	**Aunt** 10 years younger than uncle 2	**Uncle 1** 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than Uncle 1.	**Uncle 2** 2 years younger than mother.	**Potso** In 1990, her age was one-fifth the age of her Aunt
Bodo In 1985, his age was half the age of Potso	**Pako** 2 years younger than Bodo	**Vanessa** 2 years younger than Pako

(a) Use the information given in the table to complete the family tree diagram below, with grandmother at the top.



(b) What other piece of information would you need about Vanessa to work out the age of her grandmother in the year 2 000? ____________________________

Thank you for your time and co-operation.

Appendix I

Experiment Two (Experimental Group) Questionnaire/Test

Experiment Two Questionnaire/Test

Please complete this questionnaire about your studies in science as honestly as possible. Do not write your name.

Name of School:______________________________

(1) How old are you? *(Write your age in the box)* ☐

(2) *(Tick one box).* boy ☐ or girl ☐

(3) In what form are you? *(Tick in the correct box)* Form 1 ☐ Form 2 ☐ Form 3 ☐

We would like to know your opinions about how you think you can learn science better.
Here is an example of how to answer the following questions:

If you had to describe "a racing car" you could do it like this:

Quick	✓						Slow
Important			✓				Unimportant
Safe					✓		Dangerous

The positions of the ticks between the word pairs shows that you considered it s very quick, slightly more important than important and quite dangerous.

[Use this method of ticking to answer the items (4) and (5)]

(4) **I can learn science better**

on my own	☐	☐	☐	☐	☐	☐	in a group
through solving difficult activities	☐	☐	☐	☐	☐	☐	through solving easy activities
through reading science books	☐	☐	☐	☐	☐	☐	without reading science books
through science experiments	☐	☐	☐	☐	☐	☐	without doing science experiments
by relating it to events of daily life	☐	☐	☐	☐	☐	☐	by not relating it to events of daily life

(5) **What are your general opinions about the Units you did?**

Boring	☐	☐	☐	☐	☐	☐	Interesting
Easy to work out solutions to	☐	☐	☐	☐	☐	☐	Difficult to work out solutions to
Related science to events of daily life	☐	☐	☐	☐	☐	☐	Did not relate science to events of daily life
Made me like science even more	☐	☐	☐	☐	☐	☐	Made me hate science even more
Improved my thinking skills	☐	☐	☐	☐	☐	☐	Did not improve my thinking skills
I enjoyed doing most of them	☐	☐	☐	☐	☐	☐	I hated doing most of them

(6) **What are your feelings about working as a group?**
(Tick the boxes to show your opinions)

	strongly agree	agree	disagree	strongly disagree
I found the discussions boring	☐	☐	☐	☐
I enjoyed working with members of my group	☐	☐	☐	☐
Most of the ideas from other members of the group were NOT helpful	☐	☐	☐	☐
Most of the ideas came from one person	☐	☐	☐	☐
Working as a group made it easier for us to get answers to the Units	☐	☐	☐	☐
I did NOT respect ideas from others since they are always wrong.	☐	☐	☐	☐

We would like you to apply skills you used with the Units to find answers to qns 7, 8, 9 and 10.

(7) A local cattle farmer has 500 cattle. The cattle are grazed outside everyday for 9 hours and then spend 15 hours inside the kraal. The cattle farmer has been asked by a local vegetable farmer to supply 500 kg of kraal manure every week for a year. The vegetable farmer has agreed to collect the manure using her truck.

Before agreeing to supply kraal manure, LIST UP TO FOUR things that the cattle farmer should know.

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

Which **ONE** of the things you listed is MOST IMPORTANT in determining whether the cattle farmer will be able to supply enough manure? _____ *(Write the number)*.

(8) Tebogo has been studying global warming and wonders how scientists know what is actually the truth about global warming. Her friends suggest several ways to find the answers. These are listed in the shaded box.

A Read Scientific books
B Talk to experts like University professors
C Carry out experiments to test the idea of global warming
D Collect as much information as possible about global warming
E Assume global warming is true and act accordingly
F Use intelligent guesswork
G Look at information which has already been gathered through research
H Accept what majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below. The letter which comes first is the most important and the letter which comes last is the least important for you.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Most important Least important

(9) Here are some statements which are known to be true by experiment:

(a) The substance sodium fluoride contains the elements sodium and fluorine only
(b) A solution of sodium fluoride in pure water conducts electricity well
(c) The products obtained when electricity is passed through the sodium fluoride solution in water are hydrogen and oxygen

Look at these statements, which of the following is true? *(Tick the box next to the true statement)*

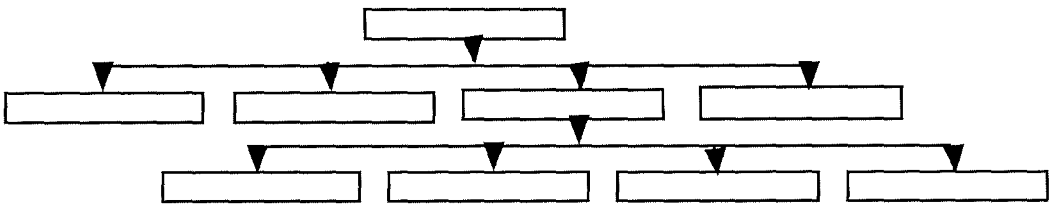
(1) Sodium fluoride contains hydrogen and oxygen ☐
(2) Water contains hydrogen and oxygen only ☐
(3) Hydrogen and oxygen are everywhere ☐
(4) Water contains hydrogen and oxygen ☐

In ONE sentence, describe the experiment which should be carried out to be sure that your answer is correct. ______________________________

(10) The table below gives information about a family, from grandmother to grandchildren. It is the year 2 000.

Grandmother Still alive in the year 2 000	**Aunt** 10 years younger than uncle 2	**Uncle 1** 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than Uncle 1.	**Uncle 2** 2 years younger than mother.	**Potso** In 1990, her age was one-fifth the age of her Aunt
Bodo In 1985, his age was half the age of Potso	**Pako** 2 years younger than Bodo	**Vanessa** 2 years younger than Pako

(a) Use the information given in the table to complete the family tree diagram below, with grandmother at the top.



(b) What other piece of information would you need about Vanessa to work out the age of her grandmother in the year 2 000? ______________________________

Appendix J

Experiment Three Questionnaire/Test

Experiment Three Questionnaire/Test

Please complete this questionnaire about your studies in science as honestly as possible.

Your Name: ________________________ Name of School: ________________________

(1) How old are you? *(Write your age in years)* ☐

(2) *(Tick one box).* boy ☐ or girl ☐

(3) In what year are you? *(Tick in the correct box)* *First* year ☐ Second year ☐ Third year ☐

We would like to know your opinions about how you think you can learn science better.

Here is an example of how to answer the following questions:

If you had to describe "a racing car" you could do it like this:

Quick	✓						Slow
Important			✓				Unimportant
Safe					✓		Dangerous

The positions of the ticks between the word pairs shows that you considered it s very quick, slightly more important than important and quite dangerous.

[Use this method of ticking to answer the item (4)]

(4) **I can learn science better**

on my own	☐ ☐ ☐ ☐ ☐ ☐	in a group
through solving difficult activities	☐ ☐ ☐ ☐ ☐ ☐	through solving easy activities
through reading science books	☐ ☐ ☐ ☐ ☐ ☐	without reading science books
through science experiments	☐ ☐ ☐ ☐ ☐ ☐	without doing science experiments
by relating it to events of daily life	☐ ☐ ☐ ☐ ☐ ☐	by not relating it to events of daily life

We would like you to apply the thinking skills you used with the Units to find answers to qns 7, 8, 9 and 10.

(5) A local cattle farmer has 500 cattle. The cattle are grazed outside everyday for 9 hours and then spend 15 hours inside the barns. The cattle farmer has been asked by a local vegetable farmer to supply 0.5 tones (500 kg) of manure from the barns every week for a year. The vegetable farmer has agreed to collect the manure using her truck.

(a) Before agreeing to supply manure, LIST UP TO FOUR things that the cattle farmer should know.

1. ________________________ 2. ________________________

3. ________________________ 4. ________________________

(b) Which **ONE** of the things you listed is MOST IMPORTANT in determining whether the cattle farmer will be able to supply enough manure? _____ *(Write the number).*

(6) Fiona has been studying global warming and wonders how scientists know what is actually the truth about global warming. Her friends suggest several ways to find the answers. These are listed in the shaded box.

A	Read Scientific books
B	Talk to experts like University professors
C	Carry out experiments to test the idea of global warming
D	Collect as much information as possible about global warming
E	Assume global warming is true and act accordingly
F	Use intelligent guesswork
G	Look at information which has already been gathered through research
H	Accept what majority of people believe is true about global warming

Arrange these suggested answers in order of their importance by placing the letters A, B, C...etc. in the boxes below. The letter which comes first is the most important and the letter which comes last is the least important for you.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Most important Least important

(7) Here are some statements which are known to be true by experiment:

(a) The substance sodium fluoride contains the elements sodium and fluorine only

(b) A solution of sodium fluoride in pure water conducts electricity well

(c) The products obtained when electricity is passed through the sodium fluoride solution in water are hydrogen and oxygen

(a) Look at these statements, which of the following is true? *(Tick the box next to the true statement)*

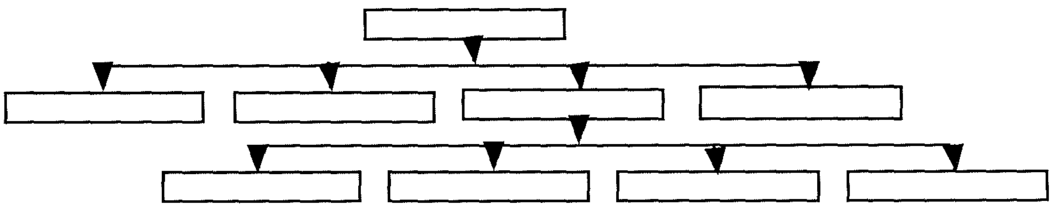
(1) Sodium fluoride contains hydrogen and oxygen ☐
(2) Water contains hydrogen and oxygen only ☐
(3) Hydrogen and oxygen are everywhere ☐
(4) Water contains hydrogen and oxygen ☐

(b) In ONE sentence, describe the experiment which should be carried out to be sure that your answer is correct. ____________________

(8) The table below gives information about a family, from grandmother to grandchildren. It is the year 2 000.

Grandmother Still alive in the year 2 000	**Aunt** 10 years younger than uncle 2	**Uncle 1** 4 years younger than aunt
Mother In 1960, she was the same age as grandmother in 1927 and 4 years younger than Uncle 1.	**Uncle 2** 2 years younger than mother.	**Potso** In 1990, her age was one-fifth the age of her Aunt
Bodo In 1985, his age was half the age of Potso	**Pako** 2 years younger than Bodo	**Vanessa** 2 years younger than Pako

(a) Use the information given in the table to complete the family tree diagram below, with grandmother at the top.



(b) What other piece of information would you need about Vanessa to work out the age of her grandmother in the year 2 000? ____________________

Thank you for you time and co-operation.

Appendix K

Chi-square Test (χ^2)

Chi-square Test (χ^2)

Chi-square test is said to to be one of the most widely used tests for statistical data generated by non-parametric analysis. There are two different of applications of chi-square test. These are used in this study.

(1) Goodness of Fit Test

This tests how well the experimental (sampling) distribution fits the control (hypothesised) distribution. An example of this could be a comparison between a group of experimentally observed responses to a group of control responses. For example,

	Positive	**Neutral**	**Negative**	
Experimental	55	95	23	N(experimental) = 173
Control	34	100	43	N(control) = 177
				(using raw numbers)

A calculation of observed and expected frequencies lead to

	Positive	**Neutral**	**Negative**
fo = observed frequency	55	95	23
fe = expected frequency	33.2	97.7	42

Where *fe* = [N(experimental)/N(control)] X (control data) or (173/177) X (control data)

$$\chi^2 = \sum \frac{(fo - fe)^2}{fe}$$

$$\chi^2 = \frac{(55 - 33.2)^2}{33.2} + \frac{(95 - 97.7)^2}{97.7} + \frac{(23 - 42)^2}{42}$$

$$\chi^2 = \mathbf{22.98}$$

The degree of freedom (df) for this comparison is 2. This comparison is significant at two degrees of freedom at greater than 1%. (χ^2 critical at 1% level = 9.21)

(2) Contingency Test

This chi-square test is commonly used in analysing data where two groups or variables are compared. Each of the variable may have two or more categories which are independent from each other. The data for this comparison is generated from the frequencies in the categories. In this study, the chi-square as a contingency test was used, for example, to compare two or more independent samples like, year groups, gender, or ages. The data is generated from one population group. For example,

	Positive	Neutral	Negative	
Male (experimental)	55	95	23	
Female (experimental)	34	100	43	
		(Actual data above)		
	Positive	**Neutral**	**Negative**	**N**
Male (experimental)	55 (44)	95 (96)	23 (33)	**173**
Female (experimental)	34 (45)	100 (97)	43 (33)	**177**
Totals	**89**	**195**	**66**	**350**
		(Expected frequencies above)		

The expected frequencies are shown in brackets ( ), and are calculated as follows: e.g. 44 = (173/350) x 89

$$\chi^2 = \frac{(55-44)^2}{44} + \frac{(95-96)^2}{96} + \frac{(23-33)^2}{33} + \frac{(34-45)^2}{45} + \frac{(100-97)^2}{97} + \frac{(43-33)^2}{33}$$

$$\chi^2 = 2.75 + 0.01 + 3.03 + 2.69 + 0.09 + 3.03$$
$$= \mathbf{11.60}$$

At two degrees of freedom, this is significant at 1%. (χ^2 critical at 1% level = 9.21)
The degree of freedom (df) must be stated for any calculated chi-square value. The value of the degree of freedom for any analysis is obtained from the following calculations:

df = (r-1) x (c-1)

where **r** is the number of rows and **c** is the number of columns in the contingency table.

Limitations on the Use of χ^2

It is know that when values within a category are small (i.e. 5, as proposed by some writers (Wiersma, 1995)), there is a chance that the calculation of χ^2 may occasionally produce inflated results which may lead to wrong interpretations. In this study, in order to avoid dubious conclusions, a 10% category limit was imposed.

Appendix L

Experiment One Confidence Results (Raw) and Coding

Coding for Responses to Confidence Level Checklist (Experiment One)

The following codes were used to score the responses to the confidence level checklist after each round of playing Eloosis:

1. The categories A, C, E, G, I and K in each round represent the question 'Have you worked out the pattern?'
   - 0 - for no response or ticking NO.
   - 1 - for ticking YES.

2. The categories B, D, F, H, J and L in each round represent answer to the question 'How confident are you?'
   - 0 - No response
   - 1 - I have no idea, so I just made a guess
   - 2 - I cannot be sure, but I think have it
   - 3 - I am almost sure, but I would like some information
   - 4 - I really believe i have it
   - 5 - I know it and I can prove it

PROGRESS ASSESSMENT RESULTS FOR FOR YEAR 1 (GAME 1)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
I	1	1	2	1	2	1	4	1	4	1	4	1	4
I	1	1	3	1	3	1	4	1	4	1	4	1	4
I	1	1	3	1	3	1	4	1	4	1	4	1	4
I	1	1	2	1	2	1	2	1	2	1	2	1	2
I	1	1	1	1	2	1	2	1	2	1	2	1	2
I	1	1	2	1	2	1	4	1	4	1	4	1	4
I	2	0	0	1	2	1	2	1	2	1	2	1	2
I	2	1	2	1	1	1	1	1	1	1	1	1	1
I	2	1	1	1	2	1	2	1	2	1	2	1	2
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	2	0	0	1	2	1	2	1	2	1	2	1	2
I	3	0	0	0	0	0	0	0	0	0	0	0	0
I	3	0	0	1	1	0	0	1	2	1	2	1	2
I	3	0	0	0	0	1	1	0	0	0	0	0	0
I	3	0	0	0	0	0	0	1	4	1	4	1	4
I	3	0	0	1	1	0	0	1	3	1	3	1	3
I	3	0	0	0	0	1	1	1	3	1	3	1	3
I	4	0	0	1	1	1	1	1	1	1	2	0	0
I	4	0	0	0	0	1	2	1	3	1	4	1	5
I	4	0	0	1	1	1	1	1	1	0	0	0	0
I	4	0	0	1	2	1	4	1	4	1	4	1	4
I	4	0	0	1	1	0	0	0	0	0	0	0	0
I	4	0	0	1	1	1	4	1	4	1	4	1	4
I	5	0	0	1	1	1	1	1	1	1	1	1	1
I	5	1	1	1	1	0	0	0	0	0	0	0	0
I	5	0	0	1	1	1	1	0	0	0	0	0	0
I	5	1	1	1	1	1	1	0	0	0	0	0	0
I	5	0	0	0	0	1	1	1	1	1	1	1	1
I	5	0	0	0	0	1	1	0	0	0	0	0	0
I	5	1	1	1	2	1	4	1	4	1	4	1	4
II	1	0	0	1	1	1	1	1	1	1	1	1	1
II	1	0	0	1	1	1	1	1	1	1	1	1	1
II	1	0	0	1	1	1	1	1	1	1	1	1	1
II	1	0	0	1	1	1	1	1	1	1	1	1	1
II	1	0	0	1	5	1	5	1	5	1	5	1	5
II	1	0	0	1	3	1	3	1	3	1	3	1	3
II	2	1	3	1	3	1	3	1	3	1	3	1	3
II	2	1	3	1	3	1	3	1	3	1	3	1	3
II	2	0	0	0	0	0	0	0	0	0	0	0	0
II	2	0	0	0	0	0	0	0	0	0	0	0	0
II	2	1	3	1	3	1	3	1	3	1	3	1	3
II	3	1	1	1	3	1	3	1	3	1	3	1	3
II	3	0	0	1	1	1	2	1	2	1	2	1	2
II	3	1	2	1	3	1	3	1	3	1	3	1	3
II	3	1	2	1	5	1	5	1	5	1	5	1	5
II	4	0	0	1	2	1	5	1	5	1	5	1	5
II	4	0	0	1	5	0	0	1	1	1	1	1	1
II	4	1	5	1	3	0	0	0	0	0	0	0	0
II	4	1	4	0	0	1	3	0	0	0	0	0	0
II	5	1	2	1	3	1	3	1	3	1	3	1	3
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	5	1	3	1	3	1	3	1	3	1	3	1	3
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	6	0	0	1	4	1	4	1	4	1	4	1	4
II	6	0	0	0	0	0	0	0	0	0	0	0	0
II	6	0	0	0	0	0	0	0	0	0	0	0	0
II	6	0	0	0	0	0	0	0	0	0	0	0	0

PROGRESS ASSESSMENT RESULTS FOR FOR YEAR 1 (GAME 1)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
II	6	0	0	1	1	1	1	1	1	1	1	1	1
II	6	0	0	0	0	1	1	1	1	1	1	1	1
IV	1	1	5	1	3	1	5	1	5	1	5	1	5
IV	1	1	4	1	3	1	3	1	3	1	3	1	3
IV	1	1	4	1	1	1	4	1	4	1	4	1	4
IV	1	1	3	1	3	1	3	1	3	1	3	1	3
IV	1	1	3	1	3	1	5	1	5	1	5	1	5
IV	2	1	1	1	1	1	1	1	1	1	1	1	1
IV	2	1	1	1	1	1	1	1	1	1	1	1	1
IV	2	1	2	1	4	1	4	1	4	1	4	1	4
IV	2	1	1	1	1	1	1	1	1	1	1	1	1
IV	2	1	1	1	1	1	1	1	1	1	1	1	1
IV	3	1	3	1	2	1	1	1	1	1	1	1	1
IV	3	1	1	1	2	1	1	1	1	1	1	1	1
IV	3	1	1	1	2	1	2	1	2	1	2	1	2
IV	3	1	1	1	1	1	2	1	2	1	2	1	2
IV	3	0	0	1	1	1	1	1	1	1	1	1	1
IV	4	1	2	1	2	1	4	1	4	1	4	1	4
IV	4	1	2	1	2	1	5	1	5	1	5	1	5
IV	4	1	2	1	3	1	5	1	5	1	5	1	5
IV	4	1	2	1	3	1	4	1	4	1	4	1	4
IV	4	1	3	1	2	1	4	1	4	1	4	1	4
IV	5	1	1	1	4	1	4	1	4	1	4	1	4
IV	5	1	3	1	3	1	3	1	3	1	3	1	3
IV	5	1	3	0	0	0	0	0	0	0	0	0	0
IV	5	0	0	1	3	1	3	1	3	1	3	1	3
IV	5	0	0	1	5	1	5	1	5	1	5	1	5
IV	6	1	1	1	5	1	5	1	5	1	5	1	5
IV	6	0	0	1	3	1	3	1	3	1	3	1	3
IV	6	0	0	1	5	1	5	1	5	1	5	1	5
IV	6	1	5	1	5	1	5	1	5	1	5	1	5
IV	6	1	3	1	4	1	4	1	5	1	5	1	5
IV	6	1	5	1	5	1	5	1	5	1	5	1	5
V	1	0	0	0	0	0	0	0	0	0	0	0	0
V	1	0	0	0	0	0	0	0	0	0	0	0	0
V	1	1	1	1	2	1	1	0	0	1	0	0	0
V	1	0	0	0	0	0	0	0	0	0	0	0	0
V	1	1	2	1	3	1	0	1	1	0	0	0	0
V	1	0	0	1	2	0	0	0	0	0	0	0	0
V	2	1	0	0	0	1	1	1	1	1	1	1	1
V	2	1	5	0	0	1	1	1	1	1	1	1	1
V	2	1	5	0	0	0	0	0	0	0	0	0	0
V	2	1	3	1	4	0	0	0	0	0	0	0	0
V	2	1	3	1	2	1	2	1	2	1	2	1	2
V	3	0	0	0	0	1	4	1	4	1	4	1	4
V	3	0	0	0	0	0	0	0	0	0	0	0	0
V	3	0	0	0	0	1	4	1	4	1	4	1	4
V	3	0	0	0	0	1	1	1	1	1	1	1	1
V	3	0	0	0	0	0	0	0	0	0	0	0	0
V	3	0	0	0	0	1	4	1	4	1	4	1	4
V	4	0	0	1	2	0	0	0	0	0	0	0	0
V	4	0	0	0	0	1	2	1	2	1	2	1	2
V	4	0	0	0	0	0	0	0	0	0	0	0	0
V	4	0	0	1	2	0	0	0	0	0	0	0	0
V	4	0	0	0	0	0	0	0	0	0	0	0	0
V	4	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	1	3	1	4	1	4	1	4
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	0	0

PROGRESS ASSESSMENT RESULTS FOR FOR YEAR 1 (GAME 1)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	6	1	2	0	0	0	0	0	0	0	0	0	0
V	6	1	5	0	0	0	0	0	0	0	0	0	0
V	6	1	2	0	0	0	0	0	0	0	0	0	0
V	6	1	5	0	0	1	5	1	5	1	5	1	5
V	6	1	5	1	5	1	5	0	0	0	0	0	0
V	6	1	5	1	5	1	5	1	5	1	5	1	5
Totals --		61	157	86	215	92	257	89	260	88	260	86	259

PROGRESS ASSESSMENT RESULTS - YEAR 1 (GAME 2)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
I	1	1	5	1	2	1	1	1	1	1	1	1	1
I	1	1	1	1	1	1	2	1	2	1	3	1	3
I	1	0	0	1	2	0	0	1	2	1	2	1	2
I	1	1	1	1	1	0	0	1	2	1	1	1	1
I	1	1	4	0	0	0	0	0	0	1	1	1	1
I	1	0	0	0	0	0	0	1	2	1	3	1	3
I	2	0	0	0	0	0	0	0	0	0	0	0	0
I	2	0	0	1	1	0	0	1	1	1	1	1	1
I	2	0	0	0	0	0	0	0	0	0	0	1	3
I	2	1	1	0	0	0	0	0	0	0	0	0	0
I	2	0	0	0	0	0	0	0	0	0	0	0	0
I	2	0	0	0	0	0	0	0	0	0	0	0	0
I	3	0	0	0	0	0	0	0	0	0	0	0	0
I	3	0	0	1	1	1	1	0	0	0	0	1	1
I	3	0	0	1	1	1	1	0	0	0	0	1	3
I	3	0	0	0	0	0	0	0	0	0	0	0	0
I	3	0	0	0	0	1	1	0	0	0	0	0	0
I	3	0	0	1	1	1	1	0	0	0	0	0	0
I	4	0	0	0	0	0	0	0	0	0	0	0	0
I	4	0	0	0	0	0	0	1	2	1	2	1	2
I	4	0	0	0	0	0	0	1	1	1	1	1	1
I	4	0	0	0	0	0	0	0	0	1	1	1	2
I	4	0	0	1	1	1	3	1	4	1	4	1	4
I	5	0	0	0	0	0	0	1	1	1	5	1	3
I	5	0	0	0	0	0	0	0	0	0	0	1	2
I	5	0	0	0	0	0	0	1	1	0	0	0	0
I	5	0	0	1	1	0	0	0	0	0	0	1	1
I	5	0	0	0	0	0	0	0	0	1	5	1	4
I	5	0	0	0	0	0	0	1	1	0	0	0	0
I	5	1	1	0	0	0	0	0	0	0	0	0	0
II	1	0	0	1	5	1	5	1	5	1	5	1	5
II	1	1	3	1	5	1	5	1	5	1	5	1	5
II	1	1	5	1	5	1	5	1	5	1	5	1	5
II	1	0	0	1	3	1	3	1	3	1	3	1	3
II	1	1	3	1	3	1	3	1	3	1	3	1	3
II	1	0	0	0	0	0	0	0	0	0	0	0	0
II	2	0	0	1	5	1	5	1	5	1	5	1	5
II	2	0	0	1	1	1	1	1	1	1	1	1	1
II	2	0	0	1	5	1	5	1	5	1	5	1	5
II	2	0	0	1	4	1	4	1	4	1	4	1	4
II	2	0	0	1	4	1	4	1	4	1	4	1	4
II	3	1	2	1	4	1	4	1	4	1	4	1	4
II	3	1	3	1	3	1	2	1	2	1	2	1	2
II	3	1	4	1	1	1	4	1	4	1	4	1	4
II	3	1	5	0	0	1	2	1	2	1	2	1	2
II	4	1	3	1	3	1	3	1	3	1	3	1	3
II	4	1	3	1	3	1	3	1	3	1	3	1	3
II	4	1	4	1	4	1	4	1	4	1	4	1	4
II	4	1	2	1	2	1	2	1	2	1	2	1	2
II	5	0	0	1	1	1	1	1	1	1	1	1	1
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	5	0	0	1	4	1	4	1	4	1	4	1	4
II	5	0	0	1	3	1	3	1	3	1	3	1	3
II	6	1	1	1	3	1	3	1	3	1	3	1	3
II	6	1	1	1	1	1	1	1	1	1	1	1	1
II	6	0	0	0	0	0	0	0	0	0	0	0	0

PROGRESS ASSESSMENT RESULTS - YEAR 1 (GAME 2)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
II	6	0	0	0	0	0	0	0	0	0	0	0	0
II	6	0	0	0	0	0	0	0	0	0	0	0	0
II	6	0	0	0	0	0	0	0	0	0	0	0	0
IV	1	1	4	0	0	0	0	0	0	0	0	0	0
IV	1	1	5	0	0	0	0	0	0	0	0	0	0
IV	1	0	0	1	5	0	0	0	0	0	0	0	0
IV	1	0	0	1	2	1	4	1	4	1	4	1	4
IV	1	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	0	0	1	2	0	0	0	0	0	0	0	0
IV	2	0	0	1	1	1	1	0	0	0	0	1	1
IV	2	0	0	0	0	0	0	0	0	0	0	0	0
IV	3	0	0	1	1	1	3	1	1	1	1	1	1
IV	3	1	1	1	1	1	1	1	1	1	1	1	2
IV	3	1	1	1	1	1	2	1	1	1	2	1	1
IV	3	1	2	1	4	1	2	1	4	1	4	1	2
IV	3	1	4	1	4	1	3	1	3	1	1	1	3
IV	4	0	0	1	3	1	2	1	2	1	2	1	2
IV	4	1	1	1	1	0	0	0	0	0	0	0	0
IV	4	0	0	1	3	1	1	1	1	1	1	1	1
IV	4	0	0	1	3	1	1	1	1	1	1	1	1
IV	4	1	1	1	3	1	1	1	1	1	1	1	1
IV	5	0	0	0	0	0	0	0	0	0	0	1	5
IV	5	1	2	0	0	0	0	1	1	1	3	1	3
IV	5	1	4	0	0	0	0	0	0	0	0	0	0
IV	5	1	4	0	0	0	0	0	0	0	0	0	0
IV	5	1	1	1	1	0	0	1	1	0	0	0	0
IV	6	0	0	1	1	0	0	1	2	1	2	1	2
IV	6	0	0	0	0	0	0	1	1	1	2	1	2
IV	6	0	0	1	1	1	1	0	0	0	0	0	0
IV	6	0	0	0	0	1	1	1	1	1	2	1	2
IV	6	0	0	0	0	0	0	1	1	1	2	1	2
IV	6	0	0	0	0	0	0	1	2	1	5	1	5
V	1	1	1	1	2	0	0	0	0	1	2	0	0
V	1	1	1	1	1	1	1	1	3	0	0	0	0
V	1	1	5	1	2	0	0	0	0	0	0	0	0
V	1	1	1	0	0	0	0	1	1	1	1	1	1
V	1	1	1	1	1	1	1	1	1	0	0	1	1
V	1	1	1	0	0	0	0	0	0	0	0	0	0
V	2	1	1	1	2	1	5	1	5	1	5	1	5
V	2	0	0	1	5	1	5	1	5	1	5	1	5
V	2	0	0	1	4	1	4	1	4	1	4	1	4
V	2	0	0	1	4	1	4	1	4	1	4	1	4
V	2	0	0	1	5	1	5	1	5	1	5	1	5
V	3	0	0	1	4	1	4	1	4	1	4	1	4
V	3	0	0	1	4	1	4	1	4	1	4	1	4
V	3	0	0	1	3	1	3	1	3	1	3	1	3
V	3	0	0	1	4	1	4	1	4	1	4	1	4
V	3	0	0	1	3	1	3	1	3	1	3	1	3
V	3	0	0	1	4	1	4	1	4	1	4	1	4
V	4	0	0	1	3	1	3	1	3	1	3	1	3
V	4	0	0	1	2	1	2	1	2	1	2	1	2
V	4	0	0	0	0	0	0	0	0	0	0	0	0
V	4	0	0	1	1	1	1	1	1	1	1	1	1
V	4	0	0	0	0	0	0	0	0	0	0	0	0
V	4	0	0	1	3	1	3	1	3	1	3	1	3

PROGRESS ASSESSMENT RESULTS - YEAR 1 (GAME 2)

		Rd 1		Rd 2		Rd 3		Rd 4		Rd 5		Rd 6	
School	Gp	A	B	C	D	E	F	G	H	I	J	K	L
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	0	0
V	5	0	0	0	0	0	0	0	0	0	0	1	4
V	6	0	0	1	1	1	3	0	0	0	0	1	4
V	6	0	0	1	5	1	5	0	0	0	0	1	5
V	6	0	0	1	4	1	1	0	0	0	0	1	2
V	6	0	0	1	4	1	4	0	0	0	0	0	0
V	6	0	0	1	4	1	4	1	4	0	0	1	4
V	6	0	0	1	5	1	5	1	5	0	0	0	0
Totals ----		38	93	76	207	68	193	74	198	71	203	83	235

PROGRESS ASSESSMENT RESULTS-YEAR 2(GAME 1)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	Group	A	B	C	D	E	F	G	H	I	J	K	L
I	1	1	3	1	3	1	3	1	3	1	3	1	3
I	1	1	3	1	3	1	3	1	3	1	3	1	3
I	1	1	3	1	4	1	4	1	4	1	4	1	4
I	1	1	3	1	4	1	5	1	5	1	5	1	5
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	2	1	4	1	4	1	4	1	4	1	4	1	4
I	3	1	1	1	4	1	4	1	4	1	4	1	4
I	3	1	4	1	4	1	4	1	4	1	4	1	4
I	3	1	4	1	4	1	4	1	4	1	4	1	4
I	3	1	1	1	4	1	4	1	4	1	4	1	4
I	3	1	4	1	4	1	4	1	4	1	4	1	4
I	4	0	0	1	1	1	1	1	1	1	1	1	1
I	4	0	0	1	1	1	4	1	4	1	4	1	4
I	4	0	0	1	1	1	1	1	1	1	1	1	1
I	4	0	0	0	0	0	0	0	0	0	0	0	0
I	4	0	0	1	1	1	1	1	1	1	1	1	1
I	5	0	0	1	1	1	4	1	4	1	4	1	4
I	5	0	0	1	1	1	4	1	4	1	4	1	4
I	5	0	0	1	2	1	2	1	2	1	2	1	2
I	5	0	0	1	3	1	3	1	3	1	3	1	3
II	1	0	0	1	2	1	2	1	2	1	2	1	2
II	1	1	1	0	0	0	0	0	0	0	0	0	0
II	1	1	1	1	1	1	4	1	4	1	4	1	4
II	1	0	0	1	2	1	2	1	2	1	2	1	2
II	1	0	0	1	1	1	4	1	4	1	4	1	4
II	2	1	1	1	4	1	4	1	4	1	4	1	4
II	2	1	5	1	5	1	5	1	5	1	5	1	5
II	2	1	1	1	4	1	4	1	4	1	4	1	4
II	2	1	1	1	1	1	1	1	1	1	1	1	1
II	2	1	1	1	1	1	1	1	1	1	1	1	1
II	3	1	1	1	2	1	2	1	2	1	2	1	2
II	3	1	1	1	2	1	2	1	2	1	2	1	2
II	3	0	0	1	2	1	2	1	2	1	2	1	2
II	3	1	2	1	2	1	2	1	2	1	2	1	2
II	3	1	2	1	2	1	2	1	2	1	2	1	2
II	3	1	1	1	2	1	2	1	2	1	2	1	2
II	4	1	5	1	5	1	5	1	5	1	5	1	5
II	4	1	5	1	5	1	5	1	5	1	5	1	5
II	4	1	5	1	5	1	5	1	5	1	5	1	5
II	4	1	5	1	5	1	5	1	5	1	5	1	5
II	4	1	5	1	5	1	5	1	5	1	5	1	5
II	4	1	1	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
II	5	1	4	1	4	1	4	1	4	1	4	1	4
III	1	1	3	1	3	1	3	1	3	1	3	1	3
III	1	1	4	1	4	1	4	1	4	1	4	1	4
III	1	1	1	1	1	1	1	1	1	1	1	1	1
III	1	1	4	1	4	1	4	1	4	1	4	1	4
III	1	1	1	1	1	1	1	1	1	1	1	1	1
III	1	1	4	1	4	1	4	1	4	1	4	1	4
III	2	0	0	1	3	1	3	1	3	1	3	1	3
III	2	0	0	1	3	1	3	1	3	1	3	1	3
III	2	0	0	0	0	0	0	0	0	0	0	0	0
III	2	0	0	0	0	0	0	0	0	0	0	0	0

PROGRESS ASSESSMENT RESULTS-YEAR 2(GAME 1)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	Group	A	B	C	D	E	F	G	H	I	J	K	L
III	2	0	0	0	0	0	0	0	0	0	0	0	0
III	2	0	0	0	0	0	0	0	0	0	0	0	0
III	2	0	0	0	0	0	0	0	0	0	0	0	0
III	3	0	0	1	3	1	3	1	3	1	3	1	3
III	3	0	0	1	2	1	2	1	2	1	2	1	2
III	3	0	0	0	0	0	0	0	0	0	0	0	0
III	3	0	0	1	2	1	2	1	2	1	2	1	2
III	3	0	0	1	1	1	1	1	1	1	1	1	1
III	3	0	0	1	2	1	2	1	2	1	2	1	2
III	4	1	2	1	2	1	2	1	2	1	2	1	2
III	4	0	0	1	3	1	3	1	3	1	3	1	3
III	4	0	0	1	3	1	3	1	3	1	3	1	3
III	4	1	3	1	3	1	3	1	3	1	3	1	3
III	4	0	0	1	4	1	4	1	4	1	4	1	4
III	4	1	3	0	0	0	0	0	0	0	0	0	0
III	5	1	4	1	4	1	4	1	4	1	4	1	4
III	5	1	4	1	4	1	4	1	4	1	4	1	4
III	5	1	3	1	3	1	3	1	3	1	3	1	3
III	5	1	3	1	3	1	3	1	3	1	3	1	3
III	5	1	1	1	1	1	1	1	1	1	1	1	1
III	5	1	3	1	3	1	3	1	3	1	3	1	3
IV	1	1	4	1	4	1	4	1	4	1	4	1	4
IV	1	1	4	1	4	1	4	1	4	1	4	1	4
IV	1	1	1	1	1	1	1	1	1	1	1	1	1
IV	1	1	1	1	1	1	1	1	1	1	1	1	1
IV	1	1	1	1	1	1	1	1	1	1	1	1	1
IV	1	1	4	1	4	1	4	1	4	1	4	1	4
IV	2	1	1	1	1	1	1	1	1	1	1	1	1
IV	2	1	5	1	5	1	5	1	5	1	5	1	5
IV	2	1	5	1	5	1	5	1	5	1	5	1	5
IV	2	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	1	5	1	5	1	5	1	5	1	5	1	5
IV	2	0	0	0	0	0	0	0	0	0	0	0	0
IV	3	1	5	1	5	1	5	1	5	1	5	1	5
IV	3	1	5	1	5	1	5	1	5	1	5	1	5
IV	3	1	5	1	5	1	5	1	5	1	5	1	5
IV	3	1	3	1	3	1	3	1	3	1	3	1	3
IV	3	1	5	1	5	1	5	1	5	1	5	1	5
IV	3	1	3	1	3	1	3	1	3	1	3	1	3
IV	4	1	4	1	4	1	4	1	4	1	4	1	4
IV	4	1	4	1	4	1	4	1	4	1	4	1	4
IV	4	1	4	1	4	1	4	1	4	1	4	1	4
IV	4	1	4	1	4	1	4	1	4	1	4	1	4
IV	4	1	4	1	4	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	0	0	0	0	0	0	0	0
IV	5	1	3	1	3	1	3	1	3	1	3	1	3
IV	5	1	4	1	4	1	4	1	4	1	4	1	4
IV	5	1	4	1	4	1	4	1	4	1	4	1	4
IV	5	1	3	1	3	1	3	1	3	1	3	1	3
IV	5	1	4	1	4	1	4	1	4	1	4	1	4
IV	6	1	3	1	4	1	4	1	4	1	4	1	4
IV	6	0	0	1	5	1	5	1	5	1	5	1	5
IV	6	0	0	1	5	1	5	1	5	1	5	1	5
IV	6	1	5	1	5	1	5	1	5	1	5	1	5
IV	6	1	5	1	5	1	5	1	5	1	5	1	5
V	1	1	1	1	2	1	2	1	2	1	2	1	2
V	1	0	0	1	1	1	1	1	1	1	1	1	1
V	1	0	0	0	0	0	0	0	0	0	0	0	0
V	1	1	1	1	1	1	1	1	1	1	1	1	1
V	1	1	2	1	4	1	4	1	4	1	4	1	4
V	1	1	3	1	2	1	2	1	2	1	2	1	2

PROGRESS ASSESSMENT RESULTS-YEAR 2(GAME 1)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	Group	A	B	C	D	E	F	G	H	I	J	K	L
V	2	1	3	1	3	1	3	1	3	1	3	1	3
V	2	1	1	1	1	1	1	1	1	1	1	1	1
V	2	1	1	1	1	1	1	1	1	1	1	1	1
V	2	1	1	1	1	1	1	1	1	1	1	1	1
V	2	1	3	1	3	1	3	1	3	1	3	1	3
V	2	1	3	1	3	1	3	1	3	1	3	1	3
V	3	1	1	0	0	1	3	1	3	1	3	1	3
V	3	0	0	1	1	1	4	1	4	1	4	1	4
V	3	0	0	1	2	1	3	1	3	1	3	1	3
V	3	0	0	1	1	1	1	1	1	1	1	1	1
V	3	0	0	1	1	1	3	1	3	1	3	1	3
V	3	1	1	1	1	1	3	1	3	1	3	1	3
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	4	1	2	1	2	1	2	1	2	1	2	1	2
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	4	1	1	1	1	1	1	1	1	1	1	1	1
V	5	1	3	1	3	1	3	1	3	1	3	1	3
V	5	0	0	1	1	1	1	1	1	1	1	1	1
V	5	0	0	1	3	1	3	1	3	1	3	1	3
V	5	1	4	1	4	1	4	1	4	1	4	1	4
V	5	1	4	1	5	1	5	1	5	1	5	1	5
V	5	1	3	1	4	1	4	1	4	1	4	1	4
V	5	1	3	1	3	1	3	1	3	1	3	1	3
V	6	1	4	1	4	1	4	1	4	1	4	1	4
V	6	1	3	1	3	1	3	1	3	1	3	1	3
V	6	1	3	1	3	1	3	1	3	1	3	1	3
V	6	1	4	1	4	1	4	1	4	1	4	1	4
V	6	1	3	1	3	1	3	1	3	1	3	1	3
V	6	1	4	1	4	1	4	1	4	1	4	1	4
V	6	1	3	1	3	1	3	1	3	1	3	1	3
'otals ----		113	335	141	419	142	446	142	446	142	446	142	446

PROGRESS ASSESSMENT RESULTS FOR YEAR 1 (GAME 2)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	Group	A	B	C	D	E	F	G	H	I	J	K	L
I	1	1	2	1	5	1	4	1	4	1	4	1	4
I	1	1	3	1	3	1	3	1	3	1	3	1	3
I	1	1	3	1	3	1	3	1	3	1	3	1	3
I	1	1	3	1	4	1	4	1	4	1	4	1	4
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	2	0	0	1	3	1	3	1	3	1	3	1	3
I	3	0	0	0	0	1	4	1	4	1	4	1	4
I	3	0	0	0	0	1	4	1	4	1	4	1	4
I	3	0	0	0	0	1	4	1	4	1	4	1	4
I	3	0	0	0	0	1	4	1	4	1	4	1	4
I	3	0	0	0	0	1	4	1	4	1	4	1	4
I	4	1	1	1	3	1	3	1	3	1	3	1	3
I	4	1	3	1	3	1	3	1	3	1	3	1	3
I	4	1	3	1	3	1	3	1	3	1	3	1	3
I	4	1	2	1	3	1	3	1	3	1	3	1	3
I	4	1	3	1	3	1	3	1	3	1	3	1	3
I	5	0	0	1	4	1	1	1	1	1	1	1	1
I	5	0	0	1	1	1	2	1	2	1	2	1	2
I	5	0	0	1	4	1	1	1	1	1	1	1	1
I	5	0	0	1	4	1	1	1	1	1	1	1	1
II	1	0	0	0	0	1	3	1	3	1	3	1	3
II	1	0	0	0	0	1	2	1	2	1	2	1	2
II	1	0	0	0	0	1	3	1	3	1	3	1	3
II	1	0	0	0	0	1	4	1	4	1	4	1	4
II	1	0	0	0	0	1	3	1	3	1	3	1	3
II	2	0	0	1	3	1	4	1	4	0	0	1	4
II	2	0	0	1	1	1	1	1	1	1	1	1	1
II	2	0	0	0	0	1	2	0	0	0	0	1	3
II	2	0	0	0	0	1	1	1	1	1	1	1	1
II	2	0	0	0	0	1	1	1	1	1	2	1	4
II	3	0	0	0	0	0	0	0	0	0	0	0	0
II	3	0	0	0	0	0	0	0	0	0	0	0	0
II	3	0	0	0	0	0	0	0	0	0	0	0	0
II	3	0	0	0	0	0	0	0	0	0	0	0	0
II	3	0	0	0	0	0	0	0	0	0	0	0	0
II	3	0	0	1	3	1	4	1	4	1	4	1	4
II	4	0	0	0	0	0	0	1	4	1	4	1	4
II	4	0	0	0	0	0	0	1	4	1	4	1	4
II	4	0	0	0	0	0	0	1	2	1	2	1	2
II	4	0	0	0	0	1	1	1	1	1	1	1	1
II	4	0	0	0	0	0	0	1	2	1	2	1	2
II	4	0	0	0	0	1	5	1	4	1	4	1	4
II	5	1	1	1	1	0	0	0	0	1	1	1	1
II	5	1	1	1	4	1	1	0	0	1	3	1	3
II	5	1	1	1	3	0	0	0	0	1	3	1	3
II	5	1	1	0	0	0	0	0	0	1	3	1	3
II	5	1	1	1	4	0	0	0	0	1	3	1	3
II	5	1	1	1	4	0	0	0	0	1	3	1	3
III	1	1	1	1	1	1	1	1	1	1	1	1	1
III	1	1	4	1	2	1	2	1	2	1	2	1	2
III	1	1	1	1	4	1	4	1	4	1	4	1	4
III	1	1	4	1	1	1	1	1	1	1	1	1	1
III	1	1	4	1	4	1	4	1	4	1	4	1	4
III	1	1	3	1	5	1	5	1	5	1	5	1	5
III	2	0	0	1	3	1	3	1	3	1	3	1	3
III	2	1	3	1	3	1	3	1	3	1	3	1	3
III	2	1	1	1	2	1	2	1	2	1	2	1	2
III	2	1	1	1	2	1	2	1	2	1	2	1	2

PROGRESS ASSESSMENT RESULTS FOR YEAR 1 (GAME 2)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	**Group**	A	B	C	D	E	F	G	H	I	J	K	L
III	2	1	2	1	2	1	2	1	2	1	2	1	2
III	2	1	4	1	3	1	3	1	3	1	3	1	3
III	2	0	0	1	3	1	3	1	3	1	3	1	3
III	3	0	0	0	0	1	1	1	1	1	1	1	1
III	3	1	1	0	0	0	0	0	0	0	0	0	0
III	3	0	0	0	0	1	5	1	5	1	5	1	5
III	3	1	1	0	0	0	0	0	0	0	0	0	0
III	3	0	0	0	0	1	5	1	5	1	5	1	5
III	3	1	1	0	0	0	0	0	0	0	0	0	0
III	4	1	3	1	3	1	3	1	3	1	3	1	3
III	4	1	3	1	3	1	3	1	3	1	3	1	3
III	4	1	3	1	3	1	3	1	3	1	3	1	3
III	4	0	0	1	2	1	2	1	2	1	2	1	2
III	4	0	0	1	1	1	1	1	1	1	1	1	1
III	4	1	3	1	3	1	3	1	3	1	3	1	3
III	5	1	1	1	2	1	2	1	2	1	2	1	2
III	5	0	0	1	3	1	1	1	1	1	1	1	1
III	5	1	1	1	1	1	4	1	4	1	4	1	4
III	5	1	1	1	1	1	4	1	4	1	4	1	4
III	5	0	0	1	3	1	3	1	1	1	1	1	1
IV	1	0	0	0	0	1	4	1	4	1	4	1	4
IV	1	0	0	0	0	0	0	0	0	0	0	0	0
IV	1	0	0	0	0	1	4	1	4	1	4	1	4
IV	1	0	0	0	0	1	1	1	1	1	1	1	1
IV	1	0	0	0	0	0	0	0	0	0	0	0	0
IV	1	0	0	0	0	1	4	1	4	1	4	1	4
IV	2	0	0	0	0	0	0	1	2	1	2	1	2
IV	2	0	0	1	4	0	0	1	2	1	2	1	2
IV	2	0	0	1	3	0	0	1	2	1	2	1	2
IV	2	0	0	0	0	0	0	1	3	1	3	1	3
IV	2	0	0	1	1	0	0	1	3	1	3	1	3
IV	2	0	0	1	3	0	0	1	3	1	3	1	3
IV	3	0	0	0	0	1	3	0	0	0	0	0	0
IV	3	1	3	1	3	1	1	0	0	0	0	0	0
IV	3	1	4	1	4	1	1	1	4	1	4	1	4
IV	3	1	3	1	3	1	3	1	1	1	1	1	1
IV	3	0	0	0	0	0	0	0	0	0	0	0	0
IV	3	1	3	1	3	1	1	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	4	0	0	0	0	1	4	1	4	1	4	1	4
IV	5	0	0	1	3	1	3	1	3	1	3	1	3
IV	5	0	0	1	4	1	4	1	4	1	4	1	4
IV	5	0	0	0	0	0	0	0	0	0	0	0	0
IV	5	0	0	0	0	0	0	0	0	0	0	0	0
IV	5	0	0	1	2	1	2	1	2	1	2	1	2
IV	6	0	0	1	5	1	2	0	0	0	0	1	5
IV	6	0	0	1	5	1	3	0	0	0	0	1	5
IV	6	0	0	1	1	0	0	0	0	0	0	1	4
IV	6	0	0	1	3	0	0	0	0	0	0	1	4
IV	6	0	0	1	3	0	0	0	0	0	0	1	5
V	1	1	2	0	0	0	0	0	0	0	0	0	0
V	1	1	2	0	0	0	0	1	4	1	2	1	2
V	1	0	0	0	0	0	0	0	0	0	0	0	0
V	1	0	0	1	1	1	2	1	2	1	4	1	4
V	1	0	0	0	0	0	0	0	0	1	1	1	1
V	1	1	1	0	0	0	0	1	2	1	2	1	2
V	2	0	0	0	0	0	0	0	0	0	0	0	0

PROGRESS ASSESSMENT RESULTS FOR YEAR 1 (GAME 2)

		Round 1		Round 2		Round 3		Round 4		Round 5		Round 6	
School	Group	A	B	C	D	E	F	G	H	I	J	K	L
V	2	1	1	1	1	1	3	1	3	1	3	1	3
V	2	0	0	0	0	0	0	0	0	0	0	0	0
V	2	0	0	0	0	0	0	0	0	0	0	0	0
V	2	0	0	1	2	1	2	1	2	1	2	1	2
V	2	0	0	0	0	1	3	1	3	1	3	1	3
V	3	1	2	1	2	0	0	0	0	0	0	0	0
V	3	0	0	1	1	0	0	0	0	0	0	1	1
V	3	0	0	1	1	0	0	1	1	0	0	0	0
V	3	1	3	1	1	1	4	0	0	0	0	0	0
V	3	0	0	1	2	0	0	0	0	0	0	0	0
V	3	1	2	0	0	1	1	1	2	0	0	0	0
V	4	0	0	0	0	1	3	1	4	1	2	0	0
V	4	0	0	1	1	1	2	1	1	0	0	0	0
V	4	0	0	1	1	1	1	1	3	0	0	0	0
V	4	0	0	0	0	0	0	1	3	0	0	0	0
V	4	0	0	1	3	0	0	1	3	0	0	0	0
V	4	0	0	0	0	1	3	1	3	0	0	0	0
V	4	0	0	0	0	1	4	1	4	1	3	1	5
V	5	0	0	0	0	0	0	0	0	0	0	1	3
V	5	0	0	0	0	0	0	0	0	0	0	1	3
V	5	0	0	0	0	0	0	0	0	0	0	1	3
V	5	0	0	0	0	0	0	0	0	0	0	1	4
V	5	0	0	0	0	0	0	0	0	0	0	1	1
V	5	0	0	0	0	0	0	0	0	1	2	1	4
V	5	0	0	0	0	0	0	0	0	0	0	1	1
V	6	0	0	1	4	1	4	1	4	1	4	1	4
V	6	0	0	1	4	1	4	1	4	1	4	1	4
V	6	0	0	1	4	1	4	1	4	1	4	1	4
V	6	0	0	0	0	0	0	0	0	0	0	0	0
V	6	0	0	1	3	1	3	1	3	1	3	1	3
V	6	0	0	1	4	1	4	1	4	1	4	1	4
V	6	0	0	1	4	1	4	1	4	1	4	1	4
Totals --		**47**	**101**	**83**	**230**	**101**	**290**	**109**	**318**	**109**	**315**	**122**	**365**

Appendix M

Experiment One Questionnaire/Test Raw Results and Codings

The following codes were used to record the responses to the Experiment One Questionnaire/Test

Q 1.5 (Languages) 'Which language do you speak?'

Categories: A - Setswana B - English C - Afrikaans D - Others

Response Codes: 0 - No response
1 - a choice of the language made

Q 1.6 (Self-descriptions) 'How do you describe yourself?'

Categories:
A - I learn better on my own
B - I like solving challenging activities
C - I like to take part during group discussions
D - I learn better when sharing ideas with others
E - I like solving easy activities
F - I like listening to others talk during group discussions

Response Codings: 0 - no tick in the box
1 - a tick in the box

Q 2.1 (Problems encountered) 'Which of the following are the problems you encountered when working out the chief's rule?'

Categories:
A - The time for playing the game was not enough
B - The chief's rule was difficult to work out
C - Other reasons
D - The instructions for playing the game were difficult to follow
E - I did not discuss my ideas with other members of the group

Response Codings: 0 - no tick in the box
1 - a tick in the box

Q 2.3 (Preferred Methods) 'Which of the following did you apply to work out the chief's rule?'

Categories:
A - By guess work.
B - Observing the pattern of cards accepted by dealer from me.
C - Anything else?
D - Observing the pattern of cards accepted by the dealer from others.
E - Observing the pattern of cards rejected.

Response Codings: 0 - no tick in the box.
1 - a tick in the box.

Q 3.1 and 3.2 (The genealogical Problem)

Categories:
Q 3.1 - Pacing 'mother' in the correct box in the family tree diagram.
Q 3.2 - Age or Date of birth of Vanessa.

Response Codings: 0 - no response or wrong response
1 - correct response given.

Evaluation Results After Two Games - Year 1

				Q. 1.5 (languages)				Q. 1.6 (description of yourself)						Q2.1(problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
I	1	4	1	0	1	0	0	0	0	1	1	1	0	0	1	0	1	0	1	0	0	0	1	4	0
I	1	3	1	1	0	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	1	4	0
I	1	3	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	4	0
I	1	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	4	0
I	1	4	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	0	1	1	4	0
I	1	3	2	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	4	0
I	2	3	2	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	1	0	0	1	4	0
I	2	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	5	0
I	2	4	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	0	4	0
I	2	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	4	0
I	2	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	4	0
I	2	3	2	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	1	0	0
I	2	3	2	1	1	0	0	1	0	1	0	1	0	0	0	0	1	1	0	0	0	1	1	4	0
I	3	3	1	1	1	0	0	0	0	1	1	1	1	1	0	0	1	0	1	1	0	0	0	4	0
I	3	2	1	1	1	0	0	1	0	1	1	1	1	0	1	0	1	0	1	0	0	1	0	4	0
I	3	3	1	1	0	0	0	0	0	1	0	1	1	0	1	0	1	0	0	1	0	1	0	5	0
I	3	3	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	4	0
I	3	4	1	1	0	0	0	1	0	0	1	1	1	1	1	0	0	1	1	0	0	1	0	5	0
I	3	5	1	1	0	0	0	1	0	1	0	1	0	0	0	0	1	1	1	0	0	1	0	4	0
I	3	3	2	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	0	0	1	0	4	0
I	4	4	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	1	4	0
I	4	4	1	1	1	0	0	0	1	1	1	0	0	0	1	0	1	0	1	0	0	1	0	4	0
I	4	4	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	4	0
I	4	3	2	1	0	0	0	1	0	1	1	0	0	0	1	1	1	0	0	1	0	0	1	4	0
I	4	4	2	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	0	1	4	0
I	4	4	2	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	3	0
I	4	2	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	1	4	0
I	5	5	1	1	1	0	0	1	0	1	0	0	0	1	1	0	1	0	0	1	0	0	1	5	0
I	5	4	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	4	0
I	5	4	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	1	0	1	0	1	1	4	0
I	5	4	2	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	4	0
I	5	3	2	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	5	0
I	5	5	2	1	1	0	0	1	0	1	1	0	0	0	1	0	1	1	1	0	0	1	0	5	0

Evaluation Results After Two Games - Year 1

				Q. 1.5 (languages)				Q. 1.6 (description of yourself)						Q2.1(problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
I	5	4	1	1	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1	1	5	0
I	5	3	1	1	1	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	5	0
II	1	4	2	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	4	0
II	1	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	4	0
II	1	3	2	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	4	0
II	1	3	2	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	4	0
II	1	3	2	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	4	0
II	1	4	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	4	0
II	1	5	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	5	0
II	2	4	2	1	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0	1	0	0	1	4	0
II	2	4	2	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	4	0
II	2	4	2	1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	1	0	4	0
II	2	3	2	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	5	0
II	2	3	2	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	4	0
II	2	2	1	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	5	1
II	3	3	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	4	0
II	3	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	4	0
II	3	4	1	1	1	0	0	0	0	1	1	0	0	1	1	0	0	0	0	1	0	0	1	4	0
II	3	5	1	0	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	4	0
II	3	5	1	0	1	0	0	0	0	1	1	0	0	0	1	0	1	0	0	1	0	1	0	4	0
II	4	3	2	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	4	0
II	4	5	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	0	5	0
II	4	4	1	1	1	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	0	0	1	4	0
II	4	5	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	1	4	0
II	4	3	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	4	0
II	5	3	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	4	0
II	5	3	1	1	1	0	0	0	1	1	1	0	0	1	0	0	0	0	1	0	0	0	1	4	1
II	5	5	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	4	0
II	5	3	2	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	5	0
II	5	4	2	1	1	0	0	0	0	1	1	0	0	0	1	0	1	1	1	0	0	1	0	4	0
II	5	3	2	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	5	0
II	6	5	2	1	1	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	4	0
II	6	3	2	1	1	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	1	0	1	4	0

Evaluation Results After Two Games - Year 1

				Q. 1.5 (languages)				Q. 1.6 (description of yourself)						Q2.1(problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
II	6	3	2	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	5	0
II	6	3	2	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	5	0
II	6	3	2	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	5	0
II	6	3	2	1	1	0	0	0	1	1	1	0	1	0	0	1	0	1	0	1	0	0	1	5	0
II	6	4	2	1	1	0	0	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	1	5	0
IV	1	4	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	4	0
IV	1	3	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	4	0
IV	1	3	1	1	0	0	0	1	1	1	0	0	0	0	1	0	1	1	0	1	0	1	0	4	0
IV	1	3	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	4	0
IV	1	3	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	4	0
IV	1	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	4	1
IV	2	4	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	1	4	0
IV	2	3	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	5	0
IV	2	4	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	5	0
IV	2	4	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	4	0
IV	2	5	2	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	4	0
IV	2	4	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	5	0
IV	3	5	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	3	0
IV	3	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	4	0
IV	3	5	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	4	0
IV	3	4	2	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	4	0
IV	3	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	5	1
IV	3	3	2	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	4	0
IV	4	5	1	1	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1	0	0	0	0	4	0
IV	4	5	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	4	0
IV	4	5	1	1	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	4	0
IV	4	4	1	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	4	0
IV	4	5	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	4	0
IV	4	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	4	0
IV	5	5	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	4	0
IV	5	5	1	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	1	0	0	1	0	4	0
IV	5	4	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	4	0
IV	5	4	2	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1	4	0

Evaluation Results After Two Games - Year 1

				Q. 1.5 (languages)				Q. 1.6 (description of yourself)						Q2.1(problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
IV	5	5	2	0	1	0	0	0	0	1	0	1	1	0	0	0	1	1	0	1	0	1	0	4	0
IV	5	4	2	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	4	1
IV	5	4	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	4	0
IV	6	2	2	1	1	0	0	1	0	1	1	0	1	0	1	0	1	1	0	1	0	1	0	4	1
IV	6	2	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	0	0	0	4	1
IV	6	5	2	1	1	0	0	1	0	1	1	1	0	0	1	0	0	0	0	0	0	1	1	4	1
IV	6	4	2	1	0	0	0	0	0	1	1	0	1	0	0	0	1	0	1	1	0	0	0	4	1
IV	6	4	2	1	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0	1	0	4	0
IV	6	3	2	1	1	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	1	0	4	1
IV	6	3	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1	4	1
V	1	3	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	4	0
V	1	4	2	1	1	0	0	0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	1	4	0
V	1	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0*	0	1	1	0	0	1	0	4	0
V	1	3	2	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	1	5	0
V	1	4	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	4	0
V	1	0*	2	1	1	0	0	1	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	4	0
V	1	3	2	0	0	0	1	1	0	1	1	1	1	0	0	0	1	0	0	1	0	1	0	4	0
V	2	3	1	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	1	0	0	0
V	2	4	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0
V	2	3	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	4	0
V	2	4	1	1	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	1	1	4	0
V	2	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	5	1
V	2	3	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0
V	3	5	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	1	4	0
V	3	4	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	4	1
V	3	5	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	4	0
V	3	3	1	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	1	0	1	0	4	0
V	3	4	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	4	0
V	3	4	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	1	0	4	0
V	3	4	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	1	0	4	0
V	4	3	0	1	0	0	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	1	3	0
V	4	3	2	1	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0	1	0	1	0	4	0
V	4	3	2	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	0	5	0

Evaluation Results After Two Games - Year 1

				Q. 1.5 (languages)				Q. 1.6 (description of yourself)						Q2.1(problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
V	4	4	2	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	5	0
V	4	3	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	5	1
V	4	3	0	1	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	1	1	5	1
V	4	5	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	4	0
V	5	5	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	4	0
V	5	4	1	1	0	0	0	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	1	5	0
V	5	5	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	5	0
V	5	4	2	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	5	0
V	5	4	2	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	4	0
V	5	4	2	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	4	0
V	6	2	2	1	1	0	1	1	1	1	1	0	0	0	1	0	1	1	0	1	1	0	0	5	0
V	6	4	2	1	1	0	0	0	0	1	1	0	1	1	0	0	1	1	0	1	0	0	0	4	0
V	6	4	2	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	4	1
V	6	3	2	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	4	1
V	6	3	2	1	0	0	0	0	0	1	0	1	1	0	0	0	1	1	0	1	0	1	0	4	1
V	6	4	2	1	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	0	0	4	1
V	6	3	2	1	0	0	0	1	0	1	0	1	1	0	1	0	1	0	0	1	0	0	1	5	0
OTALS		**549**	**217**	**137**	**61**	**2**	**4**	**40**	**16**	**73**	**82**	**23**	**44**	**42**	**62**	**3**	**66**	**49**	**71**	**59**	**2**	**70**	**67**	**611**	**19**

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
I	1	5	2	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	4	0
I	1	5	2	1	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	1	4	0
I	1	5	2	1	1	0	0	0	1	0	1	0	0	0	1	1	0	0	1	1	0	0	0	5	0
I	1	5	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	5	0
I	1	5	1	1	1	0	0	0	1	1	1	0	0	1	1	0	0	1	0	1	0	0	1	5	0
I	2	5	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	4	0
I	2	5	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	4	0
I	2	5	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	4	0
I	2	5	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	4	0
I	2	5	1	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	0	1	4	0
I	2	5	2	1	1	0	0	0	0	1	1	0	0	1	1	0	1	0	0	1	0	1	0	4	0
I	3	4	2	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	4	0
I	3	5	2	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	4	0
I	3	5	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	4	0
I	3	5	2	1	1	0	0	1	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0	4	0
I	3	5	2	1	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	4	0
I	3	5	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	4	0
I	4	5	1	1	1	0	0	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	4	0
I	4	5	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	4	1
I	4	3	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	4	0
I	4	5	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	4	0
I	4	4	2	1	1	0	0	0	0	1	1	0	1	0	1	1	0	0	1	0	0	1	0	4	0
I	4	5	2	1	1	0	0	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	1	4	0
I	5	5	2	1	1	0	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	4	0
I	5	5	2	1	1	0	0	0	1	1	1	0	1	0	1	0	0	1	0	1	0	1	0	4	0
I	5	4	1	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	1	4	0
I	5	5	1	1	1	0	0	0	1	1	1	0	0	1	0	1	0	1	0	1	1	0	0	4	0
I	5	5	1	1	1	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	4	0
Totals ------------				**28**	**21**	**1**	**0**	**9**	**7**	**14**	**19**	**1**	**8**	**4**	**11**	**8**	**8**	**13**	**7**	**12**	**2**	**12**	**13**	**115**	**1**
II	1	4	2	1	1	0	0	1	1	1	0	0	0	1	1	1	1	1	0	1	0	0	1	4	0
II	1	5	2	1	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	`0	1	4	0
II	1	3	2	1	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	4	0
II	1	4	2	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	1	0	4	0

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
II	1	5	2	1	1	0	0	1	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	4	0
II	1	5	2	1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	0	1	0	0	1	4	0
II	2	5	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	4	0
II	2	5	2	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	4	0
II	2	5	1	1	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1	1	4	0
II	2	5	2	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	1	4	0
II	2	5	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	4	0
II	2	5	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	4	0
II	3	4	1	1	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	5	0
II	3	5	1	1	1	0	0	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	0	5	0
II	3	4	1	1	1	0	0	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	0	4	0
II	3	4	1	1	1	0	0	0	0	1	1	0	1	0	1	1	1	1	1	0	0	0	0	5	0
II	3	4	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	4	0
II	3	5	2	1	1	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	4	0
II	3	5	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	1	1	0	0	0	0	5	1
II	4	5	2	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	4	0
II	4	4	2	1	1	0	0	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1	0	5	0
II	4	5	2	1	1	0	0	1	1	1	0	0	1	0	1	1	1	0	1	1	1	0	1	4	0
II	4	5	2	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	1	4	1
II	4	4	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	4	0
II	4	4	1	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	1	3	0
II	4	4	2	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0	4	0
II	5	4	2	1	1	0	0	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	4	0
II	5	6	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	4	0
II	5	6	2	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	4	0
II	5	5	2	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1	1	0	0	0	4	0
II	5	5	2	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	4	0
II	5	5	2	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	4	0
II	5	4	1	1	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	4	0
Totals -----------				**33**	**33**	**0**	**1**	**9**	**5**	**9**	**25**	**2**	**9**	**5**	**16**	**9**	**20**	**6**	**17**	**13**	**4**	**12**	**14**	**136**	**2**
III	1	4	2	1	1	0	1	1	1	1	0	0	0	0	0	1	0	1	0	1	0	0	1	4	0
III	1	4	2	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	4	0
III	1	5	2	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	4	0

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
III	1	4	2	1	1	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0	1	1	0	4	0
III	1	5	2	1	1	0	0	0	0	1	1	0	1	0	0	0	1	0	1	0	0	1	0	5	0
III	1	5	2	1	1	0	0	0	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	4	0
III	1	6	1	1	1	0	0	1	1	1	1	1	0	1	0	0	1	1	1	1	0	1	0	4	0
III	2	5	2	1	1	0	0	0	0	1	1	0	1	0	0	0	1	0	1	0	0	0	1	5	0
III	2	6	2	1	1	0	0	0	0	1	1	0	0	0	1	1	1	0	1	0	0	0	1	4	0
III	2	6	2	1	1	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	0	1	4	0
III	2	5	2	1	1	0	0	0	1	1	1	0	1	1	0	0	1	1	1	0	0	0	1	4	0
III	2	4	2	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	0	1	0	0	1	4	0
III	2	5	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	1	4	0
III	2	5	2	1	1	0	0	0	1	1	1	0	1	1	1	0	1	1	0	1	0	1	0	5	0
III	2	6	1	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	4	0
III	3	5	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0	1	4	0
III	3	5	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	5	0
III	3	5	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	5	0
III	3	5	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	5	0
III	3	5	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	2	0
III	3	5	1	1	1	0	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0	4	0
III	3	7	2	1	1	0	0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0	0	4	0
III	4	5	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	4	0
III	4	5	1	1	1	0	0	0	0	1	1	0	1	1	0	1	1	0	0	1	0	1	0	4	0
III	4	5	1	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	4	0
III	4	4	1	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	1	4	0
III	4	4	1	1	1	0	0	0	0	1	1	0	1	0	0	1	1	1	0	1	1	1	1	4	0
III	4	7	1	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	1	1	4	0
III	4	7	1	1	1	0	0	0	1	0	1	0	1	0	1	1	1	0	0	0	0	0	1	4	0
III	5	4	1	1	1	0	0	0	1	1	1	0	1	0	0	0	1	0	1	0	1	0	0	4	0
III	5	4	1	1	1	0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	1	1	1	5	0
III	5	2	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	4	0
III	5	5	1	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	1	0	4	0
III	5	3	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	4	0
III	5	4	1	1	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	0	4	0
Totals ----------				**35**	**35**	**0**	**1**	**3**	**13**	**21**	**23**	**5**	**13**	**4**	**14**	**12**	**18**	**17**	**14**	**17**	**7**	**16**	**19**	**145**	**0**

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
IV	1	4	2	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0	4	0
IV	1	5	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1	0	0	1	0	5	0
IV	1	5	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	4	0
IV	1	5	1	1	1	0	0	1	1	1	0	0	0	1	1	0	0	0	1	0	0	1	0	5	1
IV	1	5	1	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	1	0	5	0
IV	1	4	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	0	5	0
IV	1	4	2	1	1	0	0	0	1	1	1	0	0	0	0	0	1	0	0	1	0	1	0	4	1
IV	2	5	1	1	1	0	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	4	1
IV	2	4	1	1	1	0	0	0	0	1	1	0	1	0	1	1	1	0	0	0	1	1	1	4	0
IV	2	5	1	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	1	4	0
IV	2	5	2	1	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	1	0	1	0	4	0
IV	2	4	1	1	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	0	1	4	0
IV	2	4	1	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	5	1
IV	2	5	1	1	1	0	0	0	0	1	1	1	1	0	1	1	0	1	1	0	0	1	0	4	0
IV	3	5	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	1	1	0	0	0	4	0
IV	3	4	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	1	4	0
IV	3	4	1	1	1	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	4	0
IV	3	5	1	1	1	0	0	0	0	1	1	1	1	0	1	0	1	0	0	1	0	1	0	4	0
IV	3	5	1	1	1	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	1	4	0
IV	3	5	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	4	0
IV	3	4	2	1	1	0	0	0	0	1	1	0	1	1	1	0	1	0	1	1	0	0	0	4	0
IV	4	4	2	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	5	0
IV	4	5	2	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	5	0
IV	4	4	2	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	4	0
IV	4	4	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	1	4	0
IV	4	5	1	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	4	0
IV	4	4	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	4	0
IV	4	5	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	5	0
IV	5	4	2	1	1	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	0	1	0	4	0
IV	5	5	2	1	1	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	4	0
IV	5	5	2	1	1	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	4	0
IV	5	5	2	1	1	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1	1	4	0
IV	5	5	2	1	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	4	0

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
IV	5	3	2	1	1	0	0	1	0	1	1	0	0	0	1	0	0	1	0	0	0	1	1	4	0
IV	6	5	2	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	5	0
IV	6	5	2	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	4	0
IV	6	4	2	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	4	0
IV	6	5	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	4	0
IV	6	5	2	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	5	0
IV	6	4	1	1	1	0	0	1	1	0	0	0	0	0	1	1	0	1	0	1	0	0	1	5	1
Totals	---------			40	40	0	0	9	11	25	26	6	15	4	27	9	20	5	14	13	2	23	20	171	5
V	1	4	2	1	1	0	0	0	0	0	1	0	1	1	0	0	1	0	1	0	0	0	0	4	0
V	1	4	2	1	1	0	0	0	0	1	1	0	0	1	0	0	0	1	0	1	0	0	1	4	0
V	1	4	2	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	0	4	0
V	1	4	2	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	4	0
V	1	5	2	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	4	0
V	1	5	2	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	1	0	4	0
V	1	4	1	1	1	0	0	0	1	1	1	0	0	0	0	1	1	1	1	0	0	1	0	4	0
V	2	4	2	1	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	1	0	0	0	5	0
V	2	5	2	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	5	0
V	2	5	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	4	0
V	2	5	2	1	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	1	0	5	0
V	2	4	2	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	1	5	0
V	2	4	2	1	1	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	1	1	4	0
V	2	4	2	1	1	0	0	0	1	1	1	0	0	0	0	1	0	1	0	1	1	1	0	4	0
V	3	4	2	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0
V	3	5	1	1	1	0	0	1	0	1	1	0	1	1	1	0	1	0	1	0	0	1	0	4	0
V	3	4	2	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	4	0
V	3	4	2	1	1	0	0	0	0	0	1	0	1	1	0	0	1	0	1	0	0	0	1	4	0
V	3	5	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	1	1	0	0	0	0	4	0
V	3	4	2	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	1	0	4	0
V	3	5	2	1	1	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	4	0
V	4	5	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	1	1	0	0	0	5	0
V	4	5	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0	0	1	0	5	0
V	4	3	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	4	0
V	4	4	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	4	0

Evaluation Results After Two Games - Year 2

				Q. 1.5 (Languages)				Q. 1.6 (Self-Descriptions)						Q2.1 (Problems encountered)					Q2.3 (Preferred Methods)						
Sch	Gp	Q1.2	Q1.3	A	B	C	D	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D	E	Q3.1	Q3.2
V	4	5	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	4	0
V	4	5	2	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	4	0
V	4	4	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	5	0
V	4	4	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0	1	1	0	0	0	5	0
V	5	4	2	1	1	0	0	1	0	1	1	1	1	0	0	0	0	1	0	1	0	0	1	5	0
V	5	4	2	1	1	0	0	1	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	4	1
V	5	5	2	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4	1
V	5	5	2	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	4	0
V	5	5	2	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	4	0
V	5	5	2	1	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	4	0
V	5	5	2	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	4	0
V	5	5	2	1	1	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	4	0
V	6	5	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	4	0
V	6	5	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0	4	0
V	6	5	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	4	0
V	6	4	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	0	4	0
V	6	5	1	1	1	0	0	0	0	1	1	0	1	0	0	0	1	1	0	1	0	0	1	4	0
V	6	4	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	4	0
V	6	4	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	4	0
V	6	4	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1	0	1	0	4	0
Totals ------------				**45**	**45**	**0**	**0**	**8**	**4**	**32**	**34**	**4**	**20**	**7**	**15**	**6**	**22**	**14**	**20**	**16**	**1**	**17**	**11**	**189**	**2**
TOTAL --------------				**181**	**174**	**1**	**2**	**38**	**40**	**101**	**127**	**18**	**65**	**24**	**83**	**44**	**88**	**55**	**72**	**71**	**16**	**80**	**77**	**756**	**10**

Appendix N

Experiment One Total Frequencies by School, Age and Gender for Questionnaire/Test Results

The abbreviations used in the table on next page are described below in full:

LBO - 'I learn better on my own'

SCA - 'I like solving challenging activities'

PGD - 'I like to take part during group discussions'

SIO - 'I learn better when sharing ideas with others'

SEA - 'I like solving easy activities'

LDG - 'I like listening to others talk during group discussions'

YEAR 1 TOTAL FREQUENCIES BY SCHOOL

	Languages		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
School	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepted-me	Other methods	Cards accepted -others	Cards rejected-all	Success in Family tree	Success in Vanessa age
I	35	34	14	5	22	18	12	10	12	15	13	22	13	20	12	9	20	19	8	0
II	34	36	9	5	19	23	0	7	14	12	16	11	7	19	14	9	12	16	11	2
IV	31	38	8	4	10	20	3	10	7	21	10	14	12	19	14	6	18	15	4	9
V	38	40	9	2	22	21	8	17	10	14	13	19	17	13	19	13	20	17	11	8
Total	**138**	**148**	**40**	**16**	**73**	**82**	**23**	**44**	**43**	**62**	**52**	**66**	**49**	**71**	**59**	**37**	**70**	**67**	**34**	**19**

YEAR 1 TOTAL FREQUENCIES BY AGE

	Language		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
AGE	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepted -me	Other methods	Cards accepted -others	Cards rejecte d-all	Success in Family tree	Success in Vanessa age
13 YRS	6	6	4	1	3	5	1	2	1	5	1	4	4	2	4	1	4	1	2	3
14 YRS	52	53	15	6	36	30	9	15	16	20	20	22	14	23	25	8	25	23	16	7
15 YRS	61	63	11	6	21	37	7	20	16	24	21	29	24	31	25	22	28	31	11	8
16 YRS	19	26	10	3	13	10	6	7	10	13	10	11	7	15	5	6	13	12	5	1
Total	**138**	**148**	**40**	**16**	**73**	**82**	**23**	**44**	**43**	**62**	**52**	**66**	**49**	**71**	**59**	**37**	**70**	**67**	**34**	**19**

YEAR 1 TOTAL FREQUENCIES BY GENDER

	Language		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
Gender	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepte d-me	Other methods	Cards accepted -others	Cards rejected-all	Succes s in Family tree	Success in Vanessa age
BOYS	67	74	21	10	33	37	15	20	29	37	25	27	26	25	23	17	43	34	16	6
GIRLS	71	74	19	6	40	45	8	24	14	25	27	39	23	36	36	20	27	33	18	13
Total	**138**	**148**	**40**	**16**	**73**	**82**	**23**	**44**	**43**	**62**	**52**	**66**	**49**	**71**	**59**	**37**	**70**	**67**	**34**	**19**

YEAR 2 TOTAL FREQUENCIES BY GENDER

	Language		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
Gender	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepted -me	Other methods	Cards accepted -others	Cards rejected-all	Success in Family tree	Success in Vanessa age
Boys	82	78	12	19	41	55	10	21	9	43	20	42	28	32	34	8	41	37	18	6
Girls	99	96	26	21	60	72	8	44	15	40	24	46	27	40	37	8	39	40	17	4
Total	**181**	**174**	**38**	**40**	**101**	**127**	**18**	**65**	**24**	**83**	**44**	**88**	**55**	**72**	**71**	**16**	**80**	**77**	**35**	**10**

FORM 2 TOTAL FREQUENCIES BY AGE

	Language		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
AGE	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepted-me	Other methods	Cards accepted -others	Cards rejected-all	Success in Family tree	Success in Vanessa age
13 YRS	1	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0
14 YRS	5	5	2	0	1	4	0	0	1	1	0	2	3	2	2	0	2	3	0	0
15 YRS	62	62	12	17	36	44	7	25	7	29	18	36	15	27	25	9	31	22	13	4
16 YRS	104	97	23	18	61	73	9	37	15	47	22	43	33	35	41	6	44	47	22	6
17 YRS	6	6	1	2	2	4	1	1	1	3	2	4	3	6	2	0	1	3	0	0
18 YRS	3	3	0	3	1	1	1	2	0	3	2	2	1	1	1	1	1	2	0	0
Totals	**181**	**174**	**38**	**40**	**101**	**127**	**18**	**65**	**24**	**83**	**44**	**88**	**55**	**72**	**71**	**16**	**80**	**77**	**35**	**10**

FORM 2 TOTAL FREQUENCIES BY SCHOOL

	Language		Q1.6 Self Description						Q2..1 Problems Encountered					Q2.3 Method preferred					Q3.1	Q3.2
School	Sets.	Eng.	LBO	SCA	PGD	SIO	SEA	LDG	Time not enough	Rule difficult	Other reasons	Game instr. difficult	No sharing of ideas	Guess work	Cards accepted-me	Other methods	Cards accepted -others	Cards rejected -all	Success in Family tree	Success in Grandmother age
I	28	21	9	7	14	19	1	8	4	11	8	8	13	7	12	2	12	13	3	1
II	33	33	9	5	9	25	2	9	5	16	9	20	6	17	13	4	12	14	5	2
III	35	35	3	13	21	23	5	13	4	14	12	18	17	14	17	7	16	19	7	0
IV	40	40	9	11	25	26	6	15	4	27	9	20	5	14	13	2	23	20	11	5
V	45	45	8	4	32	34	4	20	7	15	6	22	14	20	16	1	17	11	8	2
Totals	**181**	**174**	**38**	**40**	**101**	**127**	**18**	**65**	**24**	**83**	**44**	**88**	**55**	**72**	**71**	**16**	**80**	**77**	**35**	**10**

Appendix O

Experiment One Questionnaire/Test Results by Year of Study

Comparison of the year groups their choices in question 1.6 of the questionnaire/test

Year of Study	**Question 1.6** Learn better on my own	**'How do you describe yourself?' (Tick on the right box)** Solve complex activities	Take part in group discussions	Learn better sharing ideas with others	Solving easy activities	Listen to others talk during group discussions
Year 1 (N=148)	40(27)	16(11)	73(49)	82(55)	23(16)	44(30)
Year 2 (N=182)	38(21)	40(22)	101(55)	127(70)	18(10)	65(36)

Note: The values in brackets are percentages calculated from the total number per year of study.

Comparison of the year groups their choices in question 2.3 of the questionnaire/test

Year of Study	Question 2.3 'Which of the following did you use to work out the rule?' Guess work	Observing pattern of cards accepted from me	Observing pattern of cards accepted from others	Observing Pattern of cards rejected from all	Other methods (specify)
Year 1 (N=148)	71(48)	59(40)	70(47)	67(45)	37(25)
Year 2 (N=182)	72(40)	71(39)	80(44)	77(42)	16(9)

Note: The values in brackets are percentages calculated from the total number per year of study.

Comparison of the year groups performance on question 3.1 of the questionnaire/test

	Q 3.1 'Placing mother in right position'		
Year of Study	Correct	Wrong	**Total**
Year 1	34(23)	114(77)	**148**
Year 2	35(19)	147(81)	**182**
Total	**69**	**261**	**330**

Note: The values in brackets are percentages calculated from the total number per year of study.

The difference between the year 1 and year 2 pupils in terms of placing 'mother' at the correct place on the family tree diagram has a chi-square value of **0.6** at the degree of freedom of **1**. This means that the difference is not significant.

Comparison of the year groups performance on question 3.1 of the questionnaire/test

	Success in question 3.2		
Year of Study	Correct	Wrong	Total
Year 1	19(13)	129(87)	**148**
Year 2	10(5)	172(95)	**182**
Total	**29**	**301**	**330**

Note: The values in brackets are percentages calculated from the total number per year of study.

No chi-square calculations were carried out here due to the size of some of the values which is below the limit for chi-square calculations assumed by this project.

Appendix P

Experiment Two Raw Results (in frequencies) from Questionnaire/Test and Codes

The following codes were used for scoring responses from the questionnaire/test:

Question 4, 5 and 6 (Pupils' opinion part of the test)

Categories: Questions 4(a) -(e), 5(a) - (f) and 6(a) - (f)

Response Codes: 0 - no tick in the any of the boxes

1 - a tick in box 1

2 - a tick in box 2

3 - a tick in box 3

4 - a tick in box 4

5 - a tick in box 5

6 - a tick in box 6 (this applied only to questions 5 and 6)

Question 7 (The cattle farmer item)

Category: Question 7(b) - identifying critical information needed by farmer.

Response Codes: 0 - no response or wrong response

1 - correct response

Question 8 (The global warming problem)

Categories: 8C - carry out experiments to test the idea of global warming

8D - collect as much information as possible about global warming

8G - Look at information which has already been gathered through research

Response coding: 0 - no tick for the category in the first three boxes

1 - a tick for the category in the first box

2 - a tick for the category in the second box

3 - a tick for the category in the third box

Question 9 (The Sodium fluoride problem)

Categories: 9(a) - water contains hydrogen and oxygen

9(b) - all of the four key words present (hydrogen and oxygen, combine, pure, test for water)

Response Codes: 0 - no response or wrong response

1 - a tick in the correct box for 9(a) and any one of the key words present for 9(b)

2 - any two of the key words present for 9(b)

3 - any three of the key words present fro 9(b)

4 - all four key words present for 9(b)

Question 10 (The genealogical Item)

Categories: 10(a) - placing 'mother' in the correct box of the family tree diagram

10(b) - age or date of birth for Vanessa

Response Codes: 0 - wrong response or no response

1 - correct response

Experimental Group Frequencies

	codes	4a	4b	4c	4d	4e	5a	5b	5c	5d	5e	5f	6a	6b	6c	6d	6e	6f	7b	8C	8D	8G	9a	9b	10a	10b
Year 1	**0**	4	14	10	10	11	7	13	14	14	7	10	7	4	10	8	7	7	88	10	10	10	35	39	69	84
	1	23	26	63	46	31	4	28	43	54	57	48	9	38	10	6	36	5	6	8	17	8	59	53	25	10
	2	3	7	6	5	13	1	5	9	6	15	12	21	43	13	22	35	11	0	19	16	5	0	2	0	0
	3	12	11	9	10	14	2	10	11	6	6	9	35	4	44	33	9	32	0	32	17	8	0	0	0	0
	4	12	7	2	5	8	10	14	6	3	5	5	22	5	17	25	6	38	0	12	21	10	0	0	0	0
	5	2	5	1	4	4	11	2	3	6	1	5	0	0	0	0	0	0	0	9	5	10	0	0	0	0
	6	38	24	3	14	13	59	22	8	5	3	5	0	0	0	0	1	1	0	0	5	12	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	24	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	7	0	0	0	0
Year 2	**0**	5	8	4	7	5	8	8	12	11	8	10	9	6	8	10	6	10	137	13	11	14	100	102	118	120
	1	18	48	108	83	82	7	36	78	70	79	79	9	68	15	11	87	3	18	24	33	8	56	52	38	36
	2	5	22	22	36	25	4	23	32	32	39	29	19	68	17	14	52	13	0	35	30	14	0	2	0	0
	3	12	26	9	12	23	7	18	13	21	12	13	59	8	79	62	4	57	1	33	25	14	0	0	0	0
	4	18	14	5	5	7	7	14	8	8	9	6	60	6	37	59	7	73	0	12	28	29	0	0	0	0
	5	15	14	3	6	6	20	26	7	4	2	7	0	0	0	0	0	0	0	15	10	36	0	0	0	0
	6	83	24	5	7	8	103	31	6	10	7	12	0	0	0	0	0	0	0	11	4	16	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	8	16	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	9	0	0	0	0
Year 3	**0**	13	17	10	16	20	18	19	23	20	11	21	13	8	13	12	8	13	80	8	8	8	27	63	70	71
	1	1	35	62	56	48	0	29	40	45	59	49	1	39	1	1	50	2	12	15	26	9	65	26	22	21
	2	0	9	15	10	10	0	9	21	11	11	16	3	41	4	8	25	2	0	12	22	23	0	3	0	0
	3	3	5	3	8	8	0	12	5	12	6	1	22	2	54	34	8	23	0	20	14	17	0	0	0	0
	4	4	1	0	1	3	2	7	2	4	1	2	53	2	20	37	1	52	0	11	10	13	0	0	0	0
	5	2	11	1	0	2	10	5	0	0	0	2	0	0	0	0	0	0	0	12	8	8	0	0	0	0
	6	69	14	1	1	1	62	11	1	0	4	1	0	0	0	0	0	0	0	8	2	9	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	1	0	0	0	0
	totals	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**	**342**

Control Group Frequencies

	codes	4a	4b	4c	4d	4e	5a	5b	5c	5d	5e	5f	6a	6b	6c	6d	6e	6f	7b	8C	8D	8G	9a4	9b	10a	10b
Year 1	**0**	8	12	11	14	19	13	19	18	13	12	18	3	3	4	4	2	5	89	10	9	9	28	58	68	86
	1	22	23	58	43	32	4	20	30	48	41	42	5	32	5	18	57	2	4	8	13	3	65	35	25	7
	2	1	18	2	13	7	1	9	12	12	18	15	19	45	22	16	28	15	0	14	13	14	0	0	0	0
	3	10	16	9	13	18	5	16	16	9	6	11	30	11	33	27	0	30	0	22	18	10	0	0	0	0
	4	7	6	9	3	12	7	17	12	6	10	3	36	2	29	28	6	41	0	14	21	14	0	0	0	0
	5	15	5	2	4	3	11	3	4	2	3	4	0	0	0	0	0	0	0	7	8	10	0	0	0	0
	6	30	13	2	3	2	52	9	1	3	3	0	0	0	0	0	0	0	0	5	4	10	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	19	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	4	0	0	0	0
Year 2	**0**	31	30	15	27	33	27	27	32	33	27	30	21	18	25	27	17	27	184	15	14	14	148	131	147	165
	1	34	70	117	108	68	9	38	73	84	109	79	21	74	10	14	106	8	17	23	35	21	54	65	55	37
	2	13	21	30	28	28	6	25	39	30	31	37	22	93	31	25	63	17	0	39	42	22	0	6	0	0
	3	24	23	25	26	31	7	34	33	26	13	23	79	8	78	77	13	69	1	45	41	15	0	0	0	0
	4	15	17	9	8	21	18	33	10	19	15	15	59	9	58	59	3	81	0	31	29	37	0	0	0	0
	5	10	12	4	1	11	21	15	9	6	5	8	0	0	0	0	0	0	0	22	23	39	0	0	0	0
	6	75	29	2	4	10	114	30	6	4	2	10	0	0	0	0	0	0	0	14	9	24	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	5	20	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	10	0	0	0	0
Year 3	**0**	7	11	13	8	13	11	11	13	13	10	11	5	4	5	5	0	4	97	19	20	20	41	85	87	92
	1	2	40	76	88	65	5	18	61	55	82	63	7	67	2	5	77	4	18	16	29	5	74	29	28	23
	2	4	9	16	7	11	2	13	14	23	15	17	4	37	10	11	31	11	0	22	21	16	0	1	0	0
	3	5	25	6	6	16	4	20	15	11	2	14	41	2	60	51	4	44	0	22	14	15	0	0	0	0
	4	13	7	2	3	7	11	20	9	6	2	5	58	5	38	43	3	52	0	21	21	14	0	0	0	0
	5	12	6	1	2	1	16	9	0	2	0	1	0	0	0	0	0	0	0	8	6	28	0	0	0	0
	6	72	17	1	1	2	66	24	3	5	4	4	0	0	0	0	0	0	0	4	2	7	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	7	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	0	0	0	0
	totals	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**410**

Appendix Q

Experiment Two (combined experimental and control group) Results by Gender, Control and experimental Groups by Year of Study and Control Group Only by year of Study for Items 4, 5 and 6.

Control and Experimental Groups by Year of Study for Items 4. 5 and 6

Question 4

Question 4a		own (1-2)	both (3-4)	group (5-6)	χ2	sig. level
Year 1	Experiment,l	29	27	44	3.3	n.s
	Control	27	20	53		
Year 2	Experimental	15	20	65	15.8	1%
	Control	27	23	50		
Year 3	Experimental	1	9	90	7.0(1)	1%
	Control	6	17	77		

Question 4b		Solve difficult activities (1-2)	both (3-4)	solve easy activities (5-6)	c2	sig. level
Year 1	Experiment,l	41	23	36	9.1	5%
	Control	51	27	22		
Year 2	Experimental	47	27	26	2	n.s
	Control	53	23	24		
Year 3	Experimental	59	8	33	19	1%
	Control	47	31	22		

Question 4c		read sci. books (1-2)	both (3-4)	not read sci. books (5-6)	c2	sig. level
Year 1	Experiment,l	82	13	5	3.9(1)	n.s
	Control	73	22	5		
Year 2	Experimental	86	9	5	4.3(1)	5%
	Control	79	18	3		
Year 3	Experimental	94	4	2	1.2(1)	n.s
	Control	90	8	2		

Question 4d		sci. theory & expts. (1-2)	both (3-4)	no sci. theory & expts. (5-6)	χ2	sig. level
Year 1	Experiment,l	62	17	21	3.5(1)	n.s
	Control	71	20	9		
Year 2	Experimental	80	11	9	0.4(1)	n.s
	Control	78	19	3		
Year 3	Experimental	87	12	1	1.4(1)	n.s
	Control	89	8	3		

Question 4e		relate to events of daily life (1-2)	both (3-4)	not relate to events of daily life (5-6)	χ2	sig. level
Year 1	Experiment,l	53	27	20	0(1)	n.s
	Control	53	40	7		
Year 2	Experimental	71	20	9	12.3	1%
	Control	57	31	12		
Year 3	Experimental	81	15	3	1.4(1)	n.s
	Control	75	22	3		

Question 5

Question 5a		boring (1-2)	both (3-4)	interesting (5-6)	χ2	sig. level
Year 1	Experiment,l	6	14	80	0.1	n.s
	Control	6	15	79		
Year 2	Experimental	7	9	83	3.3	n.s
	Control	9	14	77		
Year 3	Experimental	0	3	97	15.1(1)	1%
	Control	7	14	79		

Question 5b		easy to work solutions to (1-2)	both (3-4)	not easy to work solns' to (5-6)	χ2	sig. level
Year 1	Experiment,l	40	30	30	13.1	1%
	Control	39	45	16		
Year 2	Experimental	40	21	39	20.8	1%
	Control	36	38	26		
Year 3	Experimental	52	26	22	17.3	1%
	Control	30	38	32		

Question 5c		relate sc. to events of daily life (1-2)	both (3-4)	not relate sc. to events of daily life (5-6)	χ2	sig. level
Year 1	Experiment,l	65	21	14	2.7	n.s
	Control	56	37	7		
Year 2	Experimental	76	15	9	9	5%
	Control	66	25	9		
Year 3	Experimental	88	10	1	7.9(1)	1%
	Control	74	23	3		

Question 5d		make like sci. even more (1-2)	both (3-4)	not make me like sc. even more (5-6)	χ2	sig. level
Year 1	Experiment,l	75	11	14	0.0(1)	n.s
	Control	75	19	6		
Year 2	Experimental	70	20	10	0.6(1)	n.s
	Control	67	27	6		
Year 3	Experimental	78	22	0	0.1(1)	n.s
	Control	76	17	7		

Question 5e		improve thinking skills (1-2)	both (3-4)	not improve thinking skills (5-6)	χ2	sig. level
Year 1	Experiment,l	83	13	5	4.4(1)	5%
	Control	73	20	7		
Year 2	Experimental	80	14	6	0(1)	n.s
	Control	80	16	4		
Year 3	Experimental	86	9	5	4.1(1)	5%
	Control	92	4	4		

Question 5f		enjoy doing most of them (1-2)	both (3-4)	not enjoy doing most of them (5-6)	χ2	sig. level
Year 1	Experiment,l	71	17	12	0.9(1)	n.s
	Control	76	19	5		
Year 2	Experimental	74	13	13	7.3 (2)	5%
	Control	67	22	11		
Year 3	Experimental	92	4	4	6.8(1)	1%
	Control	77	18	5		

Question 6

Question 6a		agree (1-2)	disagree (3-4)	χ2	sig. level
Year 1	Experiment,l	34	66	2.7	n.s
	Control	27	73		
Year 2	Experimental	19	81	1.8	n.s
	Control	24	76		
Year 3	Experimental	5	95	2.1	n.s
	Control	10	90		

Question 6b		agree (1-2)	disagree (3-4)	χ2	sig. level
Year 1	Experiment,l	90	10	1.4	n.s
	Control	86	14		
Year 2	Experimental	91	9	0	n.s
	Control	91	9		
Year 3	Experimental	95	5	0.3	n.s
	Control	96	4		

Question 6c		agree (1-2)	disagree (3-4)	χ2	sig. level
Year 1	Experiment,l	27	73	0.3	n.s
	Control	30	70		
Year 2	Experimental	22	78	0.2	n.s
	Control	23	77		
Year 3	Experimental	6	94	1.7	n.s
	Control	11	89		

Question 6d		agree (1-2)	disagree (3-4)	χ2	sig. level
Year 1	Experiment,l	33	67	1.1	n.s
	Control	38	62		
Year 2	Experimental	17	83	2.2	n.s
	Control	22	78		
Year 3	Experimental	11	89	0.7	n.s
	Control	15	85		

Question 6e		agree (1-2)	disagree (3-4)	$\chi 2$	sig. level
Year 1	Experiment,l	83	17	16.5	1%
	Control	93	7		
Year 2	Experimental	93	7	0.3	n.s
	Control	91	9		
Year 3	Experimental	89	11	3.2	n.s
	Control	94	6		

Question 6f		agree (1-2)	disagree (3-4)	$\chi 2$	sig. level
Year 1	Experiment,l	19	81	0	n.s
	Control	19	81		
Year 2	Experimental	11	89	1.3	n.s
	Control	14	86		
Year 3	Experimental	5	95	4.9	5%
	Control	14	86		

Combined (control and experimental groups) by Gender for Items 4. 5 and 6

Question 4	Gender groups	own (1 - 2)	both (3 - 4)	group (5 - 6)	$\chi 2$	sig. level
(a)	boys	19	23	58	4.0(2)	n.s
	girls	17	17	66		
		Solve difficult activities (1 - 2)	both (3 - 4)	solve easy activities (5 - 6)		
(b)	boys	50	26	24	0.9(2)	n.s
	girls	51	23	26		
		read sci. books (1 - 2)	both (3 - 4)	not read sci. books (5 - 6)		
(c)	boys	81	14	6		
	girls	86	12	2	4.1(1)	5%
		sci. theory ınd expts. (1 - 2)	both (3 - 4)	no sci. theory & expts. (5 - 6)		
(d)	boys	74	19	7		
	girls	81	12	7	4.3(1)	5%
		relate to events of daily life (1 - 2)	both (3 - 4)	not relate to events of daily life (5 - 6)		
(e)	boys	63	28	9		
	girls	66	24	11	0.5(1)	n.s

Question 4

n(b) = 360 n(g) = 392 N = 752

Question 5	Gender	boring (1-2)	both (3-4)	interesting (5-6)	$\chi 2$	sig. level
(a)	Boys	9	14	77		
	Girls	4	10	86	7.4(1)	1%
		easy to work solutions to (1-2)	both (3-4)	not easy to work solutions to (5-6)		
(b)	Boys	37	36	28	2.2(2)	n.s
	Girls	41	30	29		
		relate sc. to events of daily life (1-2)	both (3-4)	not relate science to events of daily life (5-6)		
(c)	Boys	67	25	8		
	Girls	74	19	7	3.4(1)	n.s
		make like sci. even more (1-2)	both (3-4)	not make me like sc. even more (5-6)		
(d)	Boys	68	25	7		
	Girls	76	16	8	5.2(1)	5%
		improve thinking skills (1-2)	both (3-4)	not improve thinking skills (5-6)		
(e)	Boys	79	16	5		
	Girls	85	10	5	3.2(1)	n.s
		enjoy doing most of them (1-2)	both (3-4)	not enjoy doing most of them (5-6)		
(f)	Boys	70	19	11		
	Girls	79	14	7	6.5(1)	5%

Question 5

n(b) = 360 n(g) = 392 N = 752

Question 6	Gender Groups	agree (1 - 2)	disagree (3 - 4)	χ2	sig. level
(a) I found the discussions boring	Boys	25	75	12.6(1)	1%
	Girls	15	85		
(b) I enjoyed working with members of my group	Boys	87	13	11.1(1)	1%
	Girls	94	6		
(c) Most of the ideas from other members of the group were NOT helpful	Boys	34	66	5.7(1)	5%
	Girls	24	76		
(d) Most of the ideas came from one person	Boys	34	66	2.8(1)	n.s
	Girls	27	73		
(e) Working as a group made it easier for us to get answers to the Units or science	Boys	88	12	5.9(1)	5%
	Girls	93	7		
(f) I did NOT respect ideas from others since they were always wrong	Boys	16	84	2.0(1)	n.s
	Girls	12	88		

Question 6

n(b) = 360 **n(g) = 392** **N = 752**

Control Group Only by Year of Study for Item 4, 5 and 6

Question 4

Q 4a	own	both	group	χ2	sig. lev.
control 1	27	20	53		
control 2	27	23	50	28(4)	1%
control 3	6	17	77		

Q 4b	SDA	both	SEA	χ2	sig. lev.
control 1	51	27	22		
control 2	53	23	24	2(4)	n.s
control 3	47	31	22		

Q 4c	RSB	both	NRSB	χ2	sig. lev.
control 1	73	22	5		
control 2	79	18	3	9.6(2)	5%
control 3	90	8	2		

Q 4d	ST&E	both	NST&E	χ2	sig. lev.
control 1	71	20	9		
control 2	78	19	3	13.2(2)	5%
control 3	89	8	3		

Q 4e	RTEODL	both	NRTEODL	χ2	sig. lev.
control 1	53	40	7		
control 2	57	31	12	11.2(2)	1%
control 3	75	22	3		

Question 5

Q 5a	boring	both	interesting	χ2	sig. lev.
control 1	6	15	79		
control 2	9	14	77	0.6(2)	n.s
control 3	7	14	79		

Q 5b	ETWST	both	NETWST	χ2	sig. lev.
control 1	39	45	16		
control 2	36	38	26	5.9(4)	n.s
control 3	30	38	32		

Q 5c	RSTEODL	both	NRSTEODL	χ2	sig. lev.
control 1	56	37	7		
control 2	66	25	9	8.9(2)	n.s
control 3	74	23	3		

Q 5d	MMLSEM	both	NMMLSEM	$\chi 2$	sig. lev.
control 1	75	19	6		
control 2	67	27	6	4.3(2)	n.s
control 3	76	17	7		

Q 5e	ITS	both	NITS	$\chi 2$	sig. lev.
control 1	73	20	7		
control 2	80	16	4	14.5(2)	1%
control 3	92	4	4		

Q 5f	EDMOT	both	NEDMOT	$\chi 2$	sig. lev.
control 1	76	19	5		
control 2	67	22	11	5.0(4)	n.s
control 3	77	18	5		

Question 6

Q 6a	agree	disagree	$\chi 2$	sig. lev.
control 1	27	73		
control 2	24	76	10.7(2)	5%
control 3	10	90		

Q 6b	agree	disagree	$\chi 2$	sig. lev.
control 1	70	30		
control 2	91	9	7(2)	5%
control 3	96	4		

Q 6c	agree	disagree	$\chi 2$	sig. lev.
control 1	30	70		
control 2	23	77	11.8(2)	1%
control 3	11	89		

Q 6d	agree	disagree	$\chi 2$	sig. lev.
control 1	38	62		
control 2	22	78	15.6(2)	1%
control 3	15	85		

Q 6e	agree	disagree	$\chi 2$	sig. lev.
control 1	93	7		
control 2	91	9	0.8(2)	n.s
control 3	94	6		

Q 6f	agree	disagree	$\chi 2$	sig. lev.
control 1	19	81		
control 2	14	86	1.5(2)	n.s
control 3	14	86		

Appendix R

Experiment Three Raw Data and Codings

Scotland Pupils (Year 1, 2 and 3) Frequencies

Codes	4a	4b	4c	4d	4e	5b	6C	6D	6G	box 1-3	7a	7b	8a	8b
8=	0	0	0	0	0	0	24	9	25	0	0	0	0	0
7=	0	0	0	0	0	0	35	22	28	0	0	0	0	0
6=	216	79	60	25	33	0	39	22	46	0	0	0	0	0
5=	97	46	43	21	40	0	120	75	122	0	0	0	0	0
4=	144	150	94	39	98	0	117	118	122	0	0	0	0	0
3=	118	199	156	81	222	0	114	177	110	44	0	0	0	0
2=	64	136	170	184	153	0	146	142	118	362	0	20	0	0
1=	89	106	190	367	161	145	86	116	110	261	396	14	243	217
0=	13	25	28	24	34	596	60	60	60	74	345	707	498	524

The following codes were used for scoring responses to the question 4 in the questionnaire/test:

0 - no choice made in any of the boxes, 1 - a choice of box 1, 2 - a choice of box 2, 3 - a choice of box 3, 4 - a choice of box 4, 5 - a choice of box 5, and 6 - a choice of box 6.

The following codes were used for scoring responses to question 5(b) in the questionnaire/test:

0 - no response or wrong response and 1 - correct response.

The following codes were used for scoring responses to question 6 in the questionnaire/test

0 - no response, 1 - placing one of the letters in box 1, 2 - placing one of the letters in box 2, --------- 8 - placing one of the letters in box 8.

The following codes were used for scoring responses to question 7(a) in the questionnaire/test:

0 - wrong response or no response and 1 - correct response

The following codes were used for scoring responses to question 7(b) in the questionnaire/test:

0 - wrong response or no response, 1 - any one on the correct key words stated and, 2 - any two of the correct key words stated. **(None got beyond 3 key words)**

The following codes were used for scoring responses to question 8 in the questionnaire/test:

0 - wrong response or no response, 1 - correct response.

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

Pupil	CASE	Age	Sex	Year	4a	4b	4c	4d	4e	5b	6C	6D	6G	box 1-3	7a	7b	8a	8b
10001	0	2	1	1	5	4	4	2	2	0	5	1	2	**2**	1	0	0	1
10002	0	2	1	1	2	2	1	3	2	1	5	3	2	**2**	0	0	0	0
10003	0	2	1	1	5	3	1	1	6	1	7	4	3	**1**	1	0	0	1
10004	0	2	1	1	3	5	4	5	3	0	7	6	3	**1**	1	0	0	0
10005	0	2	2	1	3	2	4	3	5	0	3	1	6	**2**	0	0	0	0
10006	0	2	1	1	4	5	3	1	3	0	3	2	5	**2**	0	0	0	0
10007	0	2	1	1	5	4	3	2	4	1	2	4	3	**2**	1	0	0	0
10008	0	2	1	1	6	1	1	1	1	0	7	1	5	**1**	1	0	0	1
10009	0	3	1	1	1	1	6	1	1	0	1	3	4	**2**	1	0	0	0
10010	0	2	1	1	2	3	1	2	1	0	2	3	5	**2**	1	0	0	0
10011	0	2	2	1	6	5	2	4	1	0	0	0	0	**0**	1	0	1	0
10012	0	2	2	1	4	3	2	1	2	0	3	4	7	**1**	0	0	0	0
10013	0	2	2	1	5	3	4	2	4	0	4	2	5	**1**	0	0	0	0
10014	0	2	1	1	4	3	2	2	4	1	2	3	1	**3**	0	0	0	0
10015	0	2	1	1	5	3	5	2	3	0	3	2	1	**3**	1	0	0	0
10016	0	2	2	1	5	3	4	2	5	0	4	2	5	**1**	0	0	0	0
10017	0	2	2	1	3	4	2	3	3	0	6	3	4	**1**	0	0	0	0
10018	0	2	1	1	6	1	1	1	1	0	1	5	8	**1**	1	0	0	0
10019	0	2	1	1	6	1	2	1	6	0	4	2	3	**2**	0	2	0	0
10020	0	2	1	1	4	2	1	5	3	0	7	3	4	**1**	1	0	1	0
10021	0	3	1	1	1	2	1	1	3	0	2	3	5	**2**	0	0	0	0
10022	0	2	1	1	1	2	3	4	5	0	7	1	2	**2**	0	0	0	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

10023	0	3	1	1	6	3	2	1	3	0	2	3	6	2	1	0	1	1
10024	0	2	1	1	1	2	1	1	2	0	2	3	4	2	0	0	0	0
10025	0	3	1	1	6	1	2	3	4	0	2	3	6	2	1	0	1	0
10026	0	2	2	1	6	6	6	6	6	0	8	3	2	2	0	0	1	1
10027	0	3	2	1	6	6	6	6	6	0	3	4	2	2	0	0	1	1
10028	0	2	2	1	4	2	4	3	2	0	3	4	2	2	1	1	1	1
10029	0	2	2	1	6	3	3	1	1	0	4	3	5	1	0	0	1	0
10030	0	2	2	1	2	3	4	2	3	1	1	2	5	2	1	0	1	1
10031	0	2	2	1	6	2	2	2	2	0	3	4	2	2	0	0	1	1
10032	0	2	2	1	4	3	2	3	4	1	4	1	3	2	0	0	1	0
20001	1	2	1	1	2	3	2	4	2	0	4	2	1	2	1	0	1	0
20002	1	3	1	1	4	3	1	1	3	0	8	5	1	1	1	0	1	0
20003	1	2	2	1	4	3	5	2	2	0	3	1	2	3	1	0	0	1
20004	1	2	2	1	6	3	2	1	3	1	5	1	3	2	1	0	0	0
20005	1	2	2	1	6	2	1	1	2	0	4	2	5	1	1	0	1	1
20006	1	2	1	1	6	1	3	1	2	1	6	4	1	1	1	0	0	1
20007	0	2	1	1	4	4	2	1	2	0	5	1	3	2	0	0	1	0
20008	1	2	1	1	4	3	2	1	3	0	4	2	5	1	1	0	1	1
20009	1	2	1	1	2	2	1	1	3	1	5	4	1	1	1	0	1	1
20010	1	2	2	1	4	3	4	1	3	0	2	5	1	2	1	0	1	0
20011	1	2	1	1	2	2	4	1	4	0	3	4	2	2	1	0	1	0
20012	1	2	2	1	5	3	4	3	4	0	3	4	1	2	1	0	1	1
20013	1	2	2	1	6	3	4	1	2	0	3	1	2	3	1	0	0	0
20014	1	2	2	1	4	4	1	1	4	1	2	4	3	2	1	0	0	1
20015	1	2	2	1	5	4	3	2	2	0	4	1	2	2	1	0	0	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

20016	0	3	1	1	6	3	1	1	1	0	3	4	5	1	0	0	0	0
20017	1	2	1	1	5	3	5	2	3	1	3	2	1	3	1	0	0	0
20018	1	2	1	1	4	4	1	2	3	0	4	3	7	1	0	0	1	1
20019	0	2	2	1	6	1	1	1	2	1	2	1	3	3	1	2	1	1
20020	0	1	1	1	5	3	3	1	3	1	7	6	2	1	1	2	0	1
20021	0	2	2	1	6	3	1	1	4	0	2	4	5	1	1	0	0	0
20022	0	2	1	1	6	6	6	6	6	0	4	1	6	1	0	0	0	0
20023	0	2	1	1	4	1	3	1	2	0	2	3	5	2	0	0	0	0
20024	0	2	1	1	3	2	1	2	3	0	5	4	1	1	1	0	1	1
20025	0	2	2	1	6	5	1	1	2	0	3	2	4	2	0	0	0	0
20026	0	2	2	1	1	1	1	1	1	0	5	7	2	1	1	0	0	0
20027	0	2	1	1	5	3	2	1	2	0	5	3	2	2	1	0	0	0
20028	0	2	2	1	6	2	3	6	4	0	4	3	1	2	1	0	0	1
20029	0	2	1	1	3	2	3	2	1	1	5	1	3	2	1	0	0	1
20030	0	3	2	1	5	3	2	3	4	0	5	1	2	2	1	0	0	0
20031	0	2	2	1	6	4	2	1	3	0	1	4	5	1	0	0	0	0
20032	0	2	2	1	1	1	2	1	3	0	4	3	1	2	1	0	0	0
20033	0	2	2	1	6	1	1	1	1	0	7	3	2	2	0	0	0	0
20034	0	2	2	1	6	1	1	1	1	0	5	3	2	2	0	0	0	0
20035	0	2	1	1	4	1	2	2	4	0	1	3	4	2	1	0	1	1
20036	0	2	1	1	6	2	4	1	6	0	3	4	2	2	0	0	0	0
20037	0	2	2	1	5	5	3	1	3	0	1	2	3	3	0	0	0	0
20038	0	2	1	1	6	3	1	2	6	0	8	7	6	0	1	0	0	1
20039	0	2	2	1	4	4	4	5	5	0	1	3	4	2	1	0	0	0
20040	0	2	1	1	6	4	2	1	1	0	3	4	2	2	1	0	0	0

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20041	0	2	2	1	6	6	3	2	1	1	1	3	4	2	1	0	0	0
20042	0	2	1	1	4	2	1	2	1	0	3	2	5	2	1	1	0	1
20043	0	2	1	1	6	2	1	1	2	0	1	3	4	2	1	0	1	0
20044	0	2	1	1	4	2	3	1	3	1	3	2	5	2	1	0	1	1
20045	0	2	2	1	0	3	3	2	0	0	2	7	6	1	1	0	0	0
20046	0	2	2	1	5	4	2	1	3	0	2	5	4	1	0	0	0	0
20047	0	2	2	1	4	0	2	1	2	1	3	5	4	1	1	0	0	0
20048	0	3	2	1	2	0	2	2	0	1	2	4	3	2	0	0	0	0
20049	0	2	2	1	6	6	1	1	1	0	2	5	1	2	0	0	0	0
30001	0	2	1	1	5	4	2	2	3	0	2	1	0	2	0	0	0	0
30002	0	2	2	1	6	6	2	6	5	0	6	5	1	1	1	1	0	1
30003	0	2	2	1	6	5	5	5	4	0	8	1	3	2	1	0	0	0
30004	0	2	2	1	3	6	4	1	1	0	5	2	6	1	0	0	0	0
30005	0	2	1	1	3	2	5	4	3	0	4	5	1	1	1	0	0	1
30006	0	2	1	1	3	2	4	1	3	1	2	4	3	2	1	0	1	1
30007	0	2	2	1	4	2	3	1	2	0	1	3	2	3	1	0	1	0
30008	0	2	1	1	0	1	0	0	0	0	6	7	1	1	0	0	0	0
30009	0	2	2	1	5	2	3	2	3	0	5	3	2	2	1	0	1	1
30010	0	2	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0
30011	0	2	1	1	1	6	1	1	1	0	3	4	7	1	1	0	0	0
30012	0	2	1	1	6	0	1	1	0	0	2	3	8	2	0	0	0	0
30013	0	2	1	1	5	1	5	1	4	1	1	4	2	2	0	0	0	1
30014	0	2	2	1	6	2	3	1	5	0	7	5	1	1	0	0	0	0
30015	0	2	2	1	4	4	3	3	3	0	2	3	4	2	0	0	0	0
30016	0	2	1	1	6	3	3	3	4	0	3	2	4	2	1	0	0	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

30017	0	2	2	1	4	4	2	1	3	0	5	1	3	2	0	0	0	0
30018	0	2	1	1	6	2	3	1	1	1	2	3	1	3	0	0	0	0
30019	0	2	2	1	6	6	3	1	3	0	3	4	2	2	0	0	0	0
30020	0	3	2	1	6	6	1	5	3	0	3	4	2	2	0	0	0	0
30021	0	2	1	1	3	3	1	2	4	0	5	2	1	2	0	0	0	0
30022	0	2	1	1	4	1	1	1	3	0	3	5	6	1	0	0	1	0
30023	0	2	1	1	1	1	1	1	1	1	3	2	4	2	1	0	0	1
30024	0	2	1	1	6	2	3	1	1	0	0	0	0	0	0	0	0	0
30025	0	2	1	1	5	3	3	2	4	0	5	4	7	0	0	0	0	0
30026	0	3	2	1	6	0	0	0	0	0	4	5	8	0	0	0	0	1
30027	0	2	1	1	3	4	3	2	2	0	1	6	5	1	0	0	1	0
30028	0	2	2	1	6	3	1	1	1	0	3	4	6	1	1	0	0	0
30029	0	2	2	1	6	3	3	3	3	0	3	4	8	1	0	0	0	0
30030	0	2	2	1	5	4	4	3	4	0	0	0	0	0	0	0	0	0
30031	0	2	1	1	5	2	5	1	3	0	4	2	3	2	1	0	0	0
30032	0	2	1	1	1	3	6	4	3	0	0	0	1	1	1	0	0	0
30033	0	2	1	1	3	3	3	2	3	0	5	2	4	1	1	0	0	0
30034	0	2	2	1	2	2	6	1	2	0	2	7	6	1	1	0	0	0
30035	0	2	2	1	4	4	3	3	5	0	5	4	1	1	0	0	0	0
30036	0	2	1	1	6	4	6	3	4	0	0	0	0	0	0	0	0	0
30037	0	2	2	1	4	4	1	6	3	0	2	5	4	1	0	0	0	0
30038	0	2	2	1	4	4	3	2	3	0	2	3	5	2	0	0	0	0
30039	0	2	2	1	4	4	2	2	5	0	1	3	5	2	1	1	0	0
30040	0	2	1	1	1	2	3	2	5	1	3	2	1	3	1	0	0	1
30041	0	2	2	1	5	3	2	1	4	0	1	4	6	1	1	0	0	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

30042	0	2	1	1	2	3	3	2	3	0	2	3	4	2	0	0	0	0
30043	0	2	1	1	6	3	3	1	1	0	2	3	5	2	1	0	0	0
30044	0	2	1	1	6	5	4	0	5	0	0	0	0	0	1	0	0	0
30045	0	2	1	1	4	2	2	2	2	0	7	3	4	1	1	0	0	0
30046	0	3	2	1	5	4	2	1	4	0	4	5	1	1	1	0	0	0
30047	0	2	2	1	6	4	1	1	3	0	4	3	2	2	0	0	0	0
30048	0	2	2	1	6	6	4	3	4	0	3	1	5	2	0	0	0	0
30049	0	2	2	1	6	6	1	1	6	0	0	0	0	0	0	0	0	0
30050	0	2	1	1	6	6	1	3	1	0	2	5	4	1	1	0	0	0
30051	0	3	2	1	3	6	3	3	4	0	3	2	7	2	1	0	0	0
30052	0	2	2	1	3	4	1	3	1	0	5	3	2	2	0	0	0	0
30053	0	3	2	1	5	4	2	4	5	0	6	4	8	0	1	0	0	0
30054	0	2	2	1	6	6	6	1	1	0	6	4	7	0	1	0	0	0
30055	0	2	1	1	6	5	2	1	3	0	0	0	0	0	0	0	0	0
30056	0	2	1	1	6	4	2	1	5	0	0	0	0	0	0	0	0	0
30057	0	2	1	1	3	4	3	3	3	0	0	0	0	0	0	0	0	0
30058	0	2	1	1	6	6	1	1	1	0	0	0	0	0	0	0	0	0
30059	0	2	2	1	5	3	4	1	2	0	3	1	4	2	1	0	0	0
30060	0	2	2	1	5	3	4	4	3	0	4	2	3	2	1	0	0	0
30061	0	2	2	1	3	6	6	1	3	0	0	0	0	0	0	0	0	0
30062	0	2	1	1	1	1	3	1	2	0	1	2	3	3	0	0	0	0
30063	0	2	2	1	5	2	2	4	6	0	2	3	4	2	1	0	0	0
30064	0	2	2	1	4	2	2	1	6	0	1	2	4	2	1	0	0	0
30065	0	2	1	1	0	1	0	0	0	0	3	1	4	2	1	0	0	0
30066	0	2	2	1	6	6	3	1	2	0	0	0	0	0	0	0	0	0

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30067	0	2	2	1	6	6	2	1	1	0	2	6	3	2	0	0	0	0
30068	0	2	1	1	4	3	2	2	3	0	4	2	1	2	1	0	0	0
30069	0	2	2	1	4	3	3	2	1	1	2	1	4	2	1	1	1	0
30070	0	2	2	1	6	6	1	1	3	1	2	1	4	2	1	0	1	0
30071	0	3	1	1	1	3	2	1	1	0	6	2	5	1	0	0	0	0
30072	0	3	2	1	6	4	2	0	1	0	0	2	0	1	0	0	0	0
30073	0	2	2	1	2	3	2	1	3	1	3	1	5	2	0	0	0	0
30074	0	3	2	1	2	3	2	2	3	1	8	1	2	2	0	0	0	0
30075	0	2	1	1	4	2	6	1	4	0	3	7	4	1	0	0	0	0
30076	0	2	1	1	5	3	2	1	4	0	5	4	1	1	0	0	1	0
30077	0	2	1	1	5	1	1	4	3	0	3	4	7	1	0	0	1	1
30078	0	3	1	1	6	5	0	3	1	0	7	5	4	0	1	0	1	0
30079	0	2	2	1	6	6	6	1	1	0	6	3	1	2	1	0	0	0
30080	0	2	1	1	6	6	2	2	6	0	8	3	5	1	0	0	0	0
30081	0	2	1	1	5	1	2	1	3	0	3	5	2	2	0	0	1	0
30082	0	2	1	1	3	3	4	1	3	0	1	4	5	1	0	0	0	0
30083	0	2	2	1	2	3	1	2	3	0	5	3	2	2	1	0	0	1
30084	0	2	2	1	4	3	1	2	4	1	1	4	2	2	1	1	0	0
30085	0	2	2	1	4	2	4	2	4	0	5	3	2	2	1	0	0	0
30086	0	2	2	1	6	4	2	2	1	0	4	5	1	1	1	0	1	0
30087	0	2	2	1	1	1	3	6	1	0	4	3	2	2	0	0	0	0
30088	0	2	1	1	5	2	6	1	3	0	5	2	3	2	0	0	0	0
30089	0	2	2	1	6	2	5	2	1	1	1	4	7	1	1	0	0	0
30090	0	2	2	1	6	3	2	3	4	0	6	8	2	1	1	0	0	0
30091	0	3	1	1	1	1	1	1	1	0	6	7	3	1	1	0	0	0

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30092	0	2	1	1	6	6	6	1	6	0	8	5	2	1	1	0	0	0
30093	0	3	1	1	6	4	1	1	6	0	2	1	4	2	1	0	0	0
30094	0	2	2	1	6	6	6	1	1	0	1	4	2	2	1	0	1	1
30095	0	2	1	1	5	5	4	2	3	0	1	3	2	3	1	0	1	0
30096	0	2	2	1	5	2	2	2	2	0	2	3	1	3	1	0	0	0
30097	0	2	1	1	1	1	1	1	1	0	2	7	5	1	1	0	0	1
30098	0	2	1	1	4	1	2	1	2	0	1	4	2	2	1	0	1	0
30099	0	2	2	1	3	4	2	1	1	0	3	2	1	3	1	0	1	1
30100	0	2	2	1	4	3	2	3	5	0	2	5	4	1	1	0	0	1
30101	0	2	2	1	5	6	4	4	4	1	4	1	5	1	1	0	0	0
30102	0	2	1	1	5	4	3	1	3	0	3	4	2	2	1	0	1	0
30103	0	2	2	1	5	4	3	2	2	0	2	3	4	2	0	0	1	1
11001	0	3	2	2	6	4	5	2	2	0	3	4	2	2	1	0	1	0
11002	0	3	1	2	3	4	6	2	3	0	4	2	1	2	1	0	1	0
11003	0	3	1	2	6	1	6	1	1	0	4	2	8	1	0	0	0	0
11004	0	3	1	2	6	2	2	1	3	0	2	3	4	2	0	0	1	0
11005	0	3	1	2	6	1	3	1	1	0	5	2	1	2	1	1	1	1
11006	0	3	1	2	5	4	3	2	3	0	5	2	3	2	0	0	1	0
11007	0	3	2	2	4	1	2	2	1	0	4	1	5	1	1	0	0	0
11008	0	4	2	2	3	1	1	1	2	1	3	4	1	2	0	0	1	0
11009	0	3	2	2	3	6	2	1	3	0	6	5	1	1	1	0	0	0
11010	0	3	2	2	6	6	6	2	2	0	5	3	1	2	0	0	0	0
11011	0	3	2	2	4	4	5	2	2	0	8	4	3	1	0	0	0	0
11012	0	3	2	2	3	3	3	1	2	0	5	3	4	1	1	0	1	1
11013	0	3	2	2	4	3	6	5	2	1	6	2	3	2	0	0	1	1

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11014	0	4	2	2	4	6	6	1	4	0	0	0	0	0	0	0	1	0
11015	0	3	2	2	3	3	2	2	3	0	3	4	1	2	0	0	1	1
11016	0	3	1	2	1	4	1	2	4	0	3	5	2	2	0	0	1	0
11017	0	3	2	2	6	6	6	1	6	0	3	2	1	3	1	0	1	0
11018	0	3	2	2	3	4	2	1	2	0	6	5	2	1	0	0	1	1
11019	0	3	2	2	2	5	2	1	1	0	5	2	3	2	0	0	1	1
11020	0	3	1	2	4	3	4	2	4	1	5	3	4	1	0	0	1	1
11021	0	3	1	2	6	4	5	5	4	0	3	5	6	1	0	0	0	0
11022	0	3	2	2	4	2	4	1	2	1	4	1	3	2	0	0	1	1
11023	0	4	2	2	5	5	2	1	5	0	8	1	3	2	1	0	1	1
11024	0	3	2	2	4	0	4	1	2	0	2	5	3	2	1	0	1	1
11025	0	3	2	2	6	5	2	1	3	1	3	6	5	1	1	0	0	1
11026	0	4	2	2	5	4	0	1	1	0	1	3	4	2	0	0	1	0
11027	0	3	2	2	3	5	3	1	0	1	4	1	6	1	0	0	0	0
11028	0	3	2	2	4	6	6	5	3	0	1	3	2	3	1	0	0	0
11029	0	4	1	2	6	1	1	6	6	0	8	3	1	2	1	0	0	0
11030	0	3	1	2	1	1	1	1	6	0	5	4	2	1	1	0	0	0
11031	0	3	2	2	1	6	6	1	6	1	4	1	3	2	0	0	0	0
11032	0	3	1	2	6	4	3	1	3	0	2	1	5	2	0	0	0	0
11033	0	3	2	2	3	4	3	1	0	1	4	1	8	1	1	0	0	0
11034	0	3	1	2	4	3	5	1	4	1	3	4	5	1	0	0	0	0
11035	0	4	2	2	6	4	4	1	0	0	0	0	0	0	1	0	0	0
11036	0	3	2	2	3	4	3	1	0	0	2	4	6	1	0	0	0	0
11037	0	3	1	2	2	3	3	1	3	0	4	1	3	2	0	0	0	0
11038	0	3	2	2	5	3	4	3	2	1	4	5	2	1	1	0	1	1

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11039	0	3	2	2	1	1	0	3	4	0	1	2	3	3	0	0	0	0
11040	0	3	2	2	6	1	3	3	1	0	1	2	3	3	0	0	0	0
11041	0	3	1	2	5	4	2	6	1	0	8	5	3	1	1	0	0	1
11042	0	3	1	2	3	3	4	2	1	1	5	2	4	1	0	0	1	1
11043	0	3	1	2	5	3	5	4	6	1	7	3	8	1	1	0	0	0
11044	0	3	1	2	3	3	2	3	2	0	6	1	4	1	1	0	1	0
11045	0	3	2	2	3	3	4	1	1	0	5	1	2	2	1	0	1	1
11046	0	3	2	2	3	3	5	1	1	0	2	5	4	1	1	0	1	1
11047	0	4	2	2	4	3	5	3	3	0	3	4	1	2	1	0	1	0
11048	0	4	2	2	3	2	3	2	2	1	1	3	5	2	1	0	0	0
11049	0	3	2	2	3	4	1	1	1	1	7	1	4	1	1	0	0	1
11050	0	3	1	2	3	3	2	2	5	0	1	2	4	2	1	0	0	0
11051	0	4	2	2	4	3	4	1	2	0	1	4	5	1	1	0	1	0
11052	0	3	1	2	4	3	5	4	2	0	1	2	4	2	0	0	1	0
11053	0	3	2	2	3	4	4	3	4	0	1	3	5	2	1	0	0	1
11054	0	3	1	2	3	2	3	1	1	0	1	3	6	2	1	0	0	0
11055	0	3	1	2	3	3	4	1	3	1	1	4	3	2	1	0	0	1
11056	0	3	1	2	3	4	3	1	1	0	5	3	1	2	1	0	0	1
11057	0	3	2	2	6	3	6	1	3	0	5	3	1	2	1	0	0	0
11058	0	3	1	2	5	4	2	5	6	0	5	3	1	2	1	0	0	0
11059	0	3	2	2	3	5	6	2	2	1	3	5	1	2	1	0	1	1
11060	0	3	1	2	6	1	3	1	1	0	2	4	3	2	0	0	0	0
11061	0	4	1	2	6	4	2	1	2	0	7	3	2	2	1	0	0	1
11062	0	3	2	2	3	3	6	2	1	1	3	5	1	2	1	0	1	1
11063	0	3	1	2	1	4	6	1	3	1	2	3	5	2	1	0	1	0

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11064	0	3	1	2	6	4	2	0	3	0	5	7	6	0	0	0	0	0
11065	0	3	2	2	4	5	2	2	2	1	3	1	5	2	1	0	0	0
11066	0	3	2	2	4	3	5	2	3	1	1	2	3	3	0	0	0	0
11067	0	3	1	2	1	4	6	1	6	0	2	7	5	1	1	0	0	0
11068	0	3	2	2	3	3	4	1	2	1	4	3	5	1	0	0	1	0
11069	0	4	2	2	3	4	5	1	3	1	1	2	4	2	0	0	1	0
11070	0	3	1	2	6	4	3	4	3	1	2	3	5	2	0	0	0	0
11071	0	3	1	2	4	2	2	1	4	0	4	1	3	2	1	0	0	1
21001	1	3	2	2	3	4	4	2	1	0	2	3	5	2	0	0	1	0
21002	1	3	2	2	4	4	3	3	3	1	4	1	5	1	1	1	1	0
21003	1	3	2	2	3	4	3	3	3	1	4	1	5	1	0	0	1	0
21004	1	3	1	2	6	3	1	1	3	0	4	2	3	2	1	0	1	0
21005	1	3	2	2	6	6	1	1	2	0	3	5	4	1	0	0	0	0
21006	0	4	2	2	3	3	5	2	5	0	1	5	3	2	1	0	0	0
21007	1	3	2	2	4	3	2	3	4	0	3	2	1	3	1	0	1	0
21008	1	3	2	2	3	2	3	1	4	0	1	2	5	2	0	0	0	0
21009	1	3	2	2	6	2	3	1	1	0	3	2	1	3	1	0	1	0
21010	1	4	2	2	5	2	4	1	2	0	2	5	3	2	1	0	0	0
21011	0	4	1	2	1	2	6	2	4	0	4	1	5	1	1	0	1	1
21012	1	3	1	2	5	2	2	2	5	0	1	2	5	2	1	0	0	1
21013	1	3	1	2	3	1	2	1	3	1	5	4	3	1	1	0	1	0
21014	1	2	1	2	4	2	4	1	5	1	1	5	4	1	1	0	1	1
21015	0	3	2	2	4	4	6	3	2	1	4	3	2	2	1	2	0	1
21016	0	3	1	2	4	5	4	1	3	1	4	7	3	1	1	0	0	1
21017	0	3	1	2	6	1	1	1	3	1	5	4	3	1	0	0	0	0

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21018	0	3	2	2	4	0	0	0	0	1	5	4	2	1	1	0	0	0
21019	0	3	2	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0
21020	0	3	1	2	6	2	3	2	3	1	5	4	2	1	1	0	0	0
21021	0	3	1	2	2	1	1	1	3	1	1	2	3	3	1	0	1	0
21022	0	3	1	2	6	6	6	1	6	1	8	4	1	1	0	0	0	0
21023	0	3	1	2	4	3	3	1	3	1	2	3	4	2	1	0	1	1
21024	0	3	1	2	6	1	1	1	1	0	3	1	7	2	0	2	1	1
21025	0	3	1	2	6	2	4	5	3	1	1	2	3	3	1	0	0	0
21026	0	3	1	2	5	2	1	4	3	0	4	2	3	2	0	0	0	0
21027	0	3	2	2	3	2	3	2	2	1	2	1	4	2	1	0	0	1
21028	0	3	1	2	3	2	1	2	3	1	1	3	4	2	1	0	0	1
21029	0	3	2	2	5	4	2	2	1	0	1	2	4	2	1	0	0	1
21030	0	3	2	2	6	4	5	2	3	0	5	4	2	1	0	0	1	1
21031	0	3	2	2	4	3	2	2	2	0	1	3	2	3	0	0	0	0
21032	0	3	2	2	5	4	3	3	2	0	5	1	2	2	0	0	0	0
21033	0	3	2	2	4	4	4	2	2	0	5	3	2	2	0	0	0	0
21034	0	4	1	2	3	5	2	6	4	0	5	3	4	1	0	0	0	0
21035	0	3	1	2	2	4	2	2	2	0	2	3	4	2	0	0	1	0
21036	0	3	2	2	2	6	3	4	3	0	2	4	8	1	1	0	1	0
21037	0	3	2	2	2	2	2	3	3	0	1	3	7	2	1	0	0	0
21038	0	3	1	2	3	2	3	2	2	1	2	5	3	2	1	0	1	1
21039	0	3	2	2	6	3	4	1	2	1	5	3	2	2	0	0	1	1
21040	0	3	2	2	1	1	2	1	3	1	4	3	2	2	0	0	1	1
21041	0	3	2	2	2	3	4	2	2	0	2	1	5	2	1	0	1	0
21042	0	3	2	2	4	4	2	3	2	1	4	3	2	2	0	0	0	1

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21043	1	3	1	2	4	4	3	2	3	0	6	3	2	2	0	0	1	0
21044	0	3	1	2	3	3	4	4	3	0	7	3	2	2	1	0	0	0
21045	0	3	1	2	3	3	4	4	5	0	5	3	4	1	0	0	1	0
21046	0	3	2	2	5	4	6	2	4	0	3	2	1	3	1	0	0	0
21047	0	3	2	2	6	4	4	2	3	0	1	3	4	2	0	0	0	0
21048	0	3	1	2	1	1	2	1	3	0	5	4	2	1	1	0	0	1
21049	0	3	1	2	2	2	2	1	3	1	1	4	3	2	1	0	0	1
21050	0	3	2	2	6	6	1	1	1	0	1	5	0	1	1	0	1	0
21051	0	3	1	2	5	3	2	3	3	0	5	2	3	2	1	0	0	0
21052	0	4	1	2	3	4	3	1	3	0	2	5	3	2	1	0	0	0
21053	0	3	2	2	2	3	3	1	3	0	2	3	4	2	1	0	0	0
21054	0	3	1	2	2	3	2	1	2	0	1	4	2	2	0	0	0	1
21055	0	3	2	2	6	5	1	1	3	0	5	6	3	1	0	0	0	1
21056	0	4	1	2	4	3	2	2	2	0	1	3	4	2	1	0	1	0
21057	0	3	2	2	6	4	1	1	1	0	2	3	4	2	0	0	0	0
21058	0	3	1	2	6	3	2	1	2	0	5	1	2	2	1	0	0	0
21059	0	3	1	2	5	1	1	3	6	0	4	8	3	1	1	0	1	0
31001	0	3	2	2	3	4	4	3	2	0	4	5	1	1	1	0	0	1
31002	0	3	1	2	1	6	1	3	1	0	1	4	6	1	1	0	0	0
31003	0	3	2	2	3	2	2	3	2	0	5	4	1	1	0	0	1	0
31004	0	3	1	2	0	0	0	1	0	0	3	4	5	1	1	0	0	0
31005	0	3	1	2	2	2	2	3	2	0	7	3	5	1	1	1	1	1
31006	0	3	2	2	0	1	1	1	0	0	3	4	6	1	1	1	0	1
31007	0	3	1	2	6	2	1	3	3	0	4	7	3	1	0	0	0	0
31008	0	2	2	2	4	2	1	1	3	0	2	5	1	2	1	0	0	1

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31009	0	3	2	2	6	6	1	1	3	0	1	2	5	2	1	0	0	0
31010	0	3	1	2	1	3	3	2	4	0	1	3	5	2	0	0	0	0
31011	0	3	2	2	5	2	1	3	4	1	3	2	4	2	0	0	1	0
31012	0	3	2	2	6	3	1	0	4	0	7	8	2	1	1	0	0	0
31013	0	3	1	2	5	4	1	2	3	0	1	4	5	1	1	0	0	1
31014	0	3	1	2	6	3	4	1	2	0	0	0	0	0	1	0	0	1
31015	0	3	1	2	6	2	3	1	2	0	1	2	4	2	1	0	0	1
31016	0	3	2	2	6	6	1	1	1	0	4	2	1	2	1	0	0	1
31017	0	3	2	2	5	2	1	1	3	1	6	2	7	1	1	0	1	1
31018	0	3	2	2	1	2	1	2	3	0	5	1	2	2	0	0	1	1
31019	0	3	1	2	6	3	1	1	2	0	2	5	4	1	0	0	0	0
31020	0	3	2	2	3	3	4	4	5	0	3	1	5	2	0	0	0	0
31021	0	3	1	2	6	2	2	1	1	0	3	1	5	2	1	0	0	0
31022	0	3	2	2	4	3	1	1	3	0	5	3	1	2	1	0	0	0
31023	0	3	2	2	4	3	1	1	3	0	5	3	1	2	1	0	0	0
31024	0	3	2	2	4	3	1	1	2	0	5	3	1	2	1	0	0	1
31025	0	3	1	2	6	4	1	2	2	0	5	3	1	2	1	0	1	0
31026	0	3	2	2	6	5	2	3	5	0	3	4	5	1	0	0	0	0
31027	0	3	1	2	3	6	1	2	4	0	2	4	7	1	0	0	0	0
31028	0	3	2	2	6	1	0	0	0	0	3	2	1	3	0	0	0	1
31029	0	3	1	2	1	1	1	6	6	0	5	1	2	2	1	0	0	0
31030	0	3	1	2	1	2	3	1	4	0	6	8	1	1	0	0	1	0
31031	0	3	1	2	2	3	1	6	6	0	5	1	2	2	1	0	0	0
31032	0	3	1	2	6	2	2	4	3	1	7	3	4	1	0	0	0	0
31033	0	3	1	2	4	5	2	1	2	0	2	1	7	2	0	0	0	1

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31034	0	3	2	2	3	3	1	1	1	0	2	5	1	2	0	0	0	0
31035	0	3	1	2	5	2	2	5	3	1	7	3	4	1	0	0	0	0
31036	0	3	1	2	6	6	1	6	4	0	7	2	3	2	0	0	0	0
31037	0	3	2	2	6	5	1	1	1	0	3	4	5	1	0	0	1	1
31038	0	3	2	2	3	5	3	3	4	1	5	2	4	1	0	0	1	1
31039	0	3	2	2	2	4	2	3	5	1	4	1	6	1	0	0	1	1
31040	0	3	2	2	1	0	0	0	0	0	3	2	4	2	1	0	1	0
31041	0	3	2	2	5	3	2	1	2	0	3	2	5	2	1	0	1	0
31042	0	3	2	2	2	3	1	2	4	1	5	3	4	1	0	0	0	0
31043	0	3	2	2	5	2	5	1	4	0	3	2	5	2	1	0	1	0
31044	0	3	2	2	1	5	1	1	3	0	5	2	7	1	1	0	1	1
31045	0	3	1	2	6	5	1	1	2	1	7	6	8	0	1	0	1	0
31046	0	3	1	2	6	1	1	2	4	1	2	6	5	1	1	0	0	0
41047	0	3	1	2	4	2	2	1	2	1	5	3	4	1	1	0	0	0
31048	0	3	1	2	2	4	2	1	3	0	3	2	4	2	1	0	0	0
31049	0	3	2	2	6	5	1	2	3	0	5	3	4	1	0	0	0	0
31050	0	3	1	2	6	5	2	5	1	1	3	2	4	2	1	0	0	0
31051	0	3	1	2	4	3	4	2	3	0	2	8	5	1	1	0	1	1
31052	0	3	1	2	6	4	5	1	2	0	0	0	0	0	1	0	1	0
31053	0	3	2	2	1	3	1	1	2	0	2	3	4	2	0	0	1	0
31054	0	3	1	2	3	3	3	2	2	0	2	1	3	3	1	0	0	0
31055	0	3	2	2	2	1	3	1	4	0	4	3	5	1	0	0	0	1
31056	0	3	1	2	4	2	1	2	3	0	0	0	0	0	0	0	0	0
31057	0	3	2	2	1	3	2	2	4	1	5	3	1	2	0	0	0	1
31058	0	3	2	2	6	5	4	1	2	0	3	4	6	1	1	0	0	0

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31059	0	3	1	2	3	4	2	1	4	1	3	1	6	2	0	0	1	0
31060	0	3	1	2	3	3	1	3	2	0	2	1	4	2	1	0	0	0
31061	0	3	2	2	6	3	2	3	5	0	3	4	7	1	1	0	0	1
31062	0	3	1	2	1	1	1	1	3	1	0	0	0	0	1	0	0	0
31063	0	3	1	2	4	3	2	1	4	0	5	7	2	1	1	0	0	0
31064	0	3	2	2	6	1	1	1	3	0	1	2	6	2	1	0	0	0
31065	0	3	2	2	1	3	1	1	1	0	1	2	6	2	1	0	1	0
31066	0	3	2	2	3	3	1	1	1	0	5	1	2	2	1	0	1	0
31067	0	3	1	2	1	1	1	1	1	0	5	3	4	1	1	0	1	0
31068	0	3	2	2	1	3	1	1	1	0	3	2	1	3	1	0	1	0
31069	0	3	1	2	2	4	6	2	3	0	3	2	6	2	1	0	1	0
31070	0	3	1	2	4	5	3	1	3	0	4	3	5	1	0	0	0	0
31071	0	3	1	2	5	1	1	1	2	0	5	1	4	1	1	0	0	0
31072	0	3	1	2	2	3	3	2	4	0	3	1	5	2	0	0	0	0
31073	0	3	2	2	4	3	1	3	3	0	7	4	1	1	0	0	0	0
31074	0	3	2	2	6	1	3	1	2	0	4	3	5	1	0	0	0	0
31075	0	2	1	2	3	2	2	2	2	0	5	3	2	2	0	0	1	0
31076	0	3	1	2	4	4	2	3	2	0	2	4	5	1	0	0	0	0
31077	0	3	2	2	1	6	1	1	6	0	2	3	4	2	1	0	0	0
31078	0	4	2	2	4	3	1	4	2	0	5	1	3	2	0	0	0	0
31079	0	3	2	2	4	6	4	4	4	0	2	3	1	3	1	0	1	1
31080	0	3	1	2	4	2	1	1	5	1	7	3	5	1	1	0	0	0
31081	0	2	1	2	1	1	0	2	6	0	5	1	3	2	1	0	1	1
31082	0	3	1	2	4	2	3	2	2	1	1	3	2	3	1	0	0	1
31083	0	3	1	2	5	4	1	1	2	0	4	5	3	1	1	0	0	1

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31084	0	3	2	2	6	0	0	0	0	0	0	0	0	0	1	0	0	1
31085	0	3	2	2	3	4	3	4	3	0	3	4	1	2	0	0	0	1
31086	0	3	2	2	1	0	1	0	1	0	3	4	6	1	1	0	0	0
31087	0	3	2	2	6	2	3	2	3	0	4	2	3	2	1	0	0	0
31088	0	3	2	2	2	4	3	1	2	0	2	4	3	2	1	0	1	1
31089	0	3	2	2	3	4	3	2	3	0	0	0	0	0	1	0	1	0
31090	0	3	2	2	3	4	3	2	2	0	2	6	3	2	1	0	1	1
31091	0	3	2	2	4	3	2	2	2	0	6	5	4	0	1	0	1	1
31092	0	3	2	2	4	3	3	4	3	0	2	0	3	2	1	0	1	0
31093	0	3	1	2	4	4	2	3	4	0	2	3	5	2	1	0	0	1
31094	0	3	1	2	6	3	6	1	3	0	4	5	2	1	0	0	0	0
31095	0	3	2	2	2	1	3	1	1	1	2	5	6	1	0	0	0	0
31096	0	3	1	2	2	1	1	1	2	0	3	2	1	3	0	0	1	0
31097	0	3	2	2	5	1	1	2	3	0	4	5	1	1	0	0	0	1
31098	0	3	1	2	2	1	1	1	1	1	1	2	5	2	1	0	0	0
31099	0	3	2	2	2	3	4	2	2	0	3	1	4	2	1	0	1	0
31100	0	4	2	2	4	4	3	4	3	0	5	1	2	2	0	0	0	0
31101	0	3	2	2	4	1	1	1	1	0	2	4	5	1	1	0	0	0
31102	0	3	1	2	6	3	4	5	3	0	2	3	7	2	0	0	0	0
31103	0	4	1	2	6	3	6	1	3	0	3	2	5	2	0	0	0	0
31104	0	3	1	2	5	4	4	2	1	1	4	2	1	2	0	0	0	1
31105	0	3	2	2	3	4	1	3	2	0	3	4	2	2	0	0	0	1
31106	0	3	2	2	2	1	2	3	2	0	2	4	1	2	1	0	0	0
31107	0	3	2	2	3	2	1	1	2	0	5	2	1	2	0	0	0	0
31108	0	3	2	2	6	4	4	1	4	0	0	0	0	0	0	0	0	0

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31109	0	3	1	2	3	5	3	4	3	1	5	6	3	1	1	0	1	1
12001	0	4	1	3	3	6	1	2	4	0	0	0	0	0	0	0	0	0
12002	0	4	1	3	1	3	6	2	1	0	3	1	7	2	0	0	0	0
12003	0	4	1	3	2	6	6	1	3	0	1	5	8	1	0	0	0	1
12004	0	4	1	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0
12005	0	4	1	3	5	4	6	1	3	0	2	3	1	3	1	0	0	0
12006	0	4	1	3	0	0	0	1	0	0	3	2	6	2	0	0	1	0
12007	0	4	1	3	0	0	0	1	0	0	3	2	6	2	0	0	1	0
12008	0	4	1	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0
12009	0	4	1	3	1	2	3	4	5	0	0	0	0	0	0	0	0	0
12010	0	4	1	3	6	6	1	1	1	0	4	6	7	0	0	0	0	0
12011	0	4	1	3	0	1	0	0	0	0	6	5	2	1	0	0	0	0
12012	0	4	1	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0
12013	0	4	1	3	6	5	4	3	2	0	6	2	5	1	0	0	0	0
12014	0	4	1	3	0	0	0	0	0	0	3	2	5	2	0	0	0	0
12015	0	4	1	3	6	3	2	1	1	0	3	5	1	2	1	0	0	0
12016	0	4	1	3	0	1	0	1	0	0	3	5	1	2	1	0	0	0
12017	0	4	1	3	1	2	5	3	3	0	1	8	5	1	0	0	0	0
12018	0	4	2	3	6	3	1	2	2	0	2	4	8	1	1	0	0	0
12019	0	4	2	3	6	4	1	2	2	0	2	4	8	1	0	0	0	0
12020	0	4	2	3	6	3	1	2	4	0	2	4	8	1	1	0	0	1
12021	0	4	2	3	6	4	1	3	4	0	2	4	8	1	0	0	0	1
12022	0	4	2	3	6	3	5	6	2	0	1	4	3	2	1	0	0	0
12023	0	4	2	3	6	4	3	1	4	0	0	0	0	0	0	0	0	0
12024	0	4	1	3	6	3	3	2	5	0	5	3	4	1	1	0	1	1

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12025	0	4	1	3	6	3	4	6	5	0	4	7	2	1	1	0	0	1
12026	0	4	1	3	4	3	6	1	2	0	5	2	4	1	1	0	0	0
12027	0	5	1	3	6	4	6	6	1	0	8	4	5	0	1	0	0	1
12028	0	4	2	3	5	4	5	2	3	0	5	1	6	1	1	0	0	0
12029	0	4	2	3	1	6	1	0	1	0	0	0	0	0	0	0	0	0
12030	0	4	2	3	6	1	1	1	1	0	0	0	0	0	0	0	0	0
12031	0	4	2	3	1	4	2	2	4	0	2	1	4	2	0	0	0	0
12032	0	4	1	3	6	6	4	1	5	0	8	5	2	1	1	0	0	0
12033	0	4	2	3	6	6	6	1	3	1	2	3	4	2	0	0	0	0
12034	0	4	2	3	6	6	6	1	1	0	2	1	4	2	0	0	0	0
12035	0	4	2	3	6	4	1	1	1	0	3	2	7	2	0	0	0	0
12036	0	4	2	3	4	6	3	1	2	0	2	3	8	2	1	0	0	0
12037	0	4	2	3	6	5	2	1	3	0	4	1	5	1	0	0	1	1
12038	0	4	2	3	6	6	1	1	1	0	2	3	5	2	1	0	0	1
12039	0	4	1	3	6	4	6	6	1	0	2	4	5	1	0	0	0	0
22001	0	4	1	3	3	3	2	5	1	0	4	1	3	2	1	0	1	0
22002	0	4	1	3	4	3	3	2	3	0	3	1	4	2	1	0	0	1
22003	0	4	1	3	5	6	1	1	1	0	4	2	3	2	1	0	1	1
22004	0	5	1	3	4	2	3	1	1	0	5	7	8	0	1	0	0	0
22005	1	4	1	3	6	1	6	1	6	0	1	4	2	2	1	0	1	1
22006	0	4	1	3	1	1	2	1	1	1	1	2	4	2	0	2	1	1
22007	0	4	1	3	2	3	5	2	1	0	1	2	5	2	1	0	1	1
22008	0	4	1	3	3	2	3	1	2	0	4	1	2	2	1	0	0	0
22009	0	4	1	3	2	4	5	1	3	1	0	0	0	0	1	0	0	0
22010	0	4	1	3	4	2	4	6	1	0	3	2	4	2	1	0	1	1

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22011	1	4	1	3	4	4	3	2	4	1	1	2	5	2	1	0	1	0
22012	0	4	2	3	2	1	2	1	2	0	4	3	2	2	1	0	1	1
22013	0	4	2	3	3	3	1	1	3	0	8	1	2	2	1	0	1	1
22014	0	4	1	3	1	3	4	6	1	0	5	3	2	2	0	0	0	0
22015	0	4	1	3	4	4	3	1	2	0	5	1	4	1	0	0	1	1
22016	0	4	1	3	5	2	1	1	2	1	2	4	5	1	1	0	0	1
22017	0	4	1	3	1	6	1	1	6	0	5	2	6	1	0	0	0	1
22018	1	4	1	3	1	3	3	2	4	1	2	3	4	2	1	0	0	0
22019	1	5	1	3	2	3	5	1	1	1	4	5	3	1	1	0	0	1
22020	0	4	1	3	6	1	6	1	1	0	8	1	6	1	1	0	0	0
22021	0	4	1	3	6	4	2	1	1	0	2	8	3	2	1	0	0	1
22022	0	5	1	3	3	2	6	5	3	0	2	7	4	1	0	0	0	0
22023	0	4	1	3	3	2	1	1	3	1	5	2	3	2	0	0	0	0
22024	0	4	1	3	5	4	2	1	3	0	7	2	3	2	1	0	1	0
22025	0	4	1	3	5	4	6	5	3	0	2	3	0	2	1	0	0	1
22026	0	4	1	3	6	4	0	1	1	0	2	4	1	2	1	0	0	0
22027	1	5	1	3	6	5	4	3	2	0	4	3	6	1	1	0	0	0
22028	0	4	1	3	1	3	2	2	5	0	7	1	3	2	1	0	0	0
22029	0	4	1	3	1	4	2	4	2	0	7	4	2	1	1	0	0	0
22030	0	5	1	3	6	3	3	5	4	0	5	6	8	0	0	0	0	0
22031	0	4	1	3	5	5	4	2	2	0	2	3	7	2	1	0	0	0
22032	0	4	1	3	6	4	2	1	1	0	6	4	3	1	1	0	0	0
22033	0	4	2	3	6	1	1	1	1	0	4	1	8	1	1	0	1	0
22034	1	4	1	3	3	4	2	1	3	0	4	1	6	1	0	0	0	0
22035	1	4	2	3	6	6	1	1	0	0	7	1	3	2	0	0	0	1

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22036	0	4	2	3	6	6	1	1	1	0	7	1	3	2	0	1	0	0
32001	0	4	1	3	6	3	4	6	3	0	5	1	2	2	1	0	0	0
32002	0	4	1	3	1	1	3	1	4	0	6	2	3	2	1	0	0	0
32003	0	4	1	3	4	5	2	1	3	0	3	2	4	2	0	0	0	0
32004	0	5	1	3	6	3	4	1	3	0	3	1	2	3	0	0	0	0
32005	0	5	1	3	5	3	2	2	3	1	3	2	4	2	0	0	0	0
32006	0	4	2	3	5	4	5	2	3	0	2	3	5	2	0	0	1	1
32007	0	4	2	3	5	4	3	2	3	0	2	3	5	2	1	0	1	1
32008	0	5	2	3	2	3	4	3	2	1	4	3	2	2	0	0	1	1
32009	0	4	2	3	3	4	3	4	3	0	3	2	5	2	0	0	0	0
32010	0	4	2	3	3	4	2	2	3	0	2	3	1	3	1	0	0	0
32011	0	4	1	3	3	4	4	1	5	0	4	5	1	1	1	0	1	0
32012	0	5	1	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0
32013	0	4	1	3	6	1	6	1	1	0	0	1	6	1	1	0	0	0
32014	0	4	2	3	6	3	2	2	1	0	5	2	4	1	1	0	0	0
32015	0	4	1	3	5	3	2	1	5	0	0	0	0	0	0	0	1	0
32016	0	4	1	3	3	4	3	4	3	0	2	7	4	1	0	0	1	0
32017	0	4	1	3	6	0	3	3	0	0	2	7	1	2	0	0	1	1
32018	0	4	1	3	5	4	6	3	3	0	7	1	3	2	0	0	1	0
32019	0	4	2	3	2	0	0	0	0	0	4	3	5	1	0	0	0	0
32020	0	4	1	3	3	6	6	5	3	0	3	4	2	2	0	0	0	0
32021	0	4	1	3	1	6	1	1	1	0	0	0	0	0	0	0	0	0
32022	0	4	1	3	1	2	4	1	3	0	7	2	4	1	0	0	0	0
32023	0	4	2	3	6	5	1	2	3	0	3	1	5	2	0	0	0	0
32024	0	4	1	3	6	6	3	1	2	0	5	6	1	1	0	0	0	0

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32025	0	4	2	3	1	6	6	1	1	0	2	1	6	**2**	0	0	0	0
32026	0	4	1	3	1	3	4	2	6	0	1	3	7	**2**	0	0	0	0
32027	0	5	2	3	6	3	1	4	4	0	5	4	2	**1**	0	0	0	0
32028	0	4	2	3	4	3	3	1	2	0	5	1	3	**2**	0	0	1	0
32029	0	4	2	3	5	4	2	3	2	0	8	1	4	**1**	0	0	0	0
32030	0	4	2	3	2	4	5	3	3	0	0	0	0	**0**	0	0	0	0
32031	0	4	1	3	2	3	1	1	1	0	2	3	4	**2**	0	0	0	0
32032	0	4	2	3	2	3	1	2	3	0	0	0	0	**0**	0	0	0	0
32033	0	4	2	3	6	0	5	1	1	0	0	0	0	**0**	1	0	0	0
32034	0	4	2	3	1	6	5	1	1	0	0	0	0	**0**	1	0	0	0
32035	0	4	1	3	6	1	6	1	1	0	5	2	1	**2**	0	0	0	0
32036	0	4	1	3	6	3	3	1	1	0	5	2	1	**2**	1	0	1	0
32037	0	4	1	3	3	3	5	2	3	1	4	3	1	**2**	0	0	0	0
32038	0	4	1	3	1	1	1	1	1	0	1	2	3	**3**	0	0	0	0
32039	0	4	1	3	1	1	1	1	1	0	1	2	3	**3**	0	0	0	0
32040	0	4	1	3	3	3	4	1	3	0	2	3	4	**2**	0	0	0	0
32041	0	4	1	3	3	3	4	1	2	0	4	3	2	**2**	0	0	1	0
32042	0	4	1	3	2	2	4	2	3	1	4	1	2	**2**	1	0	1	1
32043	0	4	1	3	3	3	4	1	2	0	0	0	0	**0**	0	0	1	0
32044	0	4	2	3	1	2	3	4	5	0	2	6	5	**1**	1	0	1	1
32045	0	3	2	3	1	2	3	4	5	0	2	1	5	**2**	0	0	1	1
32046	0	4	2	3	1	1	3	2	3	0	2	6	5	**1**	0	0	1	0
32047	0	4	2	3	4	1	1	1	2	0	4	3	7	**1**	0	0	0	0
32048	0	4	1	3	6	3	6	1	2	0	1	5	3	**2**	0	0	0	0
32049	0	4	1	3	2	2	4	2	3	0	4	5	2	**1**	0	0	0	0

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32050	0	4	1	3	2	3	5	1	3	0	4	5	2	1	0	0	0	1
32051	0	4	2	3	4	5	2	3	2	1	2	3	1	3	0	0	0	0
32052	0	4	2	3	4	4	3	2	3	0	0	0	0	0	0	0	0	0
32053	0	4	1	3	5	5	2	3	3	0	0	0	0	0	1	0	0	0
32054	0	4	2	3	6	2	1	2	2	0	0	0	0	0	0	0	1	0
32055	0	4	2	3	6	2	1	3	3	0	0	0	0	0	1	0	1	0
32056	0	4	2	3	1	1	6	1	1	0	0	0	0	0	0	0	0	0
32057	0	4	2	3	4	4	3	2	2	0	6	0	2	1	1	0	0	0
32058	0	4	2	3	6	6	1	1	1	0	2	3	1	3	0	0	1	0
32059	0	4	2	3	4	4	3	3	3	0	0	0	0	0	0	0	0	0
32060	0	4	1	3	5	4	1	1	3	0	5	2	3	2	0	0	0	0
32061	0	4	1	3	4	3	2	2	2	0	5	2	1	2	0	0	0	1
32062	0	4	2	3	4	4	4	4	4	1	3	4	1	2	0	0	1	0
32063	0	4	1	3	6	3	2	1	2	0	2	3	4	2	1	0	0	1
32064	0	4	1	3	5	5	2	2	2	0	4	5	3	1	0	0	0	1
32065	0	4	2	3	4	3	3	2	3	0	4	3	2	2	0	0	0	1
32066	0	4	2	3	5	3	3	2	4	1	6	1	5	1	0	0	1	0
32067	0	4	2	3	5	2	2	1	1	0	3	4	1	2	1	0	1	0
32068	0	4	1	3	3	3	2	2	3	0	2	4	1	2	1	0	0	0
32069	0	4	1	3	2	1	3	1	3	0	5	2	3	2	0	0	1	1
32070	0	4	1	3	4	1	2	1	1	0	6	2	7	1	1	0	0	1
32071	0	4	2	3	5	3	3	1	3	0	3	5	2	2	0	0	1	1
32072	0	4	2	3	4	4	2	1	5	1	5	4	1	1	0	0	0	0
32073	0	4	2	3	6	3	2	1	4	0	4	2	1	2	1	1	0	1
32074	0	4	2	3	4	2	4	1	3	1	2	1	3	3	0	0	1	1

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32075	0	4	2	3	4	4	3	1	3	1	2	3	1	3	0	0	0	1
32076	0	4	2	3	2	4	2	3	4	0	4	5	2	1	0	0	1	0
32077	0	4	2	3	6	6	2	2	3	0	6	2	1	2	0	0	1	0
32078	0	4	1	3	1	3	2	3	4	0	4	5	3	1	1	0	1	0
32079	0	4	1	3	2	3	3	1	4	1	4	2	1	2	1	0	1	0
32080	0	4	2	3	3	2	3	2	2	0	1	4	5	1	0	0	0	1
32081	0	4	2	3	3	2	4	3	4	0	2	4	3	2	1	2	0	1
32082	0	4	2	3	6	4	1	1	1	0	4	2	1	2	0	0	1	1
32083	0	4	2	3	2	3	2	2	4	0	4	1	2	2	1	0	1	1
32084	0	4	1	3	2	2	3	1	1	0	1	3	2	3	0	0	1	0
32085	0	4	1	3	3	3	4	2	3	0	4	3	2	2	1	0	1	0
32086	0	4	2	3	5	2	1	1	4	0	4	1	2	2	1	0	1	0
32087	0	4	1	3	2	5	2	1	3	0	4	1	2	2	0	0	0	1
32088	0	4	1	3	4	2	2	1	5	0	3	4	2	2	1	0	0	1
32089	0	4	1	3	5	3	5	1	2	0	2	3	4	2	1	0	1	1
32090	0	4	1	3	4	3	3	1	3	0	4	1	5	1	1	0	0	1
32091	0	4	1	3	4	2	3	2	3	0	4	1	2	2	1	0	0	0
32092	0	4	1	3	2	2	4	1	6	1	1	2	5	2	0	0	1	1
32093	0	4	1	3	4	2	2	3	1	1	2	3	5	2	1	1	1	0
32094	0	5	1	3	6	4	2	2	3	0	8	4	1	1	0	0	0	0
32095	0	4	1	3	3	1	2	2	1	1	5	3	4	1	0	0	1	1
32096	0	4	1	3	3	4	3	2	3	1	2	1	3	3	1	0	1	1
32097	0	4	1	3	4	2	1	3	2	0	2	3	5	2	0	0	0	0
32098	0	4	1	3	4	2	1	2	5	0	6	2	5	1	0	0	0	0
32099	0	4	1	3	3	2	5	1	1	0	2	4	3	2	0	0	0	0

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32100	0	4	1	3	4	3	3	2	1	0	5	1	4	1	1	0	0	0
32101	0	5	2	3	4	4	3	2	4	0	5	2	4	1	1	0	1	0
32102	0	4	2	3	4	2	1	1	3	0	5	3	4	1	1	0	0	0
32103	0	4	1	3	5	2	2	2	3	0	1	4	5	1	0	0	1	0
40001	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40002	0	3	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
40003	0	2	1	1	6	6	6	3	5	0	0	0	0	0	0	0	0	0
40004	0	2	1	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0
40005	0	2	2	1	3	1	2	1	3	0	0	0	0	0	1	0	0	0
40006	0	3	1	1	6	3	2	6	0	0	0	0	0	0	0	0	0	0
40007	0	2	1	1	6	6	6	6	6	0	1	6	4	1	0	0	0	0
40008	0	2	2	1	6	1	1	1	6	0	2	4	5	1	0	0	0	0
40009	0	2	1	1	1	6	3	1	4	0	4	3	5	1	0	0	0	0
40010	0	2	2	1	1	6	1	1	1	0	6	5	8	0	0	0	0	0
40011	0	3	1	1	1	1	1	1	1	0	6	2	1	2	0	0	0	0
40012	0	3	2	1	6	1	1	1	1	0	5	1	4	1	0	0	0	0
40013	0	2	1	1	6	1	1	1	5	0	6	7	4	0	0	0	0	0
40014	0	2	2	1	5	3	3	2	4	0	2	4	3	2	1	0	0	0
40015	0	3	1	1	1	1	2	1	4	0	2	4	7	1	1	0	0	1
40016	0	2	2	1	5	3	3	1	4	0	3	5	2	1	1	0	0	0
40017	0	2	2	1	6	2	6	1	1	0	5	3	2	2	0	0	0	0
40018	0	2	1	1	5	4	2	1	2	0	4	1	6	1	1	0	0	1
40019	0	3	1	1	3	2	3	1	1	0	2	1	4	2	1	0	0	1
40020	0	3	1	1	1	1	1	1	1	0	1	7	5	1	0	0	1	0
40021	0	2	1	1	6	1	3	1	1	0	7	5	3	1	1	0	0	1

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40022	0	2	1	1	6	6	1	1	1	0	8	3	6	1	0	0	0	0
40023	0	2	1	1	4	1	1	1	1	0	3	8	1	2	0	2	0	1
40024	0	2	1	1	4	5	4	3	2	0	5	3	4	1	0	2	0	0
40025	0	2	1	1	3	2	5	2	2	0	1	3	5	2	0	2	1	0
40026	0	2	1	1	3	2	3	2	6	0	2	4	5	1	0	2	1	1
40027	0	3	1	1	5	2	4	1	3	0	5	4	3	1	0	0	1	1
40028	0	2	1	1	1	6	6	1	5	1	2	3	8	2	1	0	0	0
40029	0	3	1	1	1	4	3	1	4	0	3	8	1	2	1	2	0	0
40030	0	2	2	1	1	1	1	1	1	0	2	3	4	2	1	0	0	0
40031	0	2	2	1	4	2	2	1	3	1	2	3	5	2	1	2	1	1
40032	0	2	2	1	4	2	2	2	3	0	2	3	4	2	1	2	1	0
40033	0	3	1	1	5	4	2	6	3	0	3	4	5	1	1	2	1	1
40034	0	3	1	1	6	3	2	6	3	0	0	0	0	0	0	0	0	0
40035	0	3	1	1	2	5	3	1	1	0	5	1	2	2	1	0	0	0
40036	0	2	1	1	5	6	5	1	2	0	4	3	5	1	0	0	0	0
40037	0	2	1	1	1	1	2	1	1	0	2	3	8	2	0	0	0	0
40038	0	2	2	1	3	3	4	2	4	0	0	0	0	0	0	0	0	0
40039	0	2	2	1	2	6	0	0	0	0	0	0	0	0	1	0	0	0
40040	0	2	1	1	2	3	3	1	2	1	2	3	6	2	1	0	0	0
41001	0	3	1	2	1	4	6	1	1	0	5	1	2	2	1	0	1	0
41002	0	4	1	2	1	6	3	1	1	0	6	7	8	0	0	0	0	0
41003	0	3	1	2	1	3	4	1	2	0	5	2	8	1	0	0	0	0
41004	0	3	2	2	6	3	3	2	3	0	2	1	4	2	0	0	0	1
41005	0	3	1	2	3	3	2	2	3	1	4	3	2	2	0	0	1	0
41006	0	3	1	2	1	2	2	1	1	0	2	5	3	2	1	0	0	0

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41007	0	3	1	2	4	2	4	1	3	0	3	5	2	2	1	0	1	0
41008	0	4	1	2	4	1	2	1	3	0	4	3	5	1	0	0	0	0
41009	0	3	1	2	1	2	0	1	1	0	4	3	5	1	0	0	0	0
41010	0	3	1	2	1	3	4	2	3	0	6	1	3	2	1	0	0	0
41011	0	3	2	2	4	6	2	1	4	0	5	1	3	2	0	0	0	1
41012	0	3	2	2	1	6	1	1	1	0	2	3	4	2	1	0	0	0
41013	0	4	1	2	1	2	2	1	3	0	2	3	4	2	0	0	0	0
41014	0	3	2	2	6	6	2	5	4	0	5	1	3	2	1	0	0	1
41015	0	3	1	2	1	3	3	1	3	0	4	5	1	1	0	0	1	0
41016	0	3	2	2	3	1	2	5	2	0	4	2	3	2	0	0	1	0
41017	0	3	2	2	4	4	5	2	3	0	2	5	6	1	0	0	0	0
41018	0	3	2	2	4	2	3	3	1	0	2	5	6	1	1	0	0	0
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41020	0	3	2	2	3	1	4	1	3	1	1	4	2	2	1	0	1	0
41021	0	3	2	2	2	1	5	2	2	0	1	3	4	2	0	0	0	0
41022	0	3	2	2	4	2	1	1	1	0	2	5	1	2	0	0	1	0
41023	0	3	1	2	6	3	1	1	1	0	6	2	5	1	1	0	0	1
41024	0	3	1	2	3	1	1	1	3	0	4	3	2	2	1	0	0	1
41025	0	4	1	2	6	1	1	1	1	0	6	2	5	1	1	0	0	1
41026	0	3	1	2	6	2	1	1	5	0	6	2	5	1	1	0	0	1
41027	0	3	1	2	6	3	1	1	1	0	6	2	5	1	1	0	0	1
41028	0	4	1	2	1	3	1	2	1	0	5	3	1	2	1	2	0	0
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41030	0	3	1	2	4	4	2	2	3	0	1	5	2	2	1	0	0	0
41031	0	3	2	2	4	4	2	4	4	0	4	1	2	2	0	0	1	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

41032	0	3	1	2	6	2	1	1	3	0	5	3	1	2	1	2	0	1
41033	0	3	1	2	3	3	1	2	4	0	5	3	4	1	1	0	0	0
41034	0	3	2	2	5	4	3	1	4	0	4	1	3	2	1	0	1	0
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41037	0	3	1	2	4	3	2	1	3	0	3	4	2	2	1	0	1	1
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41039	0	3	1	2	6	3	1	1	1	0	0	0	0	0	1	0	1	0
41040	0	4	1	2	6	1	3	4	2	0	5	4	3	1	1	0	0	0
41041	0	4	2	2	3	2	1	1	4	1	7	2	4	1	1	0	1	0
41042	0	3	1	2	6	0	1	1	1	0	7	3	8	1	1	0	1	0
41043	0	3	2	2	5	6	6	1	4	0	5	3	1	2	0	0	1	1
41044	0	3	2	2	3	2	3	2	2	0	2	1	6	2	1	0	0	0
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41046	0	3	1	2	1	3	1	6	3	1	4	2	3	2	1	0	0	0
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41048	0	3	2	2	4	4	4	3	3	0	4	6	1	1	0	0	0	0
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41050	0	3	2	2	4	2	3	1	2	0	1	3	6	2	1	0	1	0
41051	0	3	2	2	4	3	2	1	2	1	4	2	1	2	1	0	1	1
41052	0	3	2	2	3	5	3	1	1	1	5	2	4	1	1	0	1	0
41053	0	3	2	2	0	0	0	1	0	1	4	7	2	1	0	0	1	0
41054	0	3	1	2	6	4	3	2	4	0	3	4	5	1	1	0	1	0
41055	0	3	2	2	5	2	1	3	2	0	4	6	3	1	1	0	1	0
41056	0	3	1	2	3	4	5	3	2	1	3	4	5	1	1	0	1	1

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

41057	0	4	1	2	6	1	1	2	2	0	2	4	6	1	0	0	1	1
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41059	0	3	2	2	1	2	1	2	2	1	8	3	4	1	1	0	1	0
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41064	0	3	1	2	6	2	3	2	3	0	4	1	6	1	1	0	1	1
41065	0	3	2	2	6	6	1	1	1	1	6	2	5	1	0	0	1	1
41066	0	3	1	2	5	1	5	2	1	1	5	3	2	2	1	0	1	1
41067	0	3	2	2	6	6	1	1	1	1	8	2	5	1	0	0	1	0
41068	0	3	2	2	2	4	1	4	2	0	8	6	5	0	1	0	1	1
41069	0	4	1	2	6	6	1	1	1	1	2	3	4	2	0	0	0	1
41070	0	4	1	2	6	5	1	4	3	0	0	0	3	1	1	0	1	0
41071	0	4	2	2	2	5	1	4	3	0	7	6	4	0	1	0	0	0
42001	0	4	2	3	3	3	3	3	3	1	5	4	3	1	1	0	0	1
42002	0	4	2	3	4	3	3	2	3	0	5	2	1	2	1	0	0	0
42003	0	5	1	3	5	2	1	1	1	0	7	2	4	1	1	0	0	0
42004	0	4	1	3	3	3	3	5	1	0	2	3	7	2	1	0	1	0
42005	0	4	1	3	3	3	2	1	1	1	2	6	5	1	1	0	0	1
42006	0	5	1	3	5	1	1	1	1	0	3	4	5	1	1	2	0	0
42007	0	4	1	3	5	2	1	1	2	0	3	2	5	2	1	0	0	1
42008	0	4	1	3	5	2	4	2	2	1	5	3	4	1	1	0	0	1
42009	0	5	1	3	6	3	4	2	2	1	4	1	6	1	1	0	0	1
42010	0	4	1	3	4	3	3	2	3	0	5	1	4	1	1	0	0	0

ALL SCHOOLS RAW RESULTS (YEAR 1, 2 AND 3) SCOTLAND PUPILS

42011	0	4	1	3	1	2	3	1	2	0	5	3	4	1	1	2	1	0
42012	0	4	1	3	2	1	4	2	3	0	4	2	3	2	0	2	0	1
42013	0	4	1	3	4	3	3	1	2	1	2	3	5	2	1	0	0	0
42014	0	4	2	3	6	3	1	4	2	1	3	2	5	2	1	0	1	0
42015	0	4	1	3	3	3	2	2	4	0	3	2	1	3	0	0	1	1
42016	0	4	1	3	2	2	3	2	2	1	2	5	1	2	0	0	1	1
42017	0	4	2	3	4	3	5	2	3	0	6	3	5	1	1	0	0	0
42018	0	5	2	3	3	4	2	2	3	1	1	6	2	2	0	0	0	1
42019	0	4	1	3	3	3	4	2	3	0	1	5	4	1	0	0	0	0
42020	0	4	2	3	1	5	2	2	2	1	8	4	1	1	1	0	0	0
42021	0	4	2	3	3	4	2	2	3	1	3	2	4	2	0	0	0	0
42022	0	4	2	3	6	1	3	1	2	1	8	4	2	1	0	0	0	0
42023	0	4	2	3	6	2	4	1	3	0	4	2	3	2	0	0	0	0
42024	0	4	2	3	3	4	3	1	3	0	4	2	3	2	0	0	0	0
42025	0	4	2	3	3	4	3	1	2	0	2	5	3	2	0	0	1	0
42026	0	5	1	3	6	2	3	1	3	0	4	3	2	2	1	0	0	0
42027	0	4	2	3	4	3	3	2	3	0	6	2	3	2	1	0	1	1
42028	0	4	2	3	4	3	2	2	3	0	1	2	5	2	1	0	0	0
42029	0	4	2	3	4	4	2	3	4	1	4	1	7	1	1	0	0	1

Appendix S

Scotland Pupils' Responses to Questions 3, 8, 9, 10, 11, 12 and 13 of the experiment Three Eloosis Checklist

Analysis of Eloosis Card Game Results - Scotland Group

Year Group	Question 3 and 10 - What do you think the game taught you? What is science trying to teach us?	Question 8 - How does the game relate to how science tries to find answers?	Question 9 - Why Do We Conduct Experiments in Science Lessons	Question 11 - Are Some Experiments Better than Others? -What makes a Good Experiment?	Question 12 - Are Answers from Experimets Always Right?	Question 12 - How Can You Be Certain of the Answer From an Experiment?
1 (GS)	Bad results - redesign experiment for better results and think before you use an experiment	Problem solving; Working in a group - useful for effective teamwork.	To find out things ; When you see it you accept it; How things work	Yes. If the results of the experiment fit well in the sequence	No. - 100%	Repeat the pattern that gives best results - checking for consistency
2(GS)	Logic; conbinations; sequencing; repeat trials; elimination process; how brain works to identify patterns.	Repeat experiment; drawing conclusions from experiment; performing experiments through cards playing.	Understand things; for future safety; prediction of right or wrong; prove theories.	Yes - No reason given	No - 100% Conclusions drawn could be wrong	Repeat it many times; look out for two contradicting actions
3 (C,B,P)	Logic; That things are not always what they seem; patterns of differences;.	How humanbeings think; observing patterns; Use of differences and similarities to work out things; predicting results from experiments; Logical thinking-no guess work.	To find out things - what works and doesn't work.	Yes. Especially those that show better results and prove logical answer and can work backward.	No - 100% Chance can be misleading	It has to be consistent with your expectations and expected results.
4	How to work out sequences; How to try out different ideas - make intellegent guesswork;	No response	To find things out about the natural world around us.	No. Not much information; dangerous; and impossible to do.	No - 100%	The experiment has to assist you predict next move.

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