THE USE OF A DATABASE TO IMPROVE HIGHER ORDER THINKING SKILLS IN SECONDARY SCHOOL BIOLOGY: A CASE STUDY.

THESIS

Submitted in partial fulfilment of the

requirements for the Degree of

MASTER OF EDUCATION (COMPUTERS IN EDUCATION)

of Rhodes University

by

OWEN DUDLEY PHIPPS

December 1993

ABSTRACT

The knowledge explosion of the last decade has left education in schools far behind. The emphasis in schools must change if they are to prepare students for their future lives. Tertiary institutions as well as commerce and industry need people who have well-developed cognitive skills. A further requirement is that the school leaver must have skills pertaining to information processing.

The skills that are required are those which have been labelled higher order thinking skills. The work of Piaget, Thomas and Bloom have led to a better understanding of what these skills actually are. Resnick sees these skills as being: nonalgorithmic; complex; yielding multiple solutions; involving nuanced judgements; involving the application of multiple criteria; involving uncertainty; involving self-regulation of the thinking process; imposing meaning and being effortful. How these can be taught and the implication of doing so are considered by the researcher. The outcome of this consideration is that higher order thinking entails communication skills, reasoning, problem solving and self management.

The study takes the form of an investigation of a particular case: whether a Biology field trip could be used as a source of information, which could be handled by a computer, so that higher order thinking skills could be acquired by students. Students were instructed in the use of a Database Management System called PARADOX. The students then went on an excursion to a Rocky Shore habitat to collect data about the biotic and abiotic factors pertaining to that ecosystem.

The students worked in groups sorting data and entering it into the database. Once all the data had been entered the students developed hypotheses and queried the database to obtain evidence to substantiate or disprove their hypotheses. Whilst this was in progress the researcher obtained data by means of observational field notes, tape recordings, evoked documents and interviews. The qualitative data was then arranged into classes to see if it showed that the students were using any of the higher order thinking skills.

The results showed that the students did use the listed higher order thinking skills whilst working on the database.

TABLE OF CONTENTS

CHAPTER 1. **INTRODUCTION.**
1.1 General context of the study. 1
1.2 The South African context. 3
1.3 Objectives of this study. 6

CHAPTER 2. **HIGHER ORDER THINKING SKILLS AND DATABASES**
2.1 Thinking skills. 7
2.1.1 Learning Skills. 12
2.1.2 Communication skills 14
2.1.3 Reasoning 14
2.1.4 Problem Solving. 16
2.2 Self-management and control of cognition. . . . 18
2.3 Teaching thinking skills. 18
2.3.1 Educator requirements. 19
2.3.2 Assessment criteria. 19
2.3.3 Textbooks. 20
2.3.4 New technology. 20
2.4 Databases. 22
2.4.1 Database structure 23

CHAPTER 3. **METHOD OF RESEARCH**
3.1 Research Paradigm. 28
3.2 Research Perspective. 28
3.3 Research Approach 28
3.4 Research Method 29
3.5 Research Techniques. 30

CHAPTER 4. **THE CASE STUDY.**
4.1 Methodology. 34
4.1.1 The Excursion. 34
4.1.2 Database Construction. 36
4.1.2.1 Project Planning. 36
4.1.2.2 Database Design. 37
4.1.2.3 Pilot Study. 38
4.1.3 Questioning the database. 38
4.2 Data collection. 39
4.2.1 Fieldwork. 40
4.2.1.1 Evoked Documents. 40
4.2.1.2 Observational notes. 41
4.2.1.3 Tape Recordings. 41

CHAPTER 5. **DATA ANALYSIS**
5.1 Data Analysis Methodology 43
5.2 Analysis 45
5.2.1 Paradox. 45
5.2.2 Group interactions. 48
5.2.3 Shortcomings of the worksheet. 51
5.2.4 Thinking Skills. 51
5.2.4.1 Differentiating, Grouping and Analysis. 51
5.2.4.2 Ordering. 53
5.2.4.3 Comparing. 55
5.2.4.4 Associating. 56
5.2.4.5 Hypothesizing and Planning. . . . 58
5.2.4.6 Problem Solving. 59
5.2.4.7 Inferring. 60
5.2.4.8 Testing. 61
5.2.4.9 Evaluating and Deciding. 62
5.2.4.10 Overview. 64

CHAPTER 6. **CONCLUSION AND RECOMMENDATIONS**
6.1 Limitations of the Study. 67
6.2 Prior Experience. 69
6.3 Support. 69
6.4 Conclusions. 69
6.5 Recommendations for Future Research. 71

REFERENCES 72

APPENDIX 1.
Rocky Shore Worksheet 78

APPENDIX 2.
Hypotheses prepared by researcher and Biology teachers. . 104

APPENDIX 3.
Student generated hypotheses and conclusions. 106

APPENDIX 4.
Some examples of students answers to hypotheses. 109

APPENDIX 5.
An example of a student report. 114

LIST OF TABLES

TABLE 1.

Piaget's Stage Theory of Intellectual Development. . . . 8

TABLE 2.

Thomas's Taxonomy of Higher order Cognitive skills. . . . 10

TABLE 3.

Bloom's Taxonomy of Cognitive Domain. 11

TABLE 4.

Dewey's Stages of Problem Solving. 16

TABLE 5.

Study Groups. 36

TABLE 6.

Four Stages of Classroom research 43

Acknowledgements

Cecille Marsh
My supervisor for her interest and support.

Kearsney College
For the use of students and facilities.

Pat and Wilfred Phipps
My parents for encouragement and prayers.

Delene Heukelman
For friendship and encouragement.

CHAPTER 1.

INTRODUCTION.

1.1 General context of the study.

> "We live in a scientific and technological world based on knowledge which is increasingly large, complex, and rapidly changing." (Reif, 1984)

The knowledge explosion is such that almost everyone runs the risk of falling behind unless he[1] continually keeps learning and updating his knowledge. The students of a few years ago could be secure in the knowledge that what they had learnt would be sufficient for the work place. (Champagne, 1986:1) O'Neil (1992:7) points out that:

> "in the old industrial model, thinking was left to the managers and doing to the hired hands ..."

This concept no longer operates, so as a result there must be a change in the nature of what and how knowledge is taught in schools and colleges. Education must be increasingly directed to prepare students more effectively for their future lives. Ausubel (1968) states:

> "The world is more complex and so are the challenges it presents. Meeting those challenges will require not only considerable knowledge but the skill to apply the knowledge effectively."

To use knowledge effectively will require the use of higher order thinking skills that are not taught in most schools presently. Further too:

---

1 The use of he in this manuscript is purely for simplicity of style.

> "Survival in the midst of rapid change will require the ability to adapt, to learn new skills quickly, to apply old knowledge in new ways." Ausubel (1968).

Botkin et. al. distinguish between maintenance learning, which they claim has sufficed in the past but which is now inadequate, and innovative learning, which they believe is needed for the long term. Cognitive science has led to a better theoretical understanding of the human thought processes. This understanding allows good performance in complex domains such as problem solving. This knowledge of cognitive science should be used to improve teaching methods in schools.

In recent years there has also been an explosion of our knowledge of electronics which has led to a dramatic increase in the progress in computer technology and this technology has become increasingly more available to schools. It is hoped that computers used in conjunction with our new knowledge of cognitive science will simplify the teaching of higher-order thinking skills. (Reif, 1984)

Databases, spreadsheets and wordprocessors are content free software packages designed not specifically for educational use but which none the less offer remarkable opportunities in the field of education. In the literature regarding databases in education, there is an emphasis on showing students how databases are used in professional activities as well as in school projects. Many of these activities are based on the assumption that databases enhance general logic and can increase the higher order thinking skills of students. (Degl'Innocenti & Ferraris, 1988; Underwood, 1988:91) Databases have an added advantage in that they call on many different skills, each of which requires different levels of thinking. These levels of thinking start off at a low level such as observing and proceed to the higher skills of value analysis and decision making.

In the past educators have spent far too much time on the solutions to problems rather than on the processes by which they are resolved. Mathematics and Science example problems are given to students with their solutions. The students then copy these examples to solve similar ones in the hope that they will learn some problem solving ability. The difficulty is that the solution which is a product, reveals little about the process whereby the solution was produced. When the students come to solve a problem on their own, they are unable to do so. (Ausubel, 1968:5)

Johnson-Laird's work on logic seems to suggest that the manipulation of abstract materials and puzzle problems may require special thinking skills. People in general find it easier to build and think with models of familiar or everday content. (Chipman, 1986:32)

1.2 The South African context.

South African schools are out of step with the times. The inside and outside of classrooms have not altered much over the last 100 years. Classes are divided up according to age and the way in which content is delivered has also changed little. Outside of the school everything has changed remarkably. Families, jobs, social organisations, and entertainment look nothing like they did a century ago. David (1991) points out:

> "From inside the school, however, one would hardly know the visual images, rapid motion, technology, and change are pervasive in the world outside."

The South African education system, for the most part, is an authoritarian one. This is characterised by the teacher doing most of the talking, the students answering a few direct questions and then the students doing a little writing. The reason for this is that there is an excessive emphasis on the syllabus and the evaluation thereof. The final or promotion examination looms large both for the teachers and students. Good results reflect well on the teacher and the school and they are demanded by the principal, the parents and the community. Most of the students cope in the system. Most of the students have learnt in preparation for examinations out of fear of failure and therefore have worked only for a short-term, externally initiated, goal. The question arises whether the "product" of this type of education is worth anything to society or not.

Tertiary institutions require students who have good study skills, are curious, are questioning, and who can think and solve problems (Zielinski & Sarachine, 1990). Students entering universities have very few of these attributes. Industry on the other hand has complained that their trainees lack initiative, are not self motivating and do not work well with others. The education system is therefore not fulfilling the needs of society.

Michael Aston (1992), points out that tomorrow's survivors must have the following characteristics: they must be flexible; be adaptable; be communicators; be co-operative; be creative thinkers and be investigators. Further, the survivor must be an information handler and be comfortable with the technology that will allow the handling of large amounts of information in a logical way.

> "As we move towards the twenty-first century, information processing may become a survival skill." (Strickland and Hoffer, 1991:32)

Looking at Aston's list, clearly South African schools are doing very little to prepare students to be the survivors of the future.

The school system also does very little in the way of teaching the different skills that are required at different levels of thinking. Schools achieve little beyond knowledge and comprehension. The question arises: what can be done about the shortfall in our education system? The problem may not lie so much with what is being taught but with how it is being taught. One of the reasons for this is that many secondary school pupils have not developed all their cognitive abilities. Shemesh <u>et. al.</u> (1992:29) report that 50% of secondary school students have not mastered formal operational reasoning whilst the syllabi in many subjects require this formal operational reasoning if the student is to understand the subject fully. To rectify this shortfall in formal operational reasoning there must be an educational intervention either in the method of presentation or by the introduction into the curriculum of specific interventions which will speed up cognitive development.

Thinking skills tend to be driven out of the curriculum to make way for more and more factual content. The reason for this appears to be twofold. Firstly the hierarchies of educational objectives, such as that of Bloom, promote the idea that the knowledge acquisition must come first and secondly the assessment of a person's knowledge is easier than the assessment of his thought processes. (Resnick, 1987:48)

With the arrival of computer and information technology in schools this could all change.

> "Computers, by themselves, do not lead to the restructuring of education but computer technology in the hands of good teachers' can be extremely effective tools in the education process." (Riel, 1989:250)

Most teachers' lack of knowledge and understanding of computers and their use, has led to their being used by just a few adventurous educators. It is likely that it is these educators who are going to show the way in future developments in the teaching field. The main goal of teaching should involve providing the students with the opportunity to develop higher order thinking skills both within the individual discipline and across disciplines if the teaching is to be effective. (Jongejan, 1989)

1.3 Objectives of this study.

The main objective of this study was to see whether using a computer database would lead to the development or improvement of higher order thinking skills in secondary school pupils.

1.4 Outline of the study.

The investigation took the form of a case study using twenty standard 8 Biology students at Kearsney College during the fourth quarter of 1993. The group had an average age of 15 years 6 months.

The students were first taught how to use a computerised database. When this had been mastered, the students were taken on an Ecology excursion to the Brighton Beach rocks where they completed a worksheet dealing with the distribution of the fauna and flora found on the rocky shore and on the prevailing environmental conditions.

The students with the researcher then designed a database and entered the information collected on the excursion. The pupils then formulated hypotheses and used the database to analyze the information and draw conclusions with respect to their hypotheses. The researcher kept records of all the sessions of the pupils working with the database and the questions posed by them on the database. Records were also kept of the group dynamics of the students as they worked. The data collected was then analyzed to see whether it supported the objectives of the study.

CHAPTER 2.

HIGHER ORDER THINKING SKILLS AND DATABASES

2.1 Thinking skills.

The word "think" is used in many ways and this sometimes causes confusion. In this study thinking is taken to mean, a reasoning process for making inferences, that is to say, to "consider," "reflect", "ponder", "reason" or "deliberate". Further higher order thinking skills:

> "are those that involve the orchestration and practical use of the simpler skills -- like computation in school arithmetic." (Chipman, 1986:1)

Chipman's orchestration and practical uses can be enlarged upon. Resnick (1987:3) sees the following as the characteristics of higher order thinking:

* it is nonalgorithmic.
* it tends to be complex.
* often yields multiple solutions.
* involves nuanced judgement.
* involves the application of multiple criteria.
* often involves uncertainty.
* involves self-regulation of the thinking process.
* involves imposing meaning.
* is effortful.

To teach these higher order thinking skills, it is necessary to look at the foundation on which they are to be built. During the normal course of development students gain an impressive array of cognitive skills. Jean Piaget's developmental model of how cognitive skills evolve throws some light on how these skills are gained.

"Piaget's analysis of the development of hypothetico-deductive or formal reasoning . . . The unique aspect of this approach to cognition is the belief that complex intellectual behaviour is best understood and defined via an analysis of the developmental sequence through which it emerges." (Thomas, 1972:6)

What this means is that as the child develops mentally, he passes through several stages. It is possible to plot the child's development by analyzing the child's explanations of a variety of external events. These stages are shown in the table below.

TABLE 1.

Piaget's Stage Theory of Intellectual Development.

Operations
Sensory Motor Stage Mute - no use of verbal symbols Learns to perceive - discriminate and identify objects
Pre-Operational Stage Symbols and representations Acts on perceptive impulses Self centred Static irreversible thinking
Concrete Operations Stage Analyzing Conscious of dynamic variables Measures Classifies things in groups or series
Formal Operations Stage Abstract conceptual thinking Reasoning generalized Evaluation Hypothesizing Imagining Synthesizing

(After Thomas, 1972: 6)

The lowest stage of intellectual development is the sensory motor stage that occurs in the age range birth to two years. The pre-operational stage between two and seven years builds on the first stage and leads to the operational stage that develops between seven and sixteen years of age. The operational stage is broken down into two stages. In the first, the concrete operational stage, the individual can deal effectively with concrete concepts and operation. It is in the second stage, the formal operational stage, that the individual is able to deal with abstract operations, apply reasoning and show problem solving skills. The individual can at this stage of mental development apply these skills in situations that are different from those in which the skills were learnt. If the student has not reached this higher level of cognitive development a limiting factor will be placed on what he can learn. It is the formal operations stage that uses higher order thinking skills that is of interest in this study. In this study it is the intention that there will be a stimulus that will promote a move to the more advanced level of operations. It is hoped that as Narveson points out,

> "Whatever developmental gains students make will remain with them after specific learning is forgotten and will furthermore permit qualitatively more advanced kinds of learning in the future." (Narveson, as quoted in Ausubel, 1968:32)

The higher order thinking skills that need to be acquired by students can be found in Thomas's taxonomy of higher order cognitive skills, a taxonomy that he derived after researching curriculum theory literature.

A table containing Thomas's taxonomy follows on the next page.

TABLE 2.

Thomas's Taxonomy of Higher order Cognitive skills.

I. Learning to learn skills. - Attending and Orienting - Decoding - Memorizing - Studying
II. Communication Skills. - Observing - Describing - Explaining - Discussing
III. Classifying and Comparing Skills. - Differentiating and Grouping - Classifying - Ordering - Comparing - Using Numbers
IV. Synthesizing and Producing Skills. - Inventing - Associating - Elaborating - General Implications - Planning - Solving Problems Using Strategies
V. Skills in Judging and Inferring - Coding - Judging - Inferring - Testing
VI. Skills of Value Analysis and Decision Making. - Valuing - Evaluating - Deciding

(From Thomas, 1972:21)

This taxonomy bears some resemblance to that of Bloom whose taxonomy of cognitive domain is based on task analysis.

TABLE 3.

Bloom's Taxonomy of Cognitive Domain.

1.	Knowledge - Recalling knowledge or information, including specific ideas, principles, facts, relationships, methods and abstractions.
2.	Comprehension - Given the idea, method or abstraction, the student should be able to translate into other words or symbolic representations, interpret as a different communication or extrapolate unstated data or relationships.
3.	Application - Given as new situation, the student both chooses and applies a given idea, method or abstraction.
4.	Analysis - Breaking down an idea, method or abstraction into its parts including elements such as assumptions, hypotheses, facts, norms motives, conclusions, and relationships and principles not previously stated.
5.	Synthesis - Combining the elements identified under "analysis" to create a unique communication, a plan or proposed set of operations, or a new set of abstract relations.
6.	Evaluation - Evaluating a synthesized product against a set of external criteria, or evaluating to decide internal consistency.

(After Thomas, 1972:5)

It is the last three of Bloom's educational objectives (analysis, synthesis, evaluation) that are of interest in this study. These higher order thinking skills lead on from the first three (knowledge, comprehension, application) which can be considered as being lower order thinking skills, which deal to a large extent with the acquisition of knowledge and its ordering.

Piaget's Stage Theory links cognitive skills with age. As the child ages physically, Piaget's Theory plots the childs mental development through four stages. This phenomenon of apparently changing mental capacity has many implications for the assessor and teacher of cognitive skills. It seems to suggest limits on children's potential for displaying higher order cognitive skills at a young age. (Chipman, 1986:21) Not withstanding this, educators must fight against the tendency to get all the lower order skills well learned before moving on to higher order skills. Chipman (1986) refers to the work of Heath (1981) who reasons that it is important to expose young students to higher order goals as they provide motivation for learning. Being routinely exposed to higher order goals should motivate students to strive for mastery of new areas throughout their lives.

Consideration must also be given to the concept of knowledge, that is often called "course content", because thinking and knowledge are interdependent. Knowledge has to be acquired because to think is to apply knowledge effectively; thus if one does not have knowledge, one cannot think. It is therefore important that knowledge and higher order thinking skills be taught. The higher order thinking skills should enable the knowledge which has been learnt to be applied effectively. In the light of this, teaching higher order thinking skills must not be seen as opposing what has occurred in education in the past (i.e., the predominant teaching of lower order thinking skills) but as something complementary to it. One without the other will not prepare the student for the future. (Ausubel, 1968)

The operational stage of Piaget; the higher order cognitive skills of Thomas; and the analysis, synthesis and evaluation objectives of Bloom, in my opinion, can be synthesised and arranged into four areas: learning skills, communication skills, reasoning, and problem solving.

2.1.1. Learning Skills.

When learning skills, a student who is well grounded in fundamental knowledge and who has mastered the skills associated with comprehension and application, will create an intellectual framework on which new knowledge can be built. (Champagne, 1986:2) A good student will then be competent in gaining knowledge about new subjects and in achieving higher order thinking skills.

Reading is perhaps the most important skill needed to gain knowledge. Students need to be able to gather and organise information rather than just have the ability to recognize words. The student must understand the meaning of the word in context. Reading with understanding allows the student to evaluate the motivation and purpose of the writer and so be able to decide whether his message and conclusions should be accepted or not. The student must be able to discriminate between implicit and explicit meaning in the written word.

The ability to use knowledge effectively depends to a large extent on the organisation of the knowledge. Students often do not appreciate the importance of organising their knowledge effectively. They are ill-equipped to organise it effectively when they do try. Teaching them how to organise their knowledge will help them to learn. They need to be taught a set of concepts which can be used in organising the subject matter. If the knowledge is set out logically, the students should be better able to express themselves logically when writing up experiments or reports. (Reif, 1984:13)

When learning, concepts need to be defined clearly and precisely so that there is no room for misinterpretation. Should misinterpretation occur the concept is likely to be misapplied. Higher order learning skills must be developed which will lead to more effective acquisition of new knowledge. This must come out of the realisation that a new concept is not only a new definition, but that it is also a part of ancillary knowledge. This will make it more flexible and therefore more usable. Ancillary knowledge includes the knowledge about when the concept can be legitimately applied and when not. (Reif, 1984:14)

Few students know how human beings think and learn. Consequently some students see understanding as learning relevant facts by rote so that they can be displayed in a test situation. These facts learnt by rote can seldom be used to solve problems and can therefore be considered as sterile. Knowledge should include the learnt facts and the ability to use them flexibly, in diverse situations, to solve problems and to make various inferences. The ability to use facts flexibly should encourage students to think about how they apply the knowledge. (Reif, 1984:15) Competence in the acquisition of knowledge will then lead to the ability to reason.

2.1.2. Communication skills.

When the students have gained a good grounding in learning skills, they have the basis for developing the skills that they need to become good communicators of knowledge. As set out by Thomas (1972:21), communication skills are those skills that allow the student to observe critically and then explain clearly, either in a verbal account, or as a written statement what has been observed. The observation could be made using any of the senses. Further, the communication can take a number of forms: (1) explaining what has been observed, (2) holding a discussion with a second party, (3) discussing what has been observed in the form of a written report.

Having the ability to read and communicate should improve the student's ability to reason.

2.1.3. Reasoning.

Champagne (1986) sees a person who can reason as one able to do the following tasks:

* Identify problems and evaluate ways to solve them
* Consider and evaluate possibilities
* Formulate and reach decisions logically - to draw reasonable conclusions from information
* Separate fact from opinion
* Adjust to unanticipated situations by applying established rules and facts

* Work out new ways of handling recurring problems
* Determine what is needed to accomplish work assignments (Champagne, 1986:2)

In factually rich scientific fields like Biology, students need to use their knowledge in the design of experiments and selection of variables in experiments. Chipman (1986:6) describes general scientific reasoning as "tasks involving the combinatorics and control of variables in experiments", which can be considered as high level skills when compared with simple computations and data-recording. Further, students need the ability to reason to interpret the results of experiments.

Chipman (1986:14) believes that the internal language of thought "mentalese", out of which the skills that are of interest in this study are built, can be characterised in terms of condition-action pairs. The actions of thought are taken when the existing situation is perceived to match specified, previously learned conditions. The student is able to reason (action) if he can match the present situation with a situation in the past (condition). This will occur if the present situation is of the same category as the original situation. [Example: Litmus is used to test for acidity/alkalinity. Litmus is red in an acid medium and blue in an alkaline medium (condition). Add a few drops of litmus to an unknown substance. Seeing the colour change to red, the student should be able to reason that the unknown substance has acidic properties (action).] This mental activity takes place within "an internal arena of rather limited information capacity, called working memory". (Chipman, 1986:14) Working memory controls the cognitive acts that are performed. It is influenced by information coming from the senses and from information in long term memory.

Once the student has acquired the ability to read with understanding, communicate and reason effectively, he has the tools that should allow him to tackle problem solving.

2.1.4. Problem Solving.

Controversy abounds about whether problem solving or the acquisition of a body of knowledge is the primary goal of education. It seems that these two sets of objectives are related and mutually supportive. In the science field the development of problem solving ability is important, but this cannot be achieved without a body of appropriate knowledge. The scientific method of enquiry requires the formulation and testing of hypotheses. (Nickerson, Perkins and Smith, 1985:484) The formulation of a hypothesis is impossible without substantial knowledge of the field in which the investigation is to take place.

Problem solving is a complex phenomenon. Dewey's Stages of Problem Solving developed in 1910 is one of the oldest models of the nature of thinking. It is concerned with the distinct steps involved with the solution of a problem. Dewey saw the steps as:

TABLE 4.

Dewey's Stages of Problem Solving.

1. a felt difficulty (recognize problem)
2. location and definition (analyze problem)
3. suggest a possible solution (generate solution)
4. development by reasoning of the bearing of the suggestion (test consequences)
5. further observation and experiment leading to its acceptance or rejection (judge selected solutions)

(From Thomas, 1972:7)

Problem solving skills will be transferred to a new situation if the new situation is recognized as an instance of the same category as the original situation (e.g., both situations deal with momentum in physics). (Chipman, 1986:20) It is therefore important that students be exposed to as many problem solving situations as is possible. Education should equip them to face whatever situation they may confront in the future.

The solving of a complex problem requires judicious decision making. Many students tend to proceed haphazardly, by random guessing or by sheer intuition. Using these methods, they are unlikely to find the most suitable solution. To rectify this, students need to be taught some general problem solving methods. Some methods are:-

a) **Problem decomposition with explicit decisions.**

This requires that the problem be broken down into small manageable steps. When each small step is solved, it is helpful to specify carefully the current state of the problem and the obstacles hindering its solution and all available options to overcome the obstacles. This often suggests the next step towards a useful solution.

b) **Methods of progressive refinement.**

The solution to the problem consists of working through successive detailed steps of an argument leading from known information to some desired goal. It is therefore desirable, to first outline the solution at gross level, then to fill in more detail gradually.

c) **Heuristics.**

Heuristics are general rules that give advice about how to explore possible paths towards a problem's solution. E.g., construct a simplified problem with similar features; the solution to this problem may lead to the solution of the original problem.

d) **Methods of describing problems.**

Before a problem can be solved, it must be adequately described. This entails listing clearly what is known about the problem and what the solution requires.

e) **Methods for checking solutions.**

When the student feels that he has solved the problem, he should examine his solution critically to ensure that the solution does solve the problem. It would also be desirable for him to check that the solution is the best one possible. This examination may also give him valuable insight into how the problem was solved, an insight which could be useful for solving future problems.

2.2 Self-management and control of cognition.

Students must be taught to be reflective about what they have done. This is true whether the solution to the task has been effective or not. The student must understand why a particular result was achieved. The habit of self-examination - reflecting on wrong answers as well as those that are correct - is not one that is normally taught in schools. Wrong answers with red crosses are seen by students as negative things to be ignored or forgotten as soon as possible. Ignoring or forgetting is not the best course of action because it is only by analyzing mistakes that the thought processes that lead to the mistakes can be corrected. Students need to be made aware that mistakes are natural and that they are experiences to be learnt from, thus improving one's thought processes. If the students are shown where the errors occurred, they are less likely to make the same error again.

2.3 Teaching thinking skills.

In Piagetian terms the student already has all the lower and higher thinking skills but they are latent and it is the responsibility of the teacher to provide a suitable environment for him to make the "appropriate intellectual leaps" (Underwood & Underwood, 1990:63). If an attempt is to be made to teach higher order thinking skills then cognisance must be taken of the following:

1. Tacitness of expert knowledge.
   The underlying knowledge that allows success is often outside the range of conscious awareness. It is therefore important that thinking skills that in the past have been largely taken for granted be explicitly taught to students.

2. Knowledge of novice students.
   Knowledge gained by students is often superficial and inadequate although this may not be revealed by conventional examinations. Students do not seem able to use the knowledge reliably or flexibly.

3. Need for explicit teaching.
   Cognitive science has shown that the underlying thinking skills are quite complex and that these thinking skills are learnt inefficiently by any teaching method that does not set out explicitly to teach them. It therefore seems likely that the teaching of higher order thinking skills requires explicit and systematic teaching.
   (Rief, 1984:5)

Considering the three points raised above, the question, "What are the requirements for teaching higher order thinking skills?" must be considered.

2.3.1. Educator requirements.

One of the first requirements would be that all educational experiences need to be carefully designed by the educator. Having done this, teaching of higher order thinking skills must be in context and be both explicitly and consistently taught. For educators to be successful at teaching higher order thinking skills they will have to be trained in suitable teaching methods. These new teaching methods will have to be effective if they are to ensure that the pupils achieve the standards that will be required by the new testing approach that must be developed. The teaching of higher order thinking skills and their testing will require a shift in the time allocation given both to teaching and assessment. The time taken to teach higher order thinking skills will have to be found at the expense of the time at present used to teach the lower order skills.

2.3.2. Assessment criteria.

There must be a shift in the assessment criteria and methods. This shift must be from one of straight recall to one that requires insight and other higher order skills. This view is held by Reif (1984:17) who states,

> "It is clearly difficult, if not impossible, to teach important intellectual skills if these are not recognized by assessment instruments designed to evaluate the performance of students or of schools."

When setting tests/examinations examiners must ensure that they ask questions that test across the range of levels as set out by Bloom and other psychologists. The questions should be a mixture of various levels arranged in such a way that the students are directed in their thinking. Waiting time must be considered when setting the duration of the paper so that students have time to think. The ratio of open-ended (divergent) to closed (convergent) questions must also be considered. It is usually the divergent questions that stimulate higher order thinking. Testing should also provide opportunities for students to ask and evaluate their own questions at various levels. An example of this is getting students to prepare questions on a specific aspect of work and the model answer. This work is then evaluated by the examiner. (Gilbert, 1992)

2.3.3 Textbooks.

Writers of textbooks will also have to change both the content and style of the books to keep abreast of this new movement that must occur in all schools.

2.3.4 New technology.

Perhaps the most important move that could occur is the exploitation of new technology. Computers are part of technology that seems to have much to offer education. Computers have been shown to be useful in teaching learning skills and thinking skills. Reif (1984:19) attempts to substantiate this in the statement:

> "Computers can engage students very actively in their own learning, can provide extensive opportunities for practising general learning skills, and can supply students with feedback well adapted to their individual needs and rate of learning."

In the literature regarding computers and their use in the school situation there is an emphasis on the use of computers in innovative ways to increase learning and the higher order thinking skills of pupils. (Chatterton, 1988; Jussel, 1990; Parker & Widmer, 1989;) Polin (1991:7) reviews a software package concerned with model building and the simulation of dynamic systems. This simulation package allows students to manipulate elements of a given system and see the effects of these manipulations. The students are then able, by repeated trials, to establish relationships between elements a skill which is considered to be of a higher order.

Databases are recognized as very useful tools in promoting learning and problem solving skills. (Adams & Jones, 1983; Degl'Innocenti & Ferraris, 1988; Freeman & Levett, 1985; Hunter, 1985; Strickland & Hoffer, 1991; Underwood, 1988; Watson & Strudler, 1988). Clise (1990:14) writes about her experiences as a media specialist where she teaches students how to search online databases. Clise stresses the importance of the critical thinking process that is necessary to carry out a successful search. Hunter (1985:24) provides a very useful list of projects which can be carried out once a database on inventions had been produced. These projects require that the students master the skills needed to extract useful information from the databases. These skills include, getting an overview of the data in the database, learning how to use the data management program to answer questions and learn to use these skills in solving problems. It is in problem solving that the higher order thinking skills are improved. This is because students must break the problem down into manageable parts and then decide how they will search the database for the particular data needed to solve the smaller problem. Students seldom get exactly the right information they need to solve the problem at the first attempt and must then refine their questions. Goldberg (1992:32) gives an interesting account of the use of a database in a Science class where it was used in an investigation of seashells. Goldberg stresses that the importance of the use of the database was that the students were able to generate their own questions to ask the database rather than simply to use questions prepared by the teacher. The generation of questions led the students to discover that there were different types of questions, those that gave immediate answers and those that required further research. The formation of questions also led to a better understanding of the relationships between two or more variables and the ability to identify when a relationship existed. Databases are shown to be especially suitable as information handling tools for large amounts of data.

2.4 Databases.

> "There is evidence that thinking about information with these packages (databases & word processors) can act as a catalyst for children's intellectual development." (Brackets mine)
>
> (Underwood & Underwood, 1990:59)

Authors such as Gagne have argued that the most important skill learnt at school should be higher order thinking skills. The ability to know how is seen as more important than knowing what. Gagne's (as cited in Thomas 1972) conditions of learning deal with thought processes, the way in which they are expressed and the external and internal conditions that are needed for these thought processes. To meet these objectives the learning process must be so designed that the acquisition of procedural knowledge is of paramount importance. This knowledge should lead to flexible problem solving. Databases might be one way of achieving the above. Computer databases place a high cognitive demand on students because their use requires more than just the acquisition and comprehension of knowledge. To use the database effectively, the students must use the skills of analysis, synthesis and evaluation. Another good reason for using databases in a classroom setting is that the student is encouraged to ask his own questions rather than merely respond to questions asked by the teacher. It is the asking of questions that is one of the ways in which the student's cognitive development can be stimulated. (Thomas, 1972:4, Underwood and Underwood, 1990:60-62 & 67 & Watson and Strudler, 1988-89:47)

2.4.1 Database structure.

A data base management system (**DBMS**) ("data management program," "database management programs," "filing system," "file management program" Hunter 1985) is a computer program that enables the user to design, build up and use a collection of information on a particular subject. The information collected is stored in a database.

Daines (1984) has the following list which he sees as the functions of a database management system:

Data capture
Data input
Organisation
Storage
Search
Manipulation
Retrieval
Presentation
Evaluation

A database is a collection of **records** that contain comparable types of data about people, events or objects. A record consists of several **(key) fields** each of which can contain very different types of information. The records are stored by the DBMS in a **file.** Each database file is very different to any other as each is constructed for a specific purpose. [E.g., A database for school marks used to print reports would be of no use to the accounts section in the school for printing accounts.] The DBMS can use this file directly via a Data Directory file. This Data Directory file contains the names, types and widths of all fields in the DBMS file. (Grupe, 1989:198) The result is a single large store of data that Schumann (1990:202) sees as having the following advantages:

CONSISTENCY OF DATA
: When a data item is updated, its up-to-date value is immediately available to all users.

LESS DATA PROLIFERATION
: Duplication of data is eliminated because only one copy of each data item is kept.

EASE OF SETTING UP NEW APPLICATIONS
: When a new application is contemplated, much of the data it needs is probably already in the database.

Once the database has been designed and the data entered, to get information from the database it has to be interrogated. This is done by using a special query language. This allows the users to choose which fields (columns) they wish to display and in which order, ascending or descending. It also allows the user to define a group of records and do calculations and comparisons within the data.

Taba's Inductive Thinking Model of Teaching provides a conceptual framework that places database work in the broader instructional process. The elements of the model are:

Concept formation
Interpretation of data
Application of principles.

"Taba's model fits especially well with the computer database activities as it offers specific strategies that help students to organise, and evaluate information. Students brainstorm on a topic, sort and interpret data, and apply principles that they have learned." (Watson and Strudler, 1988: 47)

Databases can be used by teachers and students to do the following:

Discovering commonalities and differences among groups of events or things and for analyzing relationships;
Looking for trends;
Testing and refining hypotheses;
Organising and sharing information;
Keeping up-to-date lists; and
Arranging information into more useful ways
(Hunter, 1985:21).

Provided that "(1) the records, are satisfactorily designed, in the first place, and (2) the computer is asked the right questions" (Adams & Jones, 1983:52), the information captured in the database can be used to investigate various problems related to the information. The educator should formulate questions that have no definite answer, i.e., that are open ended, and require higher order thinking skills to answer. These will include questions that require students to judge the importance of various aspects of the topic, explore relationships and make inferences. To use the database constructively, the information extracted by quizzing the database should be the result of well conceived questions. The answers should lead to discussions that enhance the Inductive Thinking Model of Teaching and lead students to higher order learning objectives.

The source of the data can be worksheets that the students have completed on an excursion, information from a census, a study of animals using reference books etc.. It is important that all the information collected be relevant to the students and be from a real-life situation. (Hammond, 1991) This makes it rewarding for the students. During the collection of the data, the students will learn to investigate, compare, contrast, categorise, observe and record. The collection of data can be enhanced if more than one source of data is used. It must be remembered that it is only real data that can be used to solve real problems. When dealing with data, it is important to know where the data originated and how accurate it is.

Once the data has been collected, it must be entered systematically in each record. To get students to enter large amounts of data is counter-productive as they will most likely see no point in the exercise (Foot, 1989). The databases should be created by the pupil and not by the teacher (Nash and Ball, 1982:107). This is important because if the database is the property of the students it will lead to a greater sense of achievement.

If the information that is obtained in the quizzing of the database is to be useful, the students must develop an effective research strategy. This will involve the selection of both categories and criteria to use in the search (Adams & Jones, 1983:53). Strickland and Hoffer (1991) report that students using databases quickly learn to focus their search thus making it more time effective. Students also pose criteria that search for a wider range of values than an exact value. As the quizzing of the database continues, they will need to use deduction and reasoning to evaluate the information that is discovered. As the students work with the database they will need to communicate, as discussion is involved in the formation and selection of the questions necessary for retrieval of data. In working with the database students learn to co-operate with fellow students. This is another benefit of the use of a database and a "survivor" skill. (Aston, 1992)

Before the students are required to design their own databases for educational purposes they should first be given instruction in using a pre-constructed database. It is here that students can explore how the data is organised, learn questioning techniques and apply these skills to solving problems. It is also important that students have the opportunity to build up a database from a pre-constructed template. A good subject is to get students to construct a database about themselves as a group in the school. In using a database in this way "they learn and apply skills such as:

* Analyzing the problem to be researched
* Planning their research
* Locating sources of data
* Gathering data
* Categorising data
* Ensuring accuracy of data
* Organizing data
* Entering data into a computer" (Hunter, 1985:26)

It was hoped, that during the course of the research, that the students involved would not only learn and apply the skills set out by Hunter above but also use the information to answer well-conceived questions. By developing these skills and questions the students should have been able to prove or disprove hypotheses and develop higher order thinking skills in the process.

CHAPTER 3.

METHOD OF RESEARCH

A Biology field trip was undertaken and the findings used as a source of information. This information was fed into a database which students used to process the data. By observing their use of the database the researcher hoped to ascertain whether they acquired higher order thinking skills.

3.1 Research Paradigm.

The research in this study is from a non-positivist perspective using the hermeneutic (interpretative) paradigm in that the researcher used descriptive observations to categorise the actions of students and so gain understanding. (Reason and Rowan 199 :4) The philosophical basis for this research was one of cooperative enquiry. This was so because the enquiry involved observation and the interaction with students in order to offer empirical evidence for the research conclusions. (Heron J. in Reason & Rowan 199 :19) This means that the enquiry was within the personal constructs of the researcher. This was a form of existentialism as the researcher was involved as a person (with his own feelings, perceptions, prejudices, needs, etc.). (Reason & Rowan 19 :xvii)

3.2 Research Perspective.

The research was done from an educational perspective. The researcher expected to cause a change in the way students thought and the way in which educators teach.

3.3 Research Approach.

The ethnographic research approach was used in this study. This was the most suitable as the researcher was dealing with a small scale intervention, one aspect of the syllabus, in the functioning of a real world situation, a biology class. Further the research took place in a specific situation, an ecological excursion followed by the manipulation of data collected by means of a database in a computer laboratory. In the collection and manipulation of the data the researcher required the active collaboration of the students in the designing of the database. The researcher, although an observer in the research, needed to be a participant as well. The researcher initiated the development of the database and provided the initial queries that the students ran on the database. Following this there was further collaboration in the stimulating of the students to develop their own queries which, it was expected, would lead to the development of higher order thinking skills.

3.4 Research Method.

The research method was a case study as recommended by Smyth (1977), Bell (1987:6) and Walker 1980 (in Dockerall and Hamilton). A case study being the examination of an instance in action. In terms of the goals of the research the study was an investigation of how a biological database could be used in promoting higher order thinking skills as part of the 'scientific method'. The 'scientific method' requires the following:

the definition of the problem;
the formulation of a hypothesis;
the design of an investigation to test the hypothesis;
the observation, collection, analysis and interpretation of the gathered data;
the application of the data and the establishment of further hypotheses or the modification of existing ones (Ayerst <u>et al</u>., 1989; Friedler, Nachmais & Linn, 1990).

This method of enquiry has been well documented in biological journals over the past few years. Jungwirth and Dreyfus surveyed the interest shown in the acquisition of these skills as set out in the curricula of Departments of Education of many countries and states: "Global consensus in this respect can thus be taken as established" (Jungwirth & Dreyfus, 1990: 43)

Despite this view very little biological research has been done in schools as the resources required are not normally available. The research that has been done has provided insufficient data to make the 'scientific method' workable. Smyth (1977) writes that,

> " . . . the most successful approach was likely to be through case studies, field projects or simulation exercises rather than through any predetermined choice of theoretical syllabus material."

During the investigation it was hoped that the students developed higher order thinking skills as they progressed along the steps of the 'scientific method'.

3.5 Research Techniques.

The research technique used was qualitative. This technique

> "involves more open-ended, 'free response' questions based on informal, loosely-structured interviews, observation, or diaries." (Griffin in Burgess 1985c:100)

Griffin also points out that technique and data collection is most suitable for a small-scale study such as this.

Observation has been established as an acceptable part of the hermeneutic (interpretive) paradigm. This is because it is based on description and understanding. The researcher was aware that his attitudes, prejudices, variable behaviour and so on would effect the way in which the students reacted and how he observed them. (Griffin in Burgess 1985c:101) The other drawbacks of data collection by observation are that it is a slow, intensive technique; it has an ethical dimension in that it invades privacy; may disturb the behaviour that is being observed and that it can only deal with a small sample. The data obtained is hard to quantify. (Burroughs, 1975)

The researcher used unstructured participant observation when keeping records of all sessions of the students working on the database and the questions posed by them of the database. Participant observation had an advantage in that it allowed the researcher to share some of the participants' experiences. The period of observation was approximately 10 hours divided into 45 minute sessions spread out over two weeks. The observational notes were written in longhand and then rewritten and expanded using a wordprocessor.

Two audio recorders were introduced right at the beginning of the work in the computer laboratory so that participants got used to them being there. The students were encouraged to think aloud so that the way in which they were tackling a problem could be followed by the researcher. The tapes were then edited and transcribed into summation notes as described in Chapter 4. This type of observation gave insights into aspects that the researcher had not thought of beforehand. The group dynamics of the students as well as verbal and non-verbal behaviour were observed and recorded. Some of the advantages of this type of observation are that sequence of events, unpredicted events and qualitative events can be recorded. (Sanders & Pithey, 1983)

Participant observation has been criticised from a positivist perspective as lacking methodological rigour. The data was seen to be 'impressionistic' and thus unreliable. To overcome this criticism and to improve the reliability of observations the researcher used participant verification. This verification took the form of indepth interviews of selected students at the end of the study.

Further data was collected by means of interviews which were conducted after the students had completed the task in the computer laboratory. The students were required to prepare reports for the Biology teachers and copies of these were also collected by the researcher as part of the data collecting process.

CHAPTER 4.

THE CASE STUDY.

The Database Management System (DBMS) used in this study was Paradox 4.0. This is a very powerful and complex software package that can do far more involved tasks than was required in this study. The reason for its choice was that it was important that the software did not put any restrictions on the students' queries.

Students involved in the study had not previously been instructed in the use of a database. In the two weeks before the study they were taught the basics of database construction. This took the form of four 45 minute lessons and did not form part of the study. The students were given an overview of the Paradox Database Management System. They were able at the end of the short course to do the following:

- describe a table, fields, records;
- change directories;
- display the menu;
- clear the screen of all tables and images;
- use a predefined table;
- create a small table;
- enter data into the table;
- view the table;
- print the table; and
- generate a simple graph and print it.

Watson & Strudler (1988) consider these to be sufficient skills to be able to cope with the use of a database.

The theory section in the Form Four syllabus on Ecology was dealt with by the Biology teachers in the Biology lessons in the time leading up to the excursion. The theory work in Ecology and the practical sessions on databases acted as knowledge organisers in that the work was familiar to the students. Thus, the students had relevant and appropriate ideas about the subject. These ideas allowed them to have already available cognitive structures to build the new knowledge on. These cognitive structures should have made the task easier for the students to handle. (Nickerson, Perkins & Smith, 1985)

4.1 Methodology.

The case study took place using 20, Form Four (Standard 8) boys, with an average age of 15 years and 6 months. The students were selected by means of the systematic sampling technique in which every second student on an alphabetical list of all the boys taking Biology in Fourth Form. This list of forty eight Biology pupils represented the experimentally accessible population. Four boys who had been selected had to be excluded as they were day boys and would not be available in the evenings when most of the work was done. A further four students from the end of the list were then selected to take their places. All the students selected were studying Biology as an elected subject.

Permission for conducting the research was negotiated as suggested by Bell (1987:46) and was granted by the Headmaster and the Biology teachers. Participating students were addressed by the researcher and the form of the investigation was explained to them. Anonymity of the students was guaranteed. The research took place at the beginning of the fourth quarter of 1993. The scientific investigation concerned the hypothesis: The distribution of the fauna and flora on the rocky shore is determined by the ability of the organisms found there to withstand the prevailing abiotic conditions.

4.1.1 The Excursion.

Participating students were taken by the Biology teachers and the researcher on an ecology excursion to the Brighton Beach rocks. Access to this marine reserve was via the Wildlife society offices at Wentworth on the Bluff, Durban. This site was most suitable as it is part of a marine reserve controlled by the Wildlife Society and is unspoiled by pollution and interference by man. Expenses for the excursion (Hire of the bus and access to the reserve) were covered by the Biology Department Budget. The Wildlife society provided two Field Officers to help the students with the worksheets.

The aim of the excursion was to systematically collect information concerning the Rocky Shore habitat. The students observed the distribution of the fauna and flora (biotic factors) found on the rocky shore and also the environmental conditions (abiotic condition) over a period of five hours at spring low tide. The students were provided with thermometers, quadrants, metre rules, hygrometers (to measure salinity) and balls of string. The students were given a worksheets to direct their observations and a sheet of diagrams (See appendix 1 on page 78). These diagram sheets enabled the students to identify most of the plants and animals that they found. The Biology teachers and Field Officers filled in all other detail that the students required. Students worked in 3 groups which were arranged by the Biology teachers to ensure that all members of a group were from the same class and that there was a range of Biology abilities in each group. Each of the groups was placed under the guidance of one of the Field Officers and the researcher. The groups were further divided in half as the work could only be done at spring low tide which restricts prolonged access. The tasks were allocated as shown in the table below:

TABLE 5.

Study Groups.

Group 1.	Study 1.1 & Study 2.2	% Exposure and Mollusc density Rock platform pools (sandy)
Group 2.	Study 1.2 & Study 2.3	% Exposure and algal thalli Rock platform pools (rocky)
Group 3.	Study 1.3 & Study 3	% Exposure and animal diversity Infratidal zone

The worksheets for the Studies mentioned in Table 5 can be found in Appendix 1 on page 78.

4.1.2 Database Construction.

For the successful construction of a database several steps are required,

* project planning;
* database design; and a
* pilot study. (Hunter 1985:26 & Adams and Jones 1983:54).

The steps above were followed in this study and were carried out as explained below.

4.1.2.1 Project Planning.

Students were not involved in the planning of the project. Planning was done by the researcher and the Biology teachers.

Following the excursion the students met in the Computer Centre for 14 periods (45 minutes each) during prep and normal Biology class time. The priority was to ensure that all students in the groups had all the information that was collected on the excursion. Following this, the students reformed the same six groups that they had been in for the excursion. The researcher had decided to use group work as Durren & Cherrington (1992:81) have shown that in solving problems, groups have been found to be more beneficial than working alone.

4.1.2.2 Database Design.

Each group had been given a particular part of the rocky shore to look at in detail (See table 5 on page 33). The three groups were instructed in the "brainstorming" technique to work on the field names and the size of the fields that would be needed to enter the data into a database. The fields were written down by one of the students in each group. The groups were stopped at the end of fifteen minutes and the students then discussed the pro's and con's of each field. The groups then combined to set out the fields and field types that they would all adopt. Further decisions were made regarding the layout of the fields and how they would appear on the screen of the computer. Having all the fields exactly the same ensured that the entering of the data could be undertaken by a number of students and the database files thus constructed could be combined to form one big database to which all students had access.

The verbal interactions between students and between students and facilitator that were necessary while these activities were in progress were considered to be important. It is here that students heard different points of view that may have been at odds with their own, so leading to cognitive conflicts. These conflicts had to be resolved by the student by examining his own view point and understanding and considering those of his fellow students (Riel 1989:251). The students working together in these questioning/discussion sessions had to learn to listen to each other and to question each other, thus learning the skills of effective communication. Pizzini and Shepardson (1991:348) refer to Dillon (1983) who suggested that students are more likely to ask questions of fellow students than of the teacher. The answers given to student questions were longer and more complex than those given to a teacher's question.

The researcher took the role as initiator of the discussion trying to get the students to think through the problem of setting up the database so that they could achieve the goals of their investigation and allow for higher order questions to be formulated and used to query the database. Care was taken that the researcher did not dominate the discussion. Questions were referred back to the students for answering rather than left to the researcher to answer on his own. This was necessary if using the database was to lead to the development of skills related to comprehension, application and analysis. In the setting up of the fields of the database, the students had to keep in mind what information they were going to have to extract at a later stage in their investigation. This formed the basis of the design of the database. It was important that the students selected the fields themselves so that the database was constructed at their level of understanding.

4.1.2.3 Pilot Study.

The pilot study required that the students take a small sample of data for the database and enter it. This allowed them to see any major flaws in their design and allowed them the opportunity to "debug" the design and do any revision that was needed. Underwood (1988) has shown that these revisions are an important part of the cognitive skills of data organisation. In this case initially very little modification was needed.

Students then set up the database using the Paradox system and entered the data. The researcher ensured that the task was evenly shared among the students. It was regretted that this took far more time than was anticipated by the researcher.

4.1.3 Questioning the database.

Before setting up the database the researcher, with the aid of the Biology teachers, generated a series of questions about the topic (See appendix 2 on page 104). It was important as pointed out by Watson & Strudler (1988) that the researcher look for questions that had no definite answers since answering of this type of question should require higher order thinking skills.

The students had to translate these questions into the query language required by the Paradox database system. The students were asked to write these questions in query language on the papers containing the questions so as to form part of the data for the research. It was hoped that the problem questions were thought-provoking and required students to speculate. The questions also involved students in exploring relationships, making inferences and applying principles. Questions were also designed and selected in such a way that all the students could experience the correct level of challenge. Students had to be challenged but it was hoped that all the questions were not so difficult that the students did not achieve any success and so no sense of accomplishment. (Ausubel, 1968)

The students then, working in their groups, as suggested by Resnick (1987), used the database to analyze the information and obtain answers to the questions. Whilst working in groups the students were encouraged to "think aloud" so that fellow students could criticize and help shape their thought processes and data could be captured by the tape recorders. As the groups were small, it seemed more likely that the less able members of the group would participate in all tasks performed. The small groups should have allowed students to motivate each other so that they would try new approaches. In these new approaches it was likely that the students would receive support, even if the approach was not completely successful. To analyze the data the students needed to draw up search statements. It is at this stage that the students should have required critical thinking. (Clise, 1988)

It was the researcher's intention that the students would then formulate their own hypotheses, record them on paper and draw up search questions that they would put to the database.

4.2 Data collection.

For the methodology employed in this research, a case study, to be considered reliable, sufficient data had to be collected to allow the researcher to formulate hypotheses and suggest strategies that would allow databases to be used in a Biology class (Hopkins, 1985:105). The method of validation that the researcher hoped to employ was that of saturation. Saturation according to Becker (Becker, as cited in Hopkins 1985:111) refers to:

> "the checking on the frequency and distribution of phenomenon"

and Glaser and Strauss (Glaser and Strauss, as cited in Hopkins 1985:111):

> "no additional data are being found . . . (to) develop properties of the category."

This means that observation must continue until further observation leads to no more usable data being found. When this occurs the hypothesis can be said to have been validated. This was easier said than done.

4.2.1 Fieldwork.

Stenhouse (in Keeves, 1988) sees field work as the

> "process of evoking, gathering, and organizing information . . . observing; and measuring or collecting statistics."

The collection of data took the form of evoked documents, field notes, transcripts of fieldwork and transcripts of interviews.

4.2.1.1 Evoked Documents.

The students were asked to keep short notes of the hypotheses they generated and the questions they asked of the database to test each hypothesis and the outcome. The students found this very hard to do. The other evoked documents were the reports that they generated for their Biology teachers. A copy of such a document can be found as Appendix 5 on page 114.

4.2.1.2 Observational notes.

During the study the researcher attempted to keep written notes on the pupil interactions and other relevant occurrences. The researcher found this to be almost impossible while the students were in the Computer laboratory as the students made continual demands on him for help with the use of the Database Management system. All the field notes were typed into the wordprocessor as soon after each session as possible. During the typing of the observational field notes the researcher attempted to do some analysis and make notes as to where the data substantiated the hypothesis. It was also noted that some observations did not appear relevant to the field of research but were not discarded at this stage. This analysis was important as the researcher was attempting to achieve validity in the study by the process of saturation.

4.2.1.3 Tape Recordings.

While the students were working on the databases in the Computer laboratory two tape recorders were used. Participating students were requested to think aloud so that the researcher could follow their thought processes. The students found this very hard to do as it is not normal to verbalize one's thought processes. The transcription of the audio tapes was done by the researcher directly into the wordprocessor after each session so that the observations of particular events by the researcher were included where relevant. This also ensured that the data was fresh in the researcher's mind. Parts of the tape that were not relevant were not transcribed in full, as this was found too time consuming. The students found the tape recorders obtrusive in the beginning of the study although the researcher had had them in evidence during the initial training of the students in database use. The pupils who were not as committed to the research were the most distracted by them. One problem in using the tape recorder was the high level of background noise from other groups working and the clicking of the computer keyboards as data or queries were entered. Various positions for the tape recorders were tried but none was particularly successful. Unidirectional microphones would have been an advantage over the condenser microphones used but they were not available. Tape recordings were also taken during the short interviews that ended the study.

Four interviews which Konold and Well (1981:3) refer to as Piagetian interviews, were conducted once the projects had been completed and handed in to the Biology teachers. The four interviewees were selected because of their apparent attitudes to the project. Two appeared to have a very positive attitude and the other two negative attitudes. The students were asked to reflect back on what they had done in the sessions and what they felt they personally had achieved.

CHAPTER 5.

DATA ANALYSIS

5.1 Data Analysis Methodology

As mentioned in chapter 4 some analysis of the data occurred as the tapes were transcribed and the observational field notes expanded. Once the data had been collected as described in chapter 4, the data records were printed. The analysis, "the working of thought processes" (Sander and Pinhey, 1983:361) was then begun.

The analysis of the data was carried out using a mixture of the framework method as put forward by Hopkins (1985:107), the network method proposed by Bliss, Monk and Ogborn (1983) and the method of gathering and analysing data simultaneously suggested by Sanders and Pinhey (1983:356). Hopkins's framework consists of the following stages:

TABLE 6.

Four Stages of Classroom research

1.	**Data Collection** and the generation of hypotheses.
2.	**Validation** of hypotheses using the techniques of saturation and triangulation.
3.	**Interpretation** by reference to theory, established practice or teacher judgement.
4.	**Action** for improvement that is also monitored by classroom research techniques.

(Hopkins, 1985:114)

It is the second and third stages of Hopkins's framework that are of relevance in this chapter and the fourth stage in the final chapter. In addition, Hopkins (1985) further sees data analysis requiring the following four stages; definition of the concepts and indices; a check on their frequency and distribution; the incorporation of these findings into a model; and the presentation of the evidence and proof.

The first stage of analysis was then to categorize the data according to a series of topic headings, categorizing into what Sander and Pinhey (1983) call classes. The headings of the classes were based on the higher order skills set out in chapter 2, which are:

- # Differentiating and grouping
- # Analysis
- # Ordering
- # Comparing
- # Association
- # Hypothesizing
- # Planning
- # Problem solving
- # Inferring
- # Testing
- # Evaluating
- # Deciding

This was done by analysing all the field notes and tape transcripts and then typing them into the wordprocessor under the headings above. While the analysis was being done, it was found that it was very difficult to differentiate between some categories and it was decided to join some of them together. Differentiating, grouping and analysis were joined, hypothesizing and planning, and finally evaluating and deciding. In the course of the analysis it was found that there was data on the following topics as well:

- # The use of **PARADOX**
- # Group interactions
- # The suitability of the worksheet.

The researcher felt that these had to be considered as they appeared to affect the outcome of the interaction. Slowly the chaos appeared to diminish.

The next stage of the analysis was a check on the frequency of the occurrence of these classes and the identification of linkages between the classes. This was to see how the categories were perceived to fit together or flow from one another. Throughout the collection of data and its analysis the researcher was looking for patterns. These linkages if they were to be valid as evidence ought also to have been persistent in that they occurred over a period of time. Patterns should also have been transitional in that they occurred several times. (Sanders & Pinhey, 1983)

5.2 Analysis

In analysing the data it seems appropriate to discuss the last three topics first. They appeared to have had some influence on the amount of data that was collected and on the interaction as a whole.

5.2.1 Paradox.

Contrary to the findings of Watson and Strudler (1988) as discussed in Chapter 3 the database skills that were taught to the students before the interaction were not sufficient. This lack of proficiency in using **PARADOX** led to the students becoming frustrated with their lack of progress. Comments such as:

> "These graphs take too long to set up."
>
> "Why is it giving me this, when I asked it to graph something else?"
>
> "Computers are so dumb."
>
> "It gets on my goat."
>
> "Bloody stupid piece of Japanese junk."

"What the hell did it do now?"

"Exposure to light. Percentage oxygen to zones. How the bloody hell do you delete this SIR? !!!! I don't know how to work this bloody thing!"

were found in large numbers in the early transcripts and at times were addressed to the researcher in person.

The constant requests for help also made it very difficult for the researcher to make very many field notes while the students were working. These had to be written immediately after the end of a session. Requests such as:

"I don't know how to swop these things around."

"How do you change the titles?"

"What must I do now?"

were also found too frequently in the transcripts for the researcher to be happy with the training that had been given.

There was also a large amount of data showing the researcher standing at the back of a group and having to back seat drive some **PARADOX** operations. Instructions such as:

"You have gone into **Ask** and you want **View**."

"Clear the desktop and go to **View**."

"Go to **Axes** and put in headings."

"Now set up the headings of the graph."

"Use **Alt-F5**."

"To set up the graphs you must . . . "

made up most of the data on the transcripts of the tapes from the early sessions. The researcher was also not able to get to each group as soon as they needed assistance and this could account for some of the frustration felt by students mentioned earlier. One group of four students found it was better to come to the computer centre in the afternoons rather than in the evening prep when the sessions normally occurred. When asked why they replied, "So that you can help us when we need it."

The researcher also noted that some more able students wanted to do complicated things with the tables and graphs that had not been taught them. Giving instructions on how to achieve these goals took up the researcher's time. The researcher would have preferred that the students spent the time manipulating more data in the system. On the other hand the less able students hung back and let the other students get on with the task in hand. They appeared in awe of the computer and its workings. This seemed strange as all the students had appeared to cope while receiving instruction before the beginning of the research. Students who had said that they were enjoying having the opportunity to work on the computer were now reticent about doing so. This may be because they felt under less pressure during the training sessions and now other students in their group were putting pressure on them to come up with correct answers. On one occasion when the more able students could not attend a session because of another commitment the less able students achieved success as shown by comments such as:

Student X:[2] "Hey it worked. We got it Sir! ."

Student T: "Sir it worked but it does not say Littorina

[2] The letters assigned to students during the transcription of the tape recordings serves only to indicate that a number of students were involved in the exchange. A letter does not indicate a specific student.

stuff here, but the graph's right."

Researcher: "Go to axes and put in the headings."

Here the student showed that he was capable of getting the graph to his liking.

A further frustration was that only one Laser printer was available for the printing of the tables and graphs. This meant that the pupils had to save graphs instead of printing them immediately. It would have been much more gratifying for the students to have seen the graph or table in hard copy when they had produced it.

It took too long for the whole group to reach consensus of field names and types. This meant that a large amount of time was wasted but these discussions seemed important at the time. With four groups not sticking to these decisions and having to restructure their tables later it may not have been worth while. The students took approximately four hours to get the database set up and the data entered. In terms of the length of the study the researcher felt that this was too long. This could have been because the students were unsure of themselves and lacked experience but it could also have been because during the instruction in **PARADOX** they thought they knew more about **PARADOX** than they did. A factor could have been that each group wanted to produce work independent of the other groups.

5.2.2 Group interactions.

The grouping of the students by the Biology teachers caused some problems. In hind-sight it appears that it may have been better to have allowed the students in the research group to have worked out their own groupings. Initially the researcher was satisfied as he did not want any of the less able students alienated or left out. There is evidence of some in group fighting and at one point the researcher had to intervene as tempers were getting a bit frayed. When the students were asked why this occurred in an interview, some replies were:

Student A: "Do you know why? Because normally when we get put into groups to do anything you get people who do not want to do anything and then one or two people end up doing everything then you do not need to communicate."

Student B: "You need guys with the same calibre."

Student E: "You need the top guys in one group - the top half at least."

The less able students were reluctant to put forward any reason for why the groups did not work together well.

Poor communication within the groups was evident from the transcripts of the tapes. If the researcher was nearby the students would direct their questions to the researcher rather than the group.

Student M: "Do you think I must do them down the side or both across the top?"
Researcher: "What does your group think?"
Student N: "I don't know."
Researcher: "Well group what do you want to do?"

There was poor group cohesion in three out of the six groups. In these groups there was evidence that they were not reaching consensus and that the more able students were doing most of the work. The researcher observed that when this happened the less able students tended to sit back. Sometimes they moved to observe what was going on in other groups or switched on a computer and became involved in activities not pertaining to the research. The researcher had to spend time encouraging them back to the group. There was no evidence that the less able students were belittled or made to feel unwanted in any way. When interviewed the more able students said that they had become frustrated with the rate at which the less able pupils typed in the data and so they had taken over.

There was poor intergroup communication as well in that four of the groups saw other groups of students as rivals. When all the data for each group had been entered they did not want to combine tables so that all the groups had all of the data. They had also not structured their tables the same as the other two groups who had kept to the specifications agreed to earlier. This meant that combining the tables was not possible until they had restructured them. The groups were not happy to restructure their tables so that the data from other groups could be added in but eventually they did when they needed data that other groups had.

Student X: Group 1.	"Then we can say that because of depth it {number of algae} changes."
Student Y: Group 2.	"Were dealing with the number of molluscs."
Student Z: Group 1.	"Molluscs feed on algae."
Student Y:	"I think that we must put the two tables together."
Researcher:	"I agree."

It was regrettable that during the interaction not all students could be at all the sessions. Prior commitments to other school activities had to take preference. Some less able students also found that they battled to get through their homework as well as get to the computer centre. Some students enjoyed what they were doing and put in extra time.

Student A:	"I won't go to supper."
Student B:	"I'm starving, I have to go."

Student A: "Bring me some bread or a roll or something."

5.2.3 Shortcomings of the worksheet.

The work sheet was found to be not truly scientific. This worried some more able students. The Biology department was not dogmatic about pupils making exact identifications of plants and animals and this led to confusion when data was being entered in the database. Was the alga which one group had called 'hairy red' the same as what another group had called 'spiky red'? Consultation of Branch (1981) was of little help in settling the argument as each student pointed to an alga not found on the east coast. There was a misunderstanding between the researcher and the Field Officers about how the densities of organisms on the rocks and in the pools would be calculated. This made data entry again difficult. A quadrant method should have been used rather than the counting of all the species in the pool and expressing them as a percentage of the total.

5.2.4 Thinking Skills.

The analysis of the data on thinking skills is very subjective. Some student's statements could fit into any number of categories. Some discussions appear to show a progression through the levels of thinking skills and a section of such text is dealt with in the Overview on page 64. The texts showing a progression were where the researcher looked for linkages.

5.2.4.1 Differentiating, Grouping and Analysis.

In the transcripts of the first two sessions where students were sorting out the data, that they had collected on the excursion, the thinking processes, differentiation, grouping and analysis, were found in abundance. This was true of all the groups and of all the students. Evidence of analysis was found in exchanges such as:

Student T: "Which pool is 'a' and which 'b'?"
Student K: "Look here."
Researcher: "Look at the depth."
Student T: "Ok I know which now."

Student X: "We've got no living things."
Student Y: "We had here." {Referring to worksheet.}

Further analysis of data and the extraction of what was relevant to the student then can be found in the exchanges below.

Student T: "This is the relative percentage air."
Student K: "Pool 'a' has less."
Student T: "Look at the size of the pool"

Student B: "Relative number of algae. You can count the number of species, what else?"
Researcher: "The walls of the pools were covered by algae."
Student A: "In the shallow pool the algae were free floating."
Researcher: "Living there or washed there by the tide?"
Student B: "They must have been washed there by the waves."
Student A: "Can we count them in?"
Student C: "Yes."
Student A: "Why?"
Student C: "Because they were still alive and would have produced oxygen."
Student B: "They did have bubbles on them."
Student C: "They covered about ten percent relative to the deep pool."

In another group that was busy sorting out the data from the worksheet we see that they were grouping and differentiating the relevant data into units that made sense to them.

Student E: "I don't know whether it will be possible for us to use them in the database. Well, how about the plants, we have their length and their density, so fine. Maybe we should put this in a table."

Student F: "We need the colour because we did not know any of the names of them."

Student G: "I know one of them. Do you have a pencil?"

Student F: "Its called sea lettuce. How are we going to . . . "

Student E: "No wait."

Student F: "It's all very well having all these things, their length and density."

Student G: "What else have we got?"

Student F: "Red finely branched."

Student G: "I reckon that is the bushy stuff."

Student F: "Yes that was bushy and the other one was the branched stuff."

Student G: "I think this is probably that stuff."

Following the discussion on names above the students then spent time in rewriting the data into the order in which they were going to enter it into the computer.

The discussion in 2.2 of Appendix 4 (page 109) gives a good example of a particular student's analysis of a problem. He did not make any observations which would allow him to answer the question directly. He therefore analyzed what other information he had which would allow him to make a reasoned decision concerning the hypothesis 2 of Appendix 2 on page 104.

5.2.4.2 Ordering.

The researcher saw ordering to be similar to sorting in that the students needed to arrange the data into some logical order. This entailed arranging data or the tables of data.

Student T: "I think that we must put the two tables together."

Student R: "Then we can say that because of depth it (number of algae) changes."

Student U: "We're dealing with the number of molluscs."
Student T: "We must then put these two tables together."

Ordering also entailed the ordering of the queries that the students would ask of the database. If the queries were not in the correct order, the outcome of the queries were often not what the students had expected. Sometimes to get the answer which was expected the order of the fields in the database had to be changed. When this was done the axes of the graph would be correct, the independent variable on the X-axis and the dependent variable on the Y-axis. An example of this would be getting height above spring low tide on the X-axis and the dependent variable, such as exposure, on the Y-axis. In the case below if numbers of mollusc had been the first column of the answer table, the axes would not have correct i.e. reversed.

Student J: "What must we ask?"
Student K: "We want distance and numbers."
Student L: "Ok. Lets do it."

Another example is given below where student N is aware that the fields (Columns) must be in the correct order to get the graph they require.

Student N: "We need the distance column here."
Student M: "Why?"
Student N: "So that it will plot it the other way around."

Most of the groups coped with this very nicely once they had tried it once. It seemed very logical to the students that the first field would always be on the X axis. In an interview one student said that they always put the x-axis first in Mathematics. In the extract below the students were ordering data according to the distance from the spring low water mark. It was also of interest to note that the students could correlate the distances with the actual position on the transect diagram.

Student A:	"This one is twenty eight."
Student B:	"The next one is eleven."
Student A:	"No it must be thirty nine.""
Student B:	"Why?"
Student A:	"Because we want the measurement from here (Points to diagram)."
Student B:	"Oh ja, from the low tide mark"
Student A:	"Then sixty two."

Ordering in all of the groups was illustrated by the restructuring the database table to include more information or the same information in a different order.

Student A:	"For exposure to air, the deep one will be fifty percent."
Student B:	"We need to restructure the table to include the animal counts. Is 'a' the deep?"
Student C:	"Ja"
Student D:	"Carnivores in the deep pool."
Student C:	"I will restructure it."

5.2.4.3 Comparing.

Comparing was an activity that was found in all the groups. The less able pupils found comparing fairly easy. The students compared the answer tables, that **PARADOX** produced in response to their queries, regularly and could draw conclusions from what they observed. The students were also seen comparing the graphs that they had printed out.

Student J:	"We can correlate this graph with the other graph."
Student K:	"Maybe we should."

Other students, usually those of better ability even compared graphs that they had not printed but could remember from one query to the next as illustrated below.

Student R:	"We wanted to see what this graph would do now that we have added in the two new values."
Student T:	"I don't think it is going to make a difference."
Student R:	"We wanted to do like, add in the abiotic factors to see if they had any influence."
Researcher:	"It's influence on what?"
Student T:	"The living things."

Other students could compare data and then draw two graphs that could be laid next to each other for interpretation.

Student J:	"Can we start at twenty-eight?"
Student L:	"Yes."
Student K:	"Why?"
Student L:	"It (this graph) can slot in at twenty-eight on the other graph."
Student K:	"Ok."

5.2.4.4 Associating.

All the students could associate their observations of a particular phenomenon with a specific reason.

Student J:	"How come a thirty cm pool has no plant life?"
Student K:	"Well!"
Student L:	"It could be because it had a sandy bottom."
Student J:	"Oh yeh!"
Student K:	"They can only hold onto rock."

Student B:	"We appear to get more variety due to wave action."
Student A:	"It's stable between two and five."

Many students found that they could associate cause and effect as illustrated by a graph if the graph was of a particular type. Some groups produced only bar graphs but others a variety of types, line graphs, ribbon graphs and stacked bar graphs to mention a few. To change the type of graph was very easy to do and was achieved by only three key presses. The researcher showed those groups with only one type how to get others. Some experimented and were pleased with the new result but others were happy to stay with the type that they had initially chosen.

Student A: "We want to show that the greater the exposure the higher the temperature will get. I think we have shown it and got a graph and you can clearly see that that's going up at the same time that is going up. So ok! That's what we want to show but is it possible to have the two sets of bars next to each other."

Researcher: "Don't you think a line graph might show that a little clearer? You will get two lines going up."

Student A: "Ok, we can try that." Works on computer.

Student B: "That's better they are not stacked on top of each other."

Student M: "May be a line graph will show more."

Association of cause and effect is illustrated in 1.1 and 1.2 of Appendix 4 (page 109) where a group set out to investigate hypotheses 1 of Appendix 2 (page 104). They were able to associate exposure time with size of animal and were able to relate size to the other factors (heat, desiccation) which are prevailing in the various regions.

In setting out to substantiate hypothesis 4 of Appendix 2 (page 104) the students were able to associate the lines on the graph (Appendix 4 number 4 page 110) and distance from the spring high water mark with the various zones.

5.2.4.5 Hypothesizing and Planning.

The students were asked to write down any hypothesis that they generated themselves after looking at and investigating the hypotheses that were provided by the researcher (See Appendix 2 page 104). For the most part they found this hard to do although two groups achieved this very easily. Some of the hypotheses that the students generated and investigated were: The more light in the rock pools, the more plant growth; The greater the exposure, the less feeding time. Appendix 3 (page 106) lists more of the hypotheses that the students handed in. During the researcher's observation of the groups working it was noted that some groups were doing the queries and only writing down those that they considered as successful. These groups also planned the queries in their heads which meant that not all the members of the group had input in the final query. The student behind the key board seemed to dominate in the query generation. As mentioned earlier this was often the more able of the pupils in the group. Student A was seated behind the keyboard in the example below and the Student B was perhaps the more able of the two pupils here. It must be noted that the other two members of this group did not participate in the exchanges.

Student A:	"Let's ask another one on **Intertid** now.".
Student B:	"Zone and, wait we should do zone and each one of these."
Student A:	"Let's start at zone. What do we want after that?"
Student B:	"In descending order."
Student A:	Works at the computer entering the query.
Student B:	"Try and get the numbers in descending order."
Student A:	"We want wave action first."
Student B:	"Go **F10** Image **Move** - Move wave action to the front."
Student B:	Does some back seat driving.
Student A:	"Query again."

Student A: "What other factors are we going to look at?"

Student B: "The other things that could be involved are wave action and time of day."

Student E: "But this is the mean average for the day, twenty-four hours."

Student A: "Let's try percentage exposure." Works on computer.

Student B: "Let's look at **Intertid** {Name of table} and see what other hypothesis we can find."

Student C: "Light."

Student A: "Light and exposure are the same thing."

Student B: "The amount of light penetrating the water."

Student A: "Do all plants require light for photosynthesis?"

Student C: "Yes."

Student A: "Then let's try light and species diversity. (Works on computer) We need light and total species variety. (Works on computer) Why am I getting all of these?"

Student B: "Try again."

Student A: (Works on computer) "Lights zero, thirty-three, forty and seventy . . . "

5.2.4.6 Problem Solving.

The problems that the pupils found themselves solving were for the most part the problems that using the **PARADOX** management system gave them. They tended to solve these problems by asking the researcher for help or else by trial and error as seen in the transcript above. The system had given them information that they felt that they had not asked for and instead of working out why, they went through the process of "Try again.".

There were instances where sudden insight led to the solving of problems as illustrated below.

Student B: "You asked for oxygen and it gives you wave action."

Student A: "Hey it is oxygen we just have to change these things (Labels on axes) around."

This example relates to a graph that the students had produced using **PARADOX** and the labels on the axes were incorrect. They assumed that the figures were also incorrect until Student A checked them against a table of results. He realised that the problem was not the figures, but that they had used the set up of the previous graph that they had produced and had not changed the labels on the axes.

5.2.4.7 Inferring.

Inferring implies making judgements or deductions based on the evidence. In the sections of transcript below the students have the problem of deciding how to express availability of light. This was important as the students wanted the result of their query to be drawn as a graph. **PARADOX** required a numeric quantity to draw a graph. The scientific measurement of availability of light was not possible as light meters or other devices were not available to the students. The students therefore had to look at the evidence from their observations and make a decision.

Student B: "Availability of light. We will have to do it as percentage. It will start at 100 percent."

Student C: "Why are we going to do it as a percentage?"

Student B: "Ok, availability of light. If you have a pool ten cm deep and a pool of one hundred and twenty cm therefore the pool with ten is going to get a lot more, we can do it as a ratio, 120 : 10 therefore it is 12 : 1."

Student X: "Sir is it right to do this? We have to express the availability of light. We have expressed it as a ratio between the one pool of ten cm and the other of one hundred and twenty cm. Now we have

	worked out that the deep pool has eighty percent light and the shallow pool as ninety two percent light, Is that Ok."
Student Y:	"Otherwise what must happen is the shallow pool must have a hundred percent and the other pool say fifty percent."

In Appendix 5, pages 119 and 120, we find evidence of a pupil weighing up the observations he has made about the prevailing abiotic conditions on the rocky shore. Having considered these observations, he is able to make inferences about the temperature, feeding time and oxygen levels and express them clearly.

There were many examples of students, in all of the groups, weighing up evidence and making decisions.

Student T:	"We must then deduce from this which is which."
Student R:	"Then we can say that because of depth it (number of algae) changes."

Inferring is also shown by students in hypothesis 1 of Appendix 3 (page 106). They weighed up their knowledge about the hypothesis and drew some inferences. They then asked a query of the database table that they had called 'variety' which allowed them to test the inferences and make some decisions concerning a conclusion.

5.2.4.8 Testing.

The researcher feels that testing was one thing that using a database allowed all the students to become familiar with. The students were all able to a greater or lesser extent to formulate hypotheses and then to query the database to test these hypotheses. In Appendix 3 (page 106) we see examples of student formulated hypotheses. All the hypotheses were tested and evidence gained to support or disprove their hypotheses. Testing most often followed on straight after the section Hypothesizing and Planning. In the interviews all four students said that the entering of queries and waiting for answers was for them an exciting part of the project. Two students said that the results of the queries often led to frustration if the answer was not what they expected or wanted.

5.2.4.9 Evaluating and Deciding.

Most evaluating and deciding appeared to take place when the students contemplated the graphs that they had produced using **PARADOX.** In the discussion below the students are deciding whether the graph supports their hypothesis.

Student B:	"Maybe we can deduce that there was too much light."
Student A:	"There is. In other words there is an optimum light level at sixty six or so. Our hypothesis 2 was, the more light the more plant growth and that has turned out to not be right."
Student B:	"There is a bell-shaped graph."
Student B:	"We did another one (Query) and when there is zero light there is thirty three, forty and seventy so there is an optimum."
Researcher:	"Maybe there is a correlation between light, temperature and species because light and temp could correlate. When it gets too hot the light is . . .. "
Student B:	"You can see an optimum and then it starts tapering off."
Student A:	"Isn't light and exposure more or less the same thing."
Student E:	"We could be talking about exposure as just no water."
Student C:	"Exposure to oxygen."
Researcher:	"Exposure to drying out or air."

Student A: Works on computer.

Student B: "Look with zero light exposure its that, then it slowly starts tapering up and gets to a point where it cannot handle any more light and ducks."
Student A: "So."
Student A: "Sir this seems to show that the total diversity and light are best in the lower balanoid zone."
Researcher: "Yes because it has a nice equilibrium."
Student E: "Nearer the beach it just gets too hot I think."

In another group, also looking at a graph that they had produced, a long discussion was held in deciding whether the graph substantiated or disproved their hypothesis.

Student S: "They don't increase in the same proportions so I think that there are other factors involved."
Researcher: "Ok"
Student S: "Temperature does play a part."
Researcher: "What are the other factors that could be . .. "
Student T: "Wave action."

They then went on and modified their hypothesis and after two more queries evaluated all three graphs in terms of their hypothesis and eventually were happy with the outcome. In one group, once they had produced the graph, they just accepted it and went on to something else without any evaluation.

In all of the examples in Appendices 3 and 4 the students have reached a point where they have been able to evaluate the data and been able to decide whether the hypothesis is valid or not.

Looking at the graphs on pages 120 - 123 of the student report in Appendix 5 we see that the student has been able to interpret and evaluate the graphs. Following this he has made some decisions concerning what they show and written conclusions which can be found on page 124. In the same report on page 132 the student considers the graph on page 129 and reaches the conclusion that:

> "The graph clearly shows that the distribution of mollusca in the intertidal zone is not determined by their percentage exposure."

He interprets the graph on page 131 and states that the hypothesis concerning the distribution of mollusc species being determined by the percentage exposure to be false. He postulates that the distribution is due to the molluscs being specifically suited to survive in specific and diverse habitats.

5.2.4.10 Overview.

In the last tapes there was evidence that the students had come to grips with **PARADOX** and their thought processes had become more finely tuned. They could go through the steps outlined above with comparative ease. In the section of transcript below the students set out planning their course of action:

Student A: "We must make a hypothesis like we said last night."
Student C: "Ok! Then we must ask questions of the datatable then analyze the answer table."
Student B: "Ok!"

After the planning stage the students set out to generate a hypothesis that was acceptable to the group:

Student A: "Hypotheses. We've got information about wave action, temperature, exposure, light feeding time oxygen the zones distance from high water total species variety. Ok."
Student D: "Hum"
Student A: "Doesn't it stand to reason that the greater the distance from high water the greater the feeding

time"

Student B: "The greater the distance from high water."

Student D: "Ja."

Student C: "I think we have already discussed that."

Student A: "How about the greater the exposure the greater the temperature."

Student B: "Yes because of the sunlight."

Student A: "Hypothesis 1. Write it down. The greater the exposure the higher the temperature. Ok. To solve this we need to ask for exposure, temp and zone name.

Having formulated their hypothesis the students performed the query on the database to get evidence in support of the hypothesis:

Student B: "Ok"

Student A: "Look you can see it here in the table."

Student B: "As the exposure increase so does the temperature."

Student A: "Now to get that." (Works on computer.)

The students evaluated the outcome of the query and then went back and collected more data by performing another query:

Student B: "Let's query for zone name, temp and percentage exposure."

Student C: "Lets draw a graph of it." (Work on computer.)

Having now got the evidence they required, the students translated the table that was the result of the query into a graph for more evaluation:

Student A: "This pretty much shows us. You can see here that there is a definite increase in temperature as exposure increases. There is a trend."

The students were now in a position to evaluate the evidence finally and make a decision regarding their hypothesis.

Student B: "So we have shown that the higher the exposure the higher the temperature."

It was interesting to see that some groups were not happy with the tables that the queries produced as evidence to support their hypotheses. They felt that only a graph was evidence.

Student A: "Now we've got to do the what? That ones done (Referring to a query). Are those graphs?"
Student B: "No don't worry about that they are not graphs."
Student A: "Can we express them as graphs?"
Student B: "No we cant because they are not figures."
Student A: "I think you might be able to . . . No, but we can do a table."

In the interviews the students said that they found the lines in a graph much easier to interpret than a table although the more able students included tables in the reports that they handed to the Biology teachers. See pages 128 to 131 of Appendix 5 for an example of such tables and the graphs drawn from them. The tables on page 135 and 136 were not graphed but are interpreted in the discussion on page 137.

CHAPTER 6.

CONCLUSION AND RECOMMENDATIONS

The researcher was concerned with innovation and change and in the ways in which the process of the research and the results may be implemented in an ongoing system within the specific section of the Biology syllabus. It was hoped that the results of the research would lead to additional or more innovative approaches to teaching and learning than is now the case.

6.1 Limitations of the Study.

There were several limitations to this study. The first of these was the time restraint. The constraint on time was that the study had to be done when it was convenient for the Biology department to teach the Ecology part of the syllabus. There was a further limitation as the Biology department had allowed only two weeks for the practical part of this section of the syllabus. The researcher therefore had to conclude the interaction in this period so that the students could hand in the reports to the Biology department on time.

The students involved in the research could not give up a large amount of time in the final term of the year as they needed time to prepare for the examinations that are written at the end of this term.

A further limitation was the sample size. The sample size was limited by the fact that the researcher was working alone. Sample size was restricted to twenty students as the researcher felt that this number could be spread more easily in the limited space available in the Computer Laboratory. The small sample size was also to ensure that groups did not get in each others way and that they would not be influenced to any great extent by what another group was doing or saying. Twenty also seemed a reasonable number of students for the researcher to observe.

Validity was also a problem as a third party could not be found who was prepared to be an observer so that validity could be enhanced by triangulation. With the time limit the researcher is not happy that validity by saturation was in fact reached. The time limit of two weeks was felt to be too short. Another week would have been more beneficial in this regard.

The three hours that the students received as training in the use of the PARADOX database management system was in fact found to be insufficient for its satisfactory use. This limited the number of hypotheses and further queries that the students could generate. The instruction in the use of a database management system needs to be more thorough and would probably best be spread out over several weeks with the students doing more exercises. It would be better if the topic was covered in Computer Literacy classes in Form 3. PARADOX may have been too powerful and therefore confusing for the students. It may be better to use a less powerful database management system which may be less confusing and more easily learnt.

When starting out doing group work with students who have done very little group work in the past, it may be easier to let them form their own groups to start with. This would allow them to feel more at ease and perhaps feel able to spread the work load more evenly.

When tape recorders are used to record data, unidirectional microphones should be used. This would have facilitated the making of the transcripts as background noise would have been reduced. It would also be an advantage to have had a tape recorder at each group so that all interactions could have been monitored. This would have increased the amount of data obtained thus making saturation more likely.

More care needs to be taken with the preparation of the worksheet used to ensure that nothing is ambiguous and that it is scientifically correct.

6.2 Prior Experience.

None of the students had any prior use of a database management system. Twelve of the students had been involved in a Science EXPO in which they had been exposed to the scientific method. This was not felt to be of any great advantage to them in the study as the scientific method was explained to all the students.

6.3 Support.

The Biology teachers were very supportive of the researcher but were not interested in getting involved in the actual research for various reasons. The researcher is grateful to them for organising the excursion to the rocky shore. The students were supportive and many gave up time in the afternoons to do extra work on the database.

6.4 Conclusions.

The researcher was satisfied with the outcome of the research. Analysis of the data obtained has shown that:

1. Biology students can master and use a Database Management System like **PARADOX** with a moderate amount of training. The training must be very thorough before students tackle the task of producing their own database.
2. Students who are used to working alone can adapt to work in groups and improve their communication skills. When drawing up groups it is important to take into account mental ability, personality and keyboard skills.
3. When a worksheet of a scientific nature is given to students care must be taken to ensure that it is itself scientific.
4. Once the students had mastered **PARADOX** whey were able to use it in such as way that they exercised higher order thinking skills. They progressed from simple differentiating to evaluating; deciding was achieved

relatively easily by most students. Differentiating, grouping and analysis was achieved by all the students and was displayed by them throughout the study. Ordering was practised by all the students in the groups as it was an integral part of preparing their queries for **PARADOX**. A few pupils seemed unable or lacked the inclination to compare either tables of results or graphs and they were not the less able pupils. On the other hand the majority of students found this a worthwhile activity. Having got the result of a query, in the form of a graph or table, all the students appeared to be able to associate the outcome with a particular reason. Hypothesizing and planning played a major role in the study. Only one or two of the less able students appeared to show no ability in this regard whilst the more able students found this an interesting challenge. The higher order thinking skills of inferring and testing became well developed in all of the students even the less able. A minority of students did not take the final step of evaluating the results of the queries that they had asked and reaching some conclusion concerning their hypotheses.

5. A new approach to Biology that got students away from working singularly and into group work was enjoyed by most of the students although many felt that working in groups was hard at first. Further, the novelty of being able to do Biology out in the air away from the Biology Laboratory was also enjoyed.

6. The short excursion into the world of the computer database was stimulating for most of the students who participated in the research.

6. The Biology teachers were impressed with the quality of the reports submitted by the students who had been in the research group and would therefore be likely to consider using the method in the future.

6.5 Recommendations for Future Research.

The following recommendations for future interactions need to be noted.
Further research could use this work as a pilot study and expand the database with more specific information about the fauna and flora of the Rocky shore. Additional information concerning the dune fauna and flora and the fauna and flora of the coastal dune forest found just off the beach could be included. If this was carried out the whole Form 4 Biology group could be involved.

The lessons learnt by this interaction could be applied to another subject such as History, that takes students on an excursion to Zululand and Northern Natal to visit battlefields of historic significance. The worksheets produced could ensure that the data collected was suitable for database use.

REFERENCES

Adams, A. & Jones, E. (1983). Teaching humanities in the microelectronic age. The Open University Press, Milton Keyes.

Aston, M. (April 1992). Lecture to M.Ed. Computers in education group. Unpublished manuscript. Rhodes University, Education Department.

Ausubel, D.P. (1968). Educational Psychology - A Cognitive View. Holt Rinehard, Winston.

Ayerst, P.W., van der Schijff, H.P., van Rensberg, N.P.J., and Roux, J.S. (1989). Data Response Questions in Biology. Shuter & Shooter: Pietermaritzburg.

Bell, J. (1987). Doing your research project: a guide for first-time researchers in education and social science. Open University Press: Milton Keynes.

Bliss, J., Monk, M. and Ogborn, J. (1983). Qualitative Data Analysis for Educational Research. Croom Helm: London.

Bloom, B. et al (1956). Taxonomy of Educational Objectives - Handbook I: Cognitive Domain. David McKay: New York.

Branch, G. and Branch, M. (1981). The living Shores of Southern Africa. Struik(Pty)Ltd: Cape Town.

Burgess, R.G. (Ed) (1985a). Issues in Educational Research: Qualitative Methods. The Falmer Press: London.

Burgess, R.G. (Ed) (1985b). Strategies of Educational Research: Qualitative Methods. The Falmer Press: London.

Burgess, R.G. (Ed) (1985c). Field Methods in the Study of Education. The Falmer Press: London.

Burroughs, G.E.R. (1975). Design and Analysis in Educational research. Educational Review: Oxford.

Champagne, A. (1986). Teaching for Workplace Success. National Centre for Research in Vocational Education, Ohio State Univ., Columbus.

Chatterton, J.L. (1988). Knowledge control: The effect of CAL in the classroom. Computers and Education. 12(1), 185-190

Chipman, S.F. (1986). What is Meant by "Higher-Order Cognitive Skills". Appendix B, "The Nation's Report Card", Study Group on the National Assessment of Students.

Clise, I. (1990). Critical thinking, technology, and research go hand in hand. The Computing Teacher. 17(4, 14-15.

Croll, P. (1986). Systematic Classroom Observation. The Falmer Press: Lewis.

Cohen, L. & Manion, L. (1989). Research methods in education (3rd ed.). Routledge: London.

Daines, D. (1984). Databases in the classroom. Castle House: Tunbridge Wells.

David, J. (1991). Restructuring and technology: partners in change. Phi Delta Kappan. 73(1), 37-40, 78-82.

Degl'Innocenti, R. & Ferraris, M. (1988). Database as a tool for promoting research activities in the classroom: An example in teaching humanities. Computers and Education. 12(1), 157-162.

Delmont, S. (1992). Fieldwork in Educational Settings: Methods, Pitfalls and Perspectives. The Falmer Press: London.

Dockrell, W.B. and Hamilton, D. (Ed's) 1980. Rethinking Educational Research. Hodder & Stroughton: London.

Duren, P.E. & Cherrington, A. (1992). The effects of cooperative group work versus independent practice on the learning of some problem-solving strategies. School Science and Mathematics. 92(2), 80-83.

Foot, R. (1989). Infants and databases. Micromath, 5(3)

Freeman, D. & Levett, J. (1985). Quest in the learning environment: Computer assisted information handling as a tool for learning and curriculum development. In K. Duncan and D. Harris (eds), Computers in Education 297-264. Elsevier Science Publishers B.V., North Holland.

Friedler, Y., Nachmais, R. and Linn, M.C. (1990). Learning Scientific Skills in Microcomputer-Based Laboratories. Journal of Research in Science Teaching. 27(2) : 173-191

Gilbert, S.W. (1992). Systematic Questioning - Taxonomies that develop critical thinking skills. The Science Teacher, Dec 1992, 41-46.

Goldberg, K.P. (1992). Database Programs and the Study of Seashells. The Computing Teacher. 19(7), 32-34.

Hammond, M. (1991). Looking back in hope. Micromath 7(3).

Hopkins, D. (1985). A Teacher's Guide to Classroom Research. Open University Press: Milton Keynes.

Hunter, B. (1985). Problem solving with data bases. The Computing Teacher. 12(8), 20-27.

Jongejan, T. (1989). Spreadsheets and critical thinking. Proceedings of the National Educational Computing Conference. Boston, Massachusetts : 71.

Jungwirth , E. and Dreyfus, A. (1990). Diagnosing the attainment of basic enquiry skills: the 100 year quest for critical thinking. Journal of Biological Education. 24(1), 42-49.

Jussel,M.R. (1990). Teaching problem solving strategies with and without the computer. The Computing Teacher. 17(4), 16-19

Keeves, J.P. (Ed.) (1988). Educational Research, Methodology and Measurement: An International Handbook. Pergamon: Oxford.

Konold, C.E. and Well, A.D. (1981). Analysis and Reporting of Interview Data. Paper presented at the annual meeting of AERA, Los Angeles, California.

Mc Kernan, J.C. (1991). Action Research. A Handbook of Methods and Resources for the Reflective Practitioner. Kogan Page: London.

Merriam, S.B. (1988). Case Study Research in Education. Jassey-Bass: New York.

Moll, L.C., (Ed) (1990). Instructional Implications and Applications of Sociohistorical Psychology. Cambridge University Press: Cambridge.

Nash, A. & Ball, D (1982). An Introduction to microcomputers in teaching. Hutchinson: London.

Nickerson, R.S., Perkins, D.N., Smith, E.E. (1985). The Teaching of Thinking. Lawrence Erlbaum, London.

O'Neil, J. (1992). Preparing for the changing workplace. Educational Leadership. 49(6), 6-9.

Parker, J. & Widmer, C.C. (1989). Using spreadsheets to encourage critical thinking. The Computing Teacher. 16(6), 27-28 & 55.

Pizzini, E.L. & Shepardson, D.P. (1991). Student questioning in the presence of the teacher during problem solving in science. School Science and Mathematics. 91(8),348-352.

Polin, L. (1991). Current thinking about critical thinking: Implications for technology use. The Computing Teacher. 18(5), 7-9.

Reason, P. & Rowan, J. (1981). Human Inquiry. A Sourcebook of New Paradigm Research. John Wiley & Sons: Chichester.

Reif, F. (1984). Teaching Higher-Order Thinking Skills for a Technological World: Needs and Opportunities. American Educational Research Association, Washington, D.C.

Resnick, L.B. (1987). Education and Learning to Think. National Academy Press, Washington, D.C.

Riel, M. (1989). The impact of computers on classrooms. Proceedings of the National Educational Computing Conference. Boston, Massachusetts : 250-254.

Rochford, K. (1983). Educational Theory and Research Design: The selection and critical use of research strategies, styles, perspectives, approaches, methods, models, tools and statistical techniques. Education Journal November, 31-44.

Sanders, W.B. & Pinhey, T.K. (1983). The Conduct of Social Research. Holt, Rinehart & Winston: New York.

Shemesh, M., Eckstein, S.G. & Lazarowitz, R. (1990). An experimental study of the development of formal reasoning among secondary school students. School Science and Mathematics. 92(1), 26-30.

Smyth, J.C. (1977). The biological framework of environmental education. Journal of Biological Education. 11(2), 103-108.
Strickland, A.W. & Hoffer, T. (1990). Integrating computer databases with laboratory problems. The Computing Teacher. 18(4), 30-32.

Thomas, J.W. (1972) Varieties of Cognitive Skills: Taxonomies and Models of the Intellect. Research for Better Schools, Inc., Philadelphia.

Underwood, J. (1988). An investigation of teacher intents and classroom outcomes in the use of information-handling packages. Computers and Education. 12(1), 91-100.

Underwood, J.M. and Underwood G. (1990). Computers and Learning. Basil Blackwell: Oxford.

Walker, R. (1985). Doing Research: A handbook for teachers. Methuen: London.

Watson, J. & Strudler, N. (1988-9). Teaching higher order thinking skills with databases. The Computing Teacher 16(4) : 47 - 50.

Zielinski, E.J. & Sarachine, D.M. (1990). Creativity and criticism. The Science Teacher. 57(8),18-20.
Adams, A. & Jones, E. (1983). Teaching humanities in the microelectronic age. The Open University Press, Milton Keyes.

APPENDIX 1.

Rocky Shore Worksheet

The worksheet is divided into three studies. Study 1 concerns a transect of the intertidal zone, study 2 the rocky pools and study 3 the infratidal zone. Study 1 is further divided into three sections each looking at a different aspect of the intertidal zone. Study 2 is divided into two sections, one concerned with sandy bottomed pools and the other those pools with a rocky bottom.

STUDY 1.1

A TRANSECT OF THE INTERTIDAL ZONE

Activity 1.

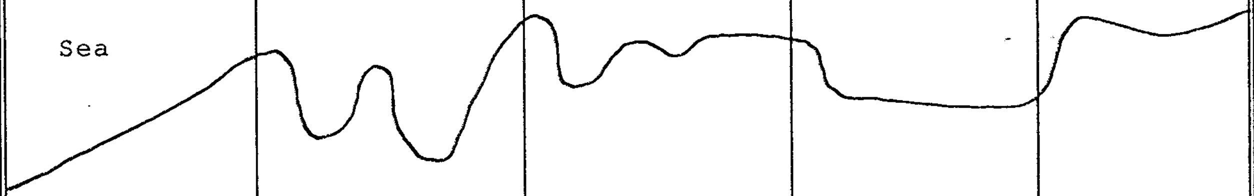
Consider the abiotic factors which prevail in the intertidal zone during low and high tide. List these in the first column of the table on the next page. In the next columns note down how these change during the daily tidal cycle in each zone, under the profile sketch (Not to scale) on the following page.

Activity 2.

HYPOTHESIS 1. The distribution of mollusca in the intertidal zone is due to the % exposure.

To test the hypotheses above it is necessary to do a transect in a line from the spring high water mark to the infratidal zone. The % exposure is best expressed as the distance from the spring high water mark. Proceed as follows:

1. Select a suitable stretch of intertidal zone and stretch a piece of string from the spring high water mark to the infratidal zone.
2. Starting at the spring high water mark measure off 1m. Place a 0,25m^2 quadrant with this mark as the centre and count the number of mollusca enclosed by the quadrant. Record the number and distance from the spring high water mark in the table which follows.
3. Repeat step 3 until the spring low water mark is reached.

	Infratidal Belt	Lower Balanoid	Upper Balanoid	Litorina Zone
	Algae & Red bait	Algae, Sponges, Mussels, Zoanthids	Barnacles, Tubeworms, Limpets.	Winkles, Oysters, Crabs
 Conditions	at high tide			
Conditions	at low tide			

RESULTS:

DISTANCE	No. MOLLUSCA	HEIGHT OF MOLLUSCA	DIAMETER OF MOLLUSCA

STUDY 1.2

A TRANSECT OF THE INTERTIDAL ZONE

Activity 1.

Consider the abiotic factors which prevail in the intertidal zone during low and high tide. List these in the first column of the table on the next page. In the next columns note down how these change during the daily tidal cycle in each zone, under the profile sketch (Not to scale) on the following page.

Activity 2.

HYPOTHESIS 2. The height of algae thalli in the intertidal zone is related to the % exposure.

To test the hypotheses above it is necessary to do a transect in a line from the spring high water mark to the infratidal zone. The % exposure is best expressed as the distance from the spring high water mark. Proceed as follows:

1. Select a suitable stretch of intertidal zone and stretch a piece of string from the spring high water mark to the infratidal zone.
2. Starting at the spring high water mark measure off a distance of 1m. Place a 0,25m^2 quadrant with this mark as the centre and find the average height of the algae thalli that are enclosed by the quadrant. Record the height in the table on following page.
3. Repeat step 3 until the spring low water mark is reached.

	Infratidal Belt	Lower Balanoid	Upper Balanoid	Litorina Zone
	Algae & Red bait	Algae, Sponges, Mussels, Zoanthids	Barnacles, Tubeworms, Limpets.	Winkles, Oysters, Crabs
Sea 				
Conditions	at high tide			
Conditions	at low tide			

RESULTS:

DISTANCE	Average height	DISTANCE	Average height

STUDY 1.3

A TRANSECT OF THE INTERTIDAL ZONE

Activity 1.

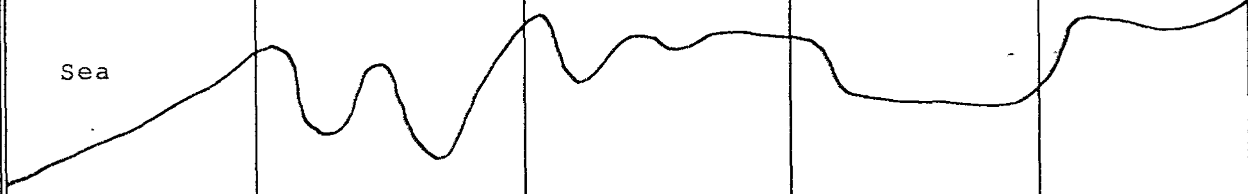
Consider the abiotic factors which prevail in the intertidal zone during low and high tide. List these in the first column of the table on the next page. In the next columns note down how these change during the daily tidal cycle in each zone, under the profile sketch (Not to scale) on the following page.

Activity 2.

HYPOTHESIS 3. The variety of animal life found in the intertidal zone is related to the % exposure.

To test the hypotheses above it is necessary to do a transect in a line from the spring high water mark to the infratidal zone. The % exposure is best expressed as the distance from the spring high water mark. Proceed as follows:

1. Select a suitable stretch of intertidal zone and stretch a piece of string from the spring high water mark to the infratidal zone.
2. Starting at the spring high water mark measure off 1m. Place a 0,25m^2 quadrant with this mark as the centre and count the number of different animals enclosed by the quadrant. Record the number and distance from the spring high water mark in the table on page 3.
3. Repeat step 3 until the spring low water mark is reached.

	Infratidal Belt	Lower Balanoid	Upper Balanoid	Litorina Zone
	Algae & Red bait	Algae, Sponges, Mussels, Zoanthids	Barnacles, Tubeworms, Limpets.	Winkles, Oysters, Crabs
Sea 				
Conditions	at high tide			
Conditions	at low tide			

RESULTS:

DISTANCE	Variety of animals	DISTANCE	Variety of animals

STUDY 2.1

A STUDY OF THE ROCK POOLS

COMPARATIVE STUDY.

HYPOTHESIS 1. The abiotic factors that prevail in a rock pool on the rocky platform influence the size and frequency of the life forms in that pool.

SECTION 1.

Select four pools of different depths and different distances from the low water mark.

Examine the profile of the rocky shore and draw it in the space below.

a = a deep pool near the sea b = shallow pool on the platform
c = Deep pool near the sand d = shallow pool near the sand.

SECTION 2.

Compare the contents of the pools 'a' and 'b' (i.e. the pools near the sand) and fill in the necessary information in the tables below.

RESULTS:

	a	b
Water depth		
Water temp.		
Substrate		
Availability of light		
Are plants producing gas?		
Does water flow in at low tide?		
Mean height of algae.		
Salinity		
Relative number of animals.		
Relative number of carnivores.		
Relative number of algae.		
Relative exposure to air		
Relative number of herbivores.		

BIOTIC FACTORS

Study the <u>animals</u> carefully and complete the table below.

Shallow pool:

Name	Shell or tube	Sessile or motile	Density	avg. height in mm.	Open or closed	Solita. or colonia l	Feedi ng

Deep Pool:

Name	Shell or tube	Sessil e or motile	Density	Avg. height in mm.	Open or closed	Solita. or colonia l	Feedi ng

Study the <u>plants</u> and complete the table below.

Shallow Pool:

Name	Colour	Length in mm	Density	Shape of branches

Deep Pool:

Name	Colour	Length in mm	Gas bubbles present	Density	Shape of branches

STUDY 2.2

A STUDY OF THE ROCK POOLS

COMPARATIVE STUDY.

HYPOTHESIS 2. The abiotic factors that prevail in a rock pool near the sand influence the size and frequency of the life forms in that pool.

SECTION 1.

Select four pools of different depths and different distances from the low water mark.

Examine the profile of the rocky shore and draw it in the space below.

Indicate on your profile the position of the following types of pools.

a = a deep pool near the sea   b = shallow pool on the platform
c = Deep pool near the sand   d = shallow pool near the sand.

SECTION 2.

Compare the contents of the pools 'c' and 'd' (i.e. the pools near the sand) and fill in the necessary information in the tables below.

	c	d
Water depth		
Water temp.		
Substrate		
Availability of light		
Are plants producing gas?		
Does water flow in at low tide?		
Mean height of algae.		
Salinity		
Relative number of animals.		
Relative number of carnivores.		
Relative number of algae.		
Relative exposure to air		
Relative number of herbivores.		

BIOTIC FACTORS

Study the <u>animals</u> carefully and complete the table below.

Shallow pool:

Name	Shell or tube	Sessile or motile	Density	avg. height in mm.	Open or closed	Solita. or colonial	Feeding

Deep Pool:

Name	Shell or tube	Sessile or motile	Density	Average height in mm.	Open or closed	Solita. or colonial	Feeding

Study the <u>plants</u> and complete the table below.

Shallow Pool:

Name	Colour	Length in mm	Density	Shape of branches

Deep Pool:

Name	Colour	Length in mm	Gas bubbles present	Density	Shape of branches

STUDY 3.

A STUDY OF THE INFRATIDAL ZONE

HYPOTHESIS: The distribution of fauna and flora in the infratidal zone is dictated by the abiotic conditions.

COMPARATIVE STUDY.

Select two different areas in the infratidal zone, one on an exposed rock surface and the other on the underside of the shelf for a comparative examination.

ABIOTIC FACTORS

Abiotic Factor	Rock Surface	Under the overhang
Rock Type		
Relative time of water Present		
Intensity of wave action		
Light Intensity		
Temperature of substrate		
Temperature of water		
Exposure to wind		

BIOTIC FACTORS

Study the <u>animals</u> carefully and complete the table below.

Rock Surface:

Name	Shell or tube	Sessile or motile	Density	Average height in mm.	Open or closed	Solitary or colonial	Method of feeding

Under the overhang:

Name	Shell or tube	Sessile or motile	Density	Average height in mm.	Open or closed	Solitar y or colonia l	Feeding

Study the <u>plants</u> and complete the table below.

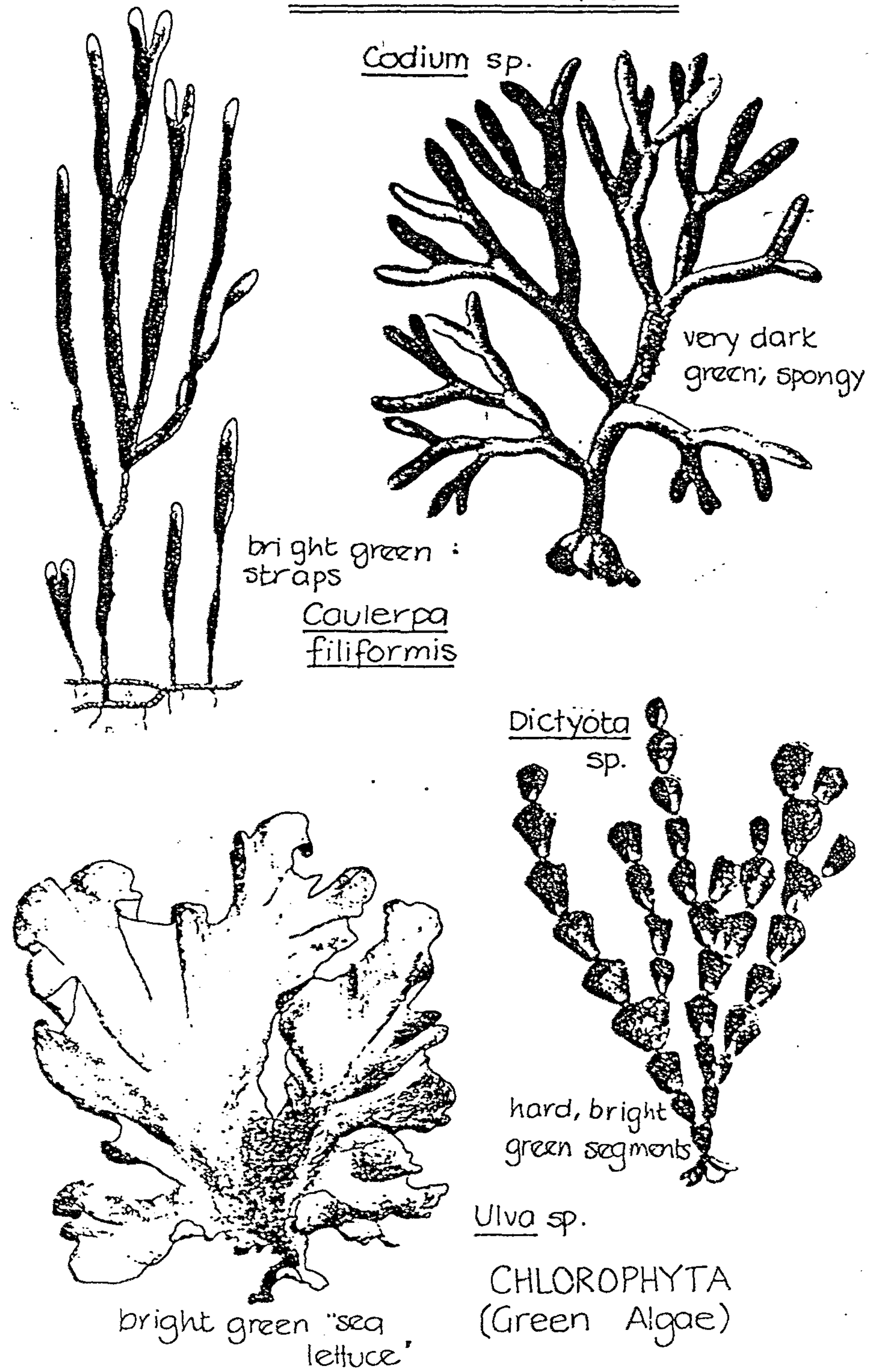
Rock Surface:

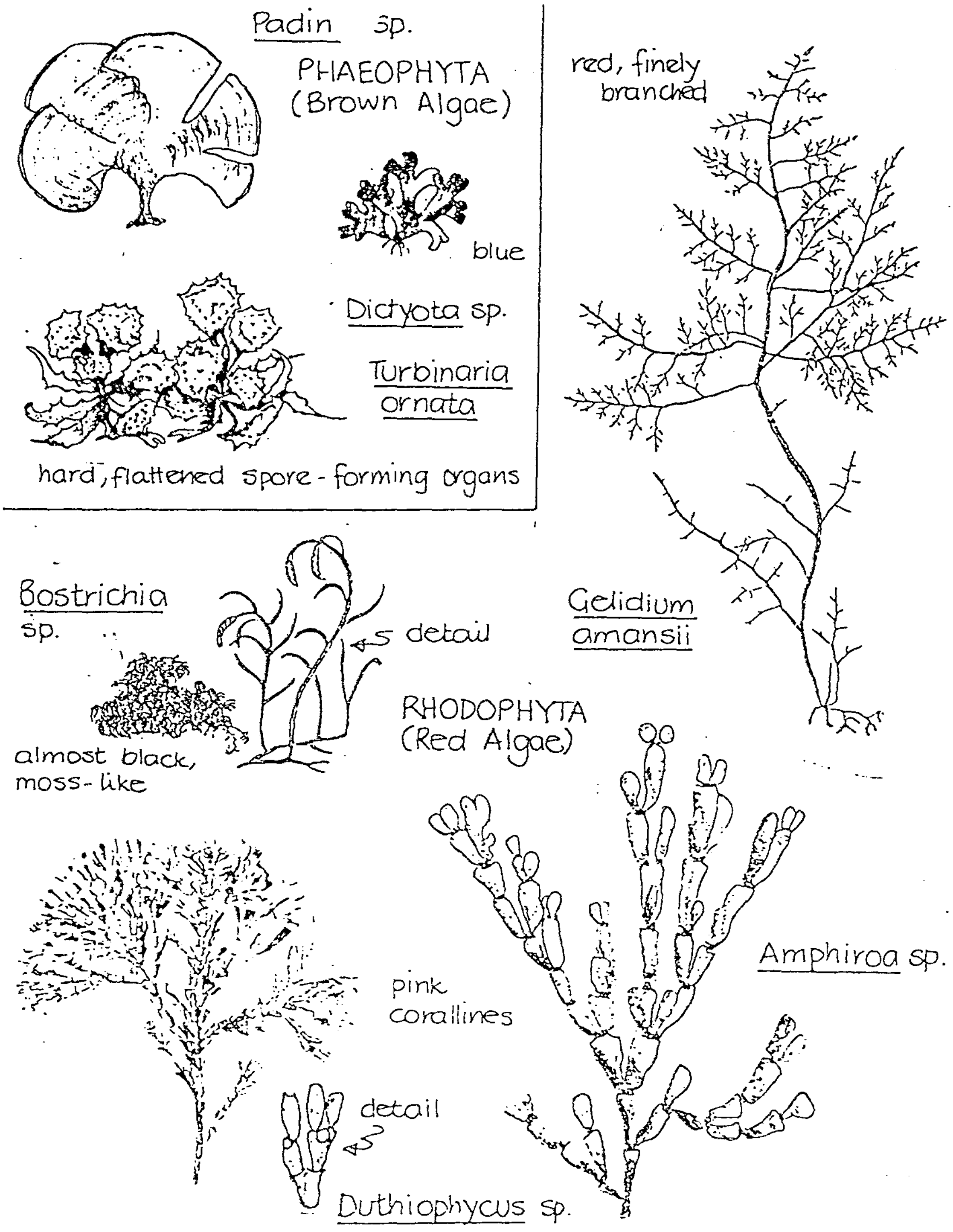
Name	Colour	Length in mm	Density	Shape of branches

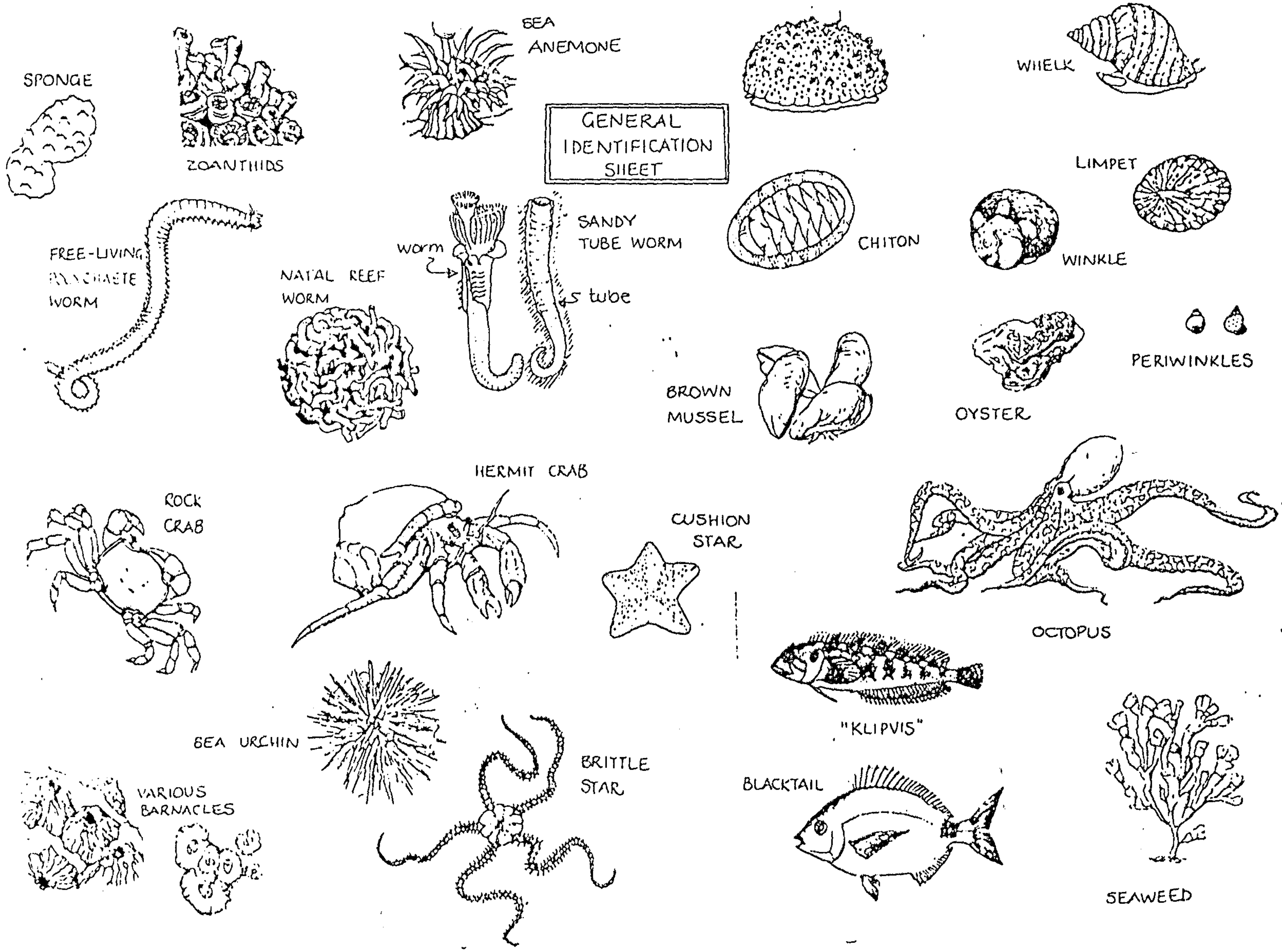
Under the overhang:

Name	Colour	Length in mm	Density	Shape of branches

COMMON SEAWEEDS




Padin sp.
PHAEOPHYTA
(Brown Algae)
blue
Dictyota sp.
Turbinaria
ornata
hard, flattened spore-forming organs
red, finely
branched
Bostrichia
sp.
detail
Gelidium
amansii
RHODOPHYTA
(Red Algae)
almost black,
moss-like
Amphiroa sp.
pink
corallines
detail
Duthiophycus sp.


GENERAL IDENTIFICATION SHEET
SPONGE
ZOANTHIDS
SEA ANEMONE
WHELK
LIMPET
WINKLE
CHITON
FREE-LIVING
WORM
NATAL REEF WORM
worm
SANDY TUBE WORM
tube
BROWN MUSSEL
OYSTER
PERIWINKLES
ROCK CRAB
HERMIT CRAB
CUSHION STAR
OCTOPUS
"KLIPVIS"
SEA URCHIN
BRITTLE STAR
BLACKTAIL
SEAWEED
VARIOUS BARNACLES

APPENDIX 2

Hypotheses prepared by researcher and Biology teachers.

1. The greater the time the mollusca are exposed the smaller the species found.
   Explain why this may be so.
   What is the relationship between the % exposure and the size of the mollusca?

2. Wave action affects the size of mollusca found on the rocky shore.
   What is the relationship between the relative wave action and the size of the mollusca?
   What evidence do you have to substantiate your answer.

3. What is the relationship between the distance above spring low water and the abundance of mollusca?

4. What is the relationship between the distance above spring low water and the abundance of algae?

5. Compare your answers of questions 3 and 4.
   What can you conclude?
   What other evidence can you find to substantiate your answer?

6. What is the relationship between relative wave action and the height of the algae?
   What can you infer from this?

7. What is the relationship between the % exposure and the abundance of algae?
   What can you infer from this?
   How could you test your conclusion?

8. Algae experience a number of problems in this habitat.

What are some of the problems algae experience living in this environment?

Prioritize these problems.

What solutions could you suggest that algae have adopted to overcome these problems.

9. Algae only grow where there is light.

What evidence is there that algae must grow where there is light.

Is this evidence conclusive?

10. The deeper the water in a pool the more animals are found.

Do you agree that water depth in pools can be related to abundance of animals?

Can you show this in the form of a graph?

Do you think that water depth is the only variable that is important?

Explain your answer.

What evidence can you find to substantiate your answer.

11. There are as number of limiting factors in a pool ecosystem.

What would you consider to be the most important limiting factor in a pool ecosystem?

Explain your answer.

Can you find data to substantiate your answer?

If not, what other factor could it be?

12. What is the major abiotic factor that would have to change to allow a wider distribution of algae?

What are the reasons for your answer?

What evidence do you have to backup your argument?

Would the same abiotic factor have to change for a wider distribution of animals?

APPENDIX 3.

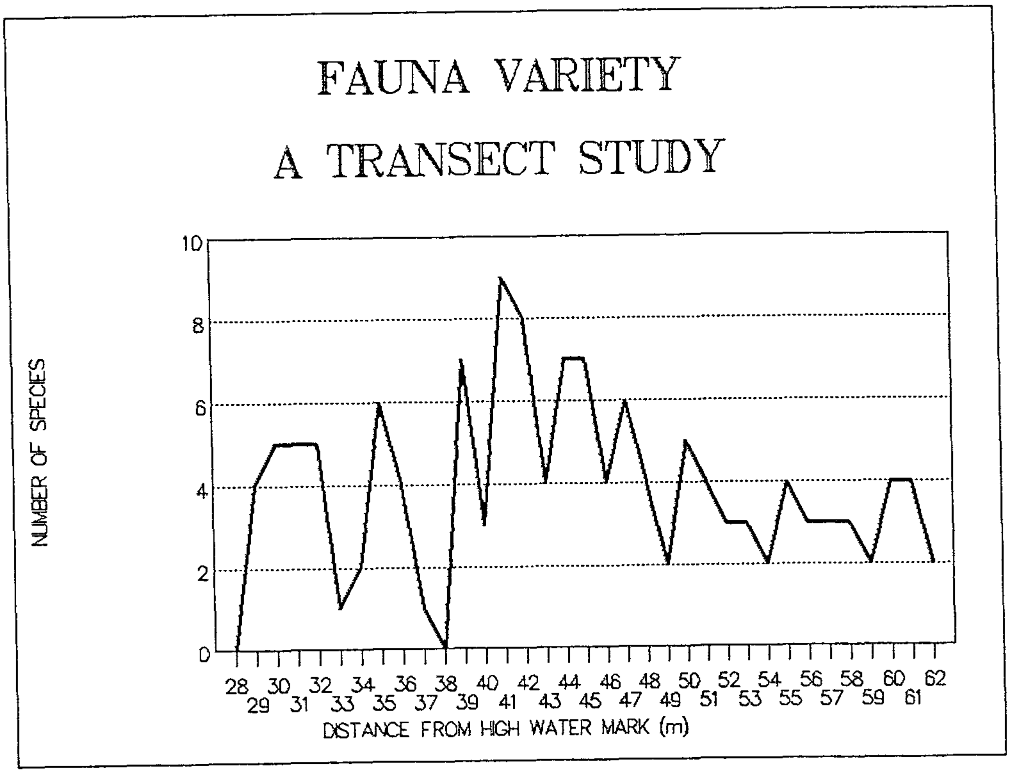
STUDENT GENERATED HYPOTHESES AND CONCLUSIONS.

Various hypotheses were formulated by students as possible explanations for phenomena observed. The meaningful ones were as follows:

Hypothesis 1: The further one goes from the high-water mark on the beach, the greater the species diversity.

The logic behind this idea is very simple: the beach appears to be a barren area of dry, infertile sand. The sea, on the other hand, is a treasure chest of life. It stands to reason that the further out to sea one goes, the greater the number of species to be found.

To answer the question, we plotted the results of the table called 'Variety'. We can see that the greatest diversity seemed to occur around the Lower Balanoid zone although this is also where the results fluctuated the most. Further out to sea the figures appeared to be lower but more constant(i.e. between 50 and 62 metres on the graph.)



Hypothesis 2: The greater the exposure, the greater the temperature on the substrate and in the water.

On the day that we visited Treasure Beach, the water was the same temperature as the rock. The graph 'Exposure vs Temperature' shows that although the two increase in the same areas, they do not do so in the same ratios. This suggests that they may be related, however there are undoubtedly other factors playing a role.

Hypothesis 3: The more light in the rock pools, the more plant growth.

All green plants need light to photosynthesize. It seems possible that the more light there is, the greater variety of plant life there will be. We queried 'Intertid' for species variety and light. In order to do this we had to consolidate the figures we had recorded for each metre into groups corresponding to the zones on the beach. Light increased steadily as we moved towards the beach. However, plant growth increased until the Lower Balanoid zone. It then fluctuated rapidly. This shows that the optimum amount of light occurs in this Zone.

Hypothesis 4: The greater the exposure, the less feeding time.

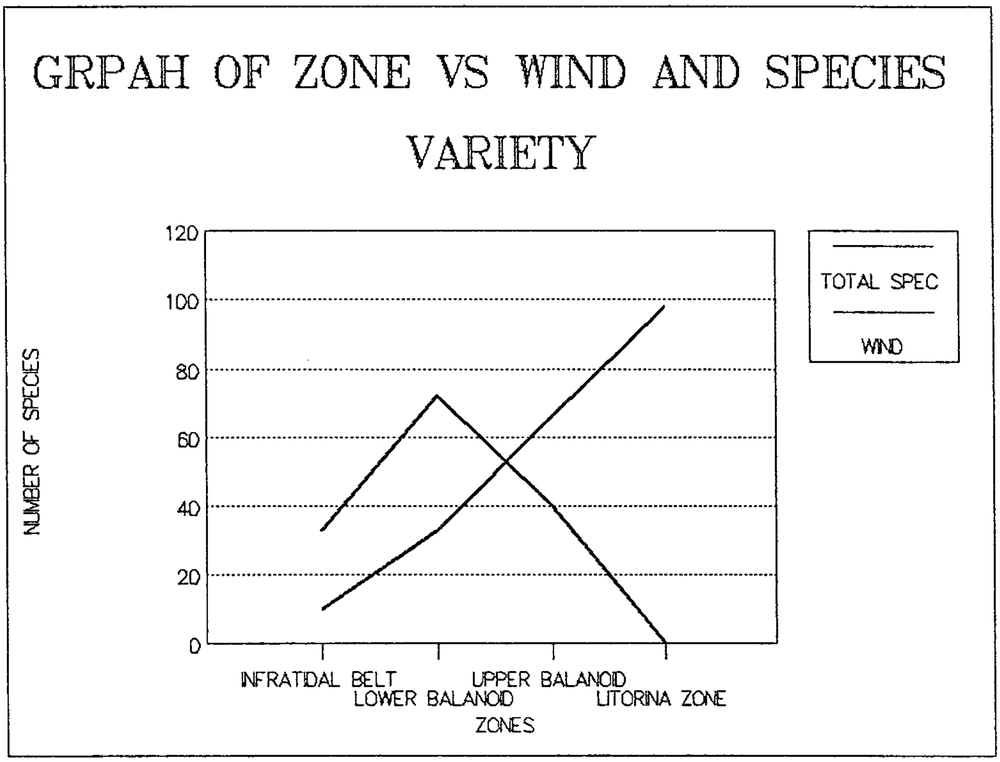
The main purpose of this idea is to show that exposure is one of the major factors influencing plant growth because it is directly related to the amount of time during which organisms could filter-feed from the water. We queried 'Intertid' for Exposure and Feeding Time. The two factors are inversely proportional as can clearly be seen.

Hypothesis 5: Does water depth affect the height of algae in pools?

This graph was an experimental failure. It has a few problems. It does not reflect the nature of the pool(e.g. sandy). It also does not show the effect of wave action. The figures therefore appear to make no sense. We can draw no conclusions without studying more related data.

Hypothesis 6: Does wind affect species variety?

Wind activity increases in a similar ratio to species variety from the infratidal zone inwards. However the variety drops again after the lower balanoid. On the whole, we do not feel that wind has a direct effect which we can see. It might, however, have a subtle effect on other abiotic factors.



APPENDIX 4.

SOME EXAMPLES OF STUDENTS ANSWERS TO HYPOTHESES.

1.1

(a) Mollusca exposed for greatest time in the Littorina Zone.

(b) Temperature in the Littorina Zone is the highest.

(c) Mollusca have small feet and shells which prevent and reduce heat gain and the chances of desiccation.

(d) Being predominantly filter feeders feeding time determined by tides. Higher up on shore = less feeding time = smaller specimen.

(e) Smaller animals could not resist and survive in infratidal because of severe action of waves.

(f) Converse of above occurs in the infratidal zone.

1.2

(a) Mollusca are most exposed for the longest period in the Littorina zone. In the Littorina zone they are the smallest.

(b) Mollusca are exposed for the least period of time in infratidal zone. In the infratidal zone they are the largest.

2.1

(a) Mollusca found nearer direct wave action in infratidal zone are larger than those mollusca in the Littorina zone where wave action is non-existent.

(b) Wave action influences algae growth.

(c) The mollusca's feeding time is therefore determined by tides which replenish nutrients in the water and sustain algal growth.

(d) The mollusca found in the Littorina zone therefore feed for a far shorter period because food supplies are limited.

(e) The mollusca in the infratidal zone can feed for a longer period because their food supplies are replenished constantly by wave action and are therefore larger in size.

2.2

We did not observe any animals feeding in the Littorina zone. Although zoanthids and anemones are not mollusca, we did observe them open and feeding in the infratidal zone which confirms my point that animals here do have the opportunity to feed for far longer periods than if they were in the Littorina zone. The limpets were also not firmly attached to the rock. if you were quick enough you could flip the limpet off the rock using your fingernail in the infratidal zone. This was not possible in the Littorina zone.

4.

The graph shows that the algae was concentrated in the infratidal and lower Balanoid zones. This obviously means that in these two zones sunlight and moisture create the optimum conditions for the cultivation of algae. In Littorina zone sunlight is present but water is not available at all times which makes it unsuitable. Algae is therefore not abundant here. It is therefore concluded, based upon these facts that algae photosynthesises best submerged in water but exposed to light.

5.

It is thus also appropriate to conclude that the larger specimens of mollusca are found where algae is abundant and it can be said that they graze on the algae beds prevailing in the Balanoid and infratidal zones. This would account for the reduction in the count of the mollusca in this area because they were concealed under the algae which they use as shelter because the flat platform does not provide many habitats. The algae conceals the mollusca from predators and oxygenate the water thereby sustain the life in the area.

6.

The algae which we observed on the rocks in the infratidal zone which experienced waves beating on them whilst dense, was relatively short +/- 3cm. It resembled the lush putting green on a golf course! The algae which occupied the stagnant pools of the Balanoid zone was far more bush and taller. The algae in the infratidal zone was also a cleaner green because of the action of the waves.

7.

The greater the percentage exposure to the elements the less abundant the algae there. High up on the shore where exposure to the elements is the greatest we observed no algae. In the upper Balanoid only Bostrichia and sea lettuce was observed in the pools. Both are very hardy species of algae. The lower Balanoid and infratidal zone on the other hand supported an abundance of algal growth. It is thus concluded that algae photosynthesises better when it is submerged in water but still exposed to sunlight. It is also observed that the algae growing in the stagnant pools was longer than that found in other environments.

7.1 Conclusion A could be tested by cultivating the same algae submerged in water and the other specimen exposed to the elements. Conclusion B could be tested by growing algae in a gully in the rocky shores environment and another specimen in a stagnant pool.

8.1

(a) Interference by humans eg. oil and chemical spills.

(b) Exposure is determined by tidal action and during spring lows the effects of exposure can be devastating because the algae is exposed for abnormally long periods of time.

(c) Population explosion of herbivores.

(d) Competition between the species for light.

(e) Storm current's can turn a rocky shore upside down.

(f) Red tide: Occurs when a particular species of phytoplankton flourishes and can result in mass mortalities of marine life.

8.2

Algae which grows in the stagnant pools tended to be longer and more dense than the specimens found in the infratidal zone. Algae was most dense in the pools of the lower Balanoid where wave action was not overly severe. They thus flourish in this area and it is where photosynthesis takes place at the fastest rate. It is concluded that algae on the high shore is flattened to allow for rapid photosynthesis during brief periods of submergence. Algae have thus adapted by growing in a specific environment in a specific way where conditions are perfect for them. Algae also grows on the rocky surface which prevents them from being torn off the rocks during storms or violent waves. They are also able to lose a large percentage of their water enabling them to survive during periods of low tide. They are not however able to withstand the effect of humans.

9.1

(a) Algae does not grow on the underside of a rock.

(b) It also does not grow in the deep sea where you start losing the light spectrum.

9.2

Yes this evidence is conclusive for my study purposes.

APPENDIX 5.

AN EXAMPLE OF A STUDENT REPORT.

ECOLOGY

Ecology is the study of plants and animals (living things) in relation to each other and in relation to their environment. Plants and animals need each other to live, feed and reproduce successfully. No living thing, animal or plant, lives alone. Humans can easily upset the balance of nature in an unspoilt state. We therefore have a responsibility to preserve the environment and restore it wherever or whenever necessary.

There are several different levels of organisation within the field of ecology. They are:

BIOSPHERE: This is the zone on earth where life exists. It consists of all eco-systems collectively.

ECO-SYSTEM: All the plants or animals in a particular area and the physical environment in which they live. It is the most complex level of organisation which exists in nature. An eco-system could be as large as an entire forest or as small as the area under a garden tap. An eco-system consists of parts or components. An abiotic (non-living) component and a biotic (living) component.

ABIOTIC COMPONENTS OF AN ECO-SYSTEM

The three most important parts are:

(a) The POSITION of the eco-system. This will effect every other component of the eco-system eg. an eco-system in the middle of the city will be very different to one in the countryside.

(b) The CLIMATE of an eco-system will depend on it's position and includes the temperature, the amount of rain and wind. A hot dry eco-system will therefore be very different to one that is submerged in water.

(c) The SUBSTRATE of an eco-system. Different plants will grow in acid soils to those in alkaline soils.

BIOTIC COMPONENTS OF AN ECOSYSTEM

The animals and plants in an eco-system constitute the living component. The type of plants which grow in an area depend on the abiotic factors which prevail and in turn the animals found there depend on the vegetation there. Ecologists divide the living world into three main levels:

(a) POPULATION: The population of an eco-system is a group of the same species that lives in an area at the same time. There are two main factors which influence the growth of a population. They are the rate at which the population would increase under the optimum conditions and the second is limiting factors such as limited food supply, predators, competition and disease. The carrying capacity is the maximum number of a particular species that an eco-system could support at one time. A population is normally smaller than its carrying capacity because of predators and poor breeding seasons.

(b) This is all the plants and animals which live in a particular area and are dependant upon each other. A community comprises more than one population. A community of plants and animals which cover a large geographical area is called a biome. Their boundaries are defined mainly by climate. Major biomes include deserts and forests. A biome derives its name from the principle vegetation which grows there.

(c) ORGANISM: This is one member of a population the ie. individual plant or animal.

FOOD CHAIN

This is the transfer of energy from one organism to the another. Plants that photosynthesize are known as the PRIMARY PRODUCERS. PRIMARY CONSUMERS are the animals that eat plants (herbivores). SECONDARY CONSUMERS eat animals (carnivores). Animals that consume both animals and plants are known as omnivores. Decomposers such as bacteria and fungi break down the remains of animals and plants and return their simple nutrients to the sea. Thus it can be seen that the energy from the sun is transferred to the photosynthesizing plant. This energy is then transferred to the animal that eats the plant. It is once again passed on to the carnivore or omnivore that eats the herbivore.

PLANT	-------->	HERBIVORE	--------->	CARNIVORE
(producer)		(primary consumer)		(primary consumer)

Most eco-systems have a variety of producers, consumers and decomposers which form an overlapping network of food chains called a food web.

INTRODUCTION

The inter-tidal rocky shore is one of the most stressful habitats to animals and plants - submerged twice a day for six hours when the tide rises experiencing icy cold water and crashing waves - then being exposed to the air and sun during low tides experiencing temperatures of up to forty degrees centigrade and losing up to forty percent of their body water. All the vital functions of life eg. respiration and excretion must be adapted to function in two completely different environments. Low on the shore the period of exposure will be minimal but moving up the shore the conditions become more harsh the period of exposure increases. Only hardier species manage to survive in the high tide regions while species that cannot tolerate exposure live near the low tide mark. Thus animals and plants are banded near the shore. This phenomenon is known as zonation.

There are four distinct zones. They are:

INFRATIDAL ZONE: At the low tide mark algae beds form a band called the infratidal zone. Very few animals inhabit this region because wave action is at its strongest and a different sort of algae predominates. Where the algae is sparse urchins and octopus hide in holes.

BALANOID ZONE: Above this is a second algae zone known as the balanoid zone which is further divided into an upper and lower zone.

(a) Lower Balanoid: Life in this zone consists of zoanthids, brown mussels, algae, limpets, whelks and anemones.

(b) Upper Balanoid: The upper balanoid zone supports animal life such as limpets, periwinkles and barnacles.

OYSTER BELT: This a belt high up on the shore which consists of a dense mass of Natal rock oysters.

LITTORINA ZONE: Highest on the shore is the Littorina Zone. Few species are hardy enough to tolerate the conditions here except three snails.

PREVAILING ABIOTIC FACTORS.

We identified four major zones. They were:

Littorina Zone - Furtherest from the spring low water mark the rocky shore.

Balañoid Zone - Consisting of the upper and lower Balanoid between the Littorina and the

Infratidal Zone - The area which was exposed to direct wave action.

Oyster Belt - This belt consisting of a band of Natal Oysters is situated between the Littorina and the upper Balanoid Zone.

I must emphasize that all our observations are based on conditions which prevailed at Treasure Beach on the day we visited. It was during a spring low and a south westerly wind was blowing. The day was overcast. These observations were converted into approximate percentages so that they could be expressed as graphs. They are however true representations.

It was observed that the area most influenced by wave action was the infratidal zone. It experiences waves breaking on the area. The Littorina zone on the contrary receives only splashes and water lapping at the rocks during high tides.

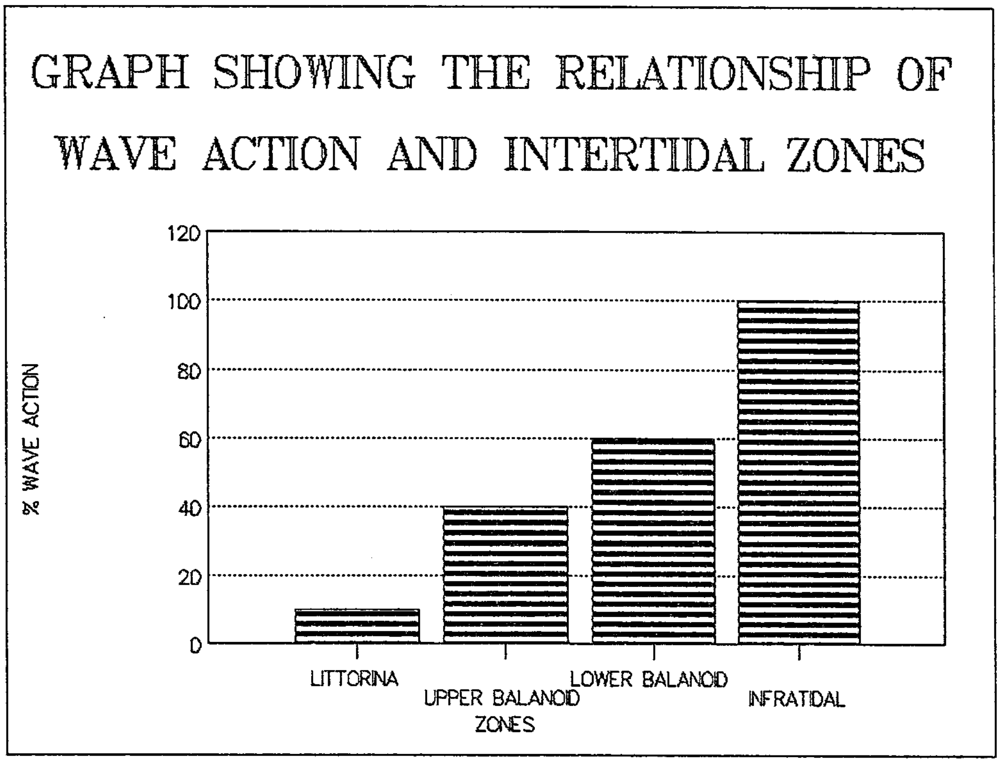
Related to this is exposure to the elements. Exposure is determined by tidal action. The Littorina zone highest up is exposed for the longest period and exposure decreases as you move nearer to the wave action.

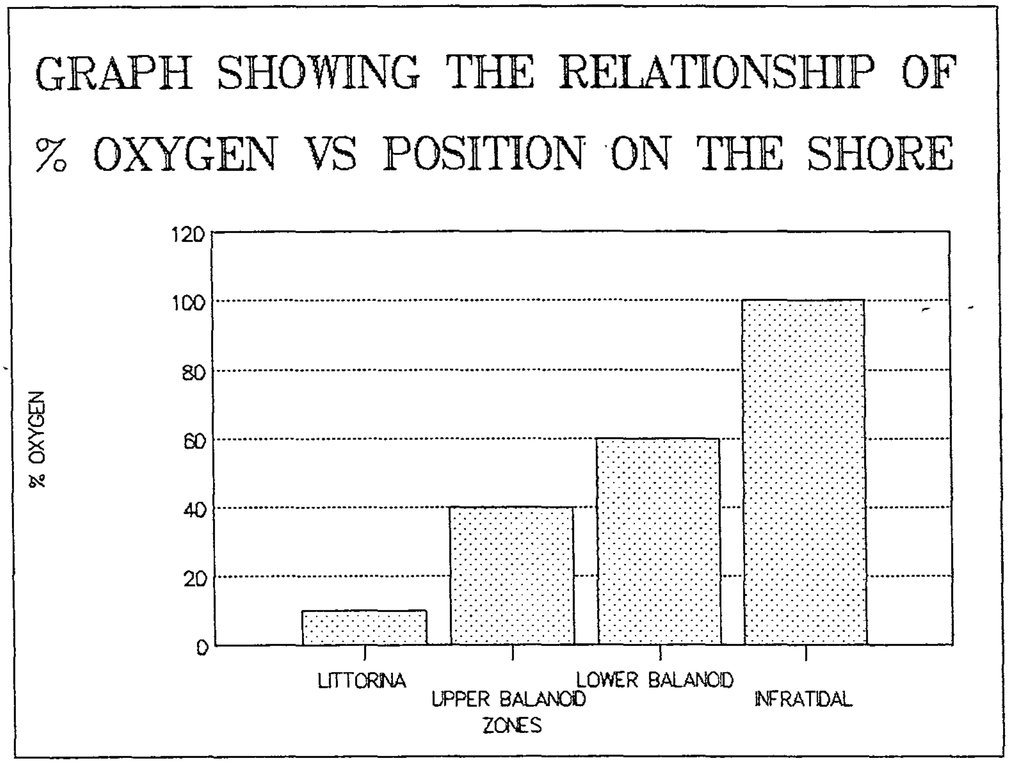
Temperature is therefore highest in the Littorina zone because the exposure here is the greatest. The infratidal zone is basically not exposed, except during the spring lows, and the temperature is therefore lowest here. It is thus easily shown that exposure increases as you move further up the rocky shores away from the wave action.

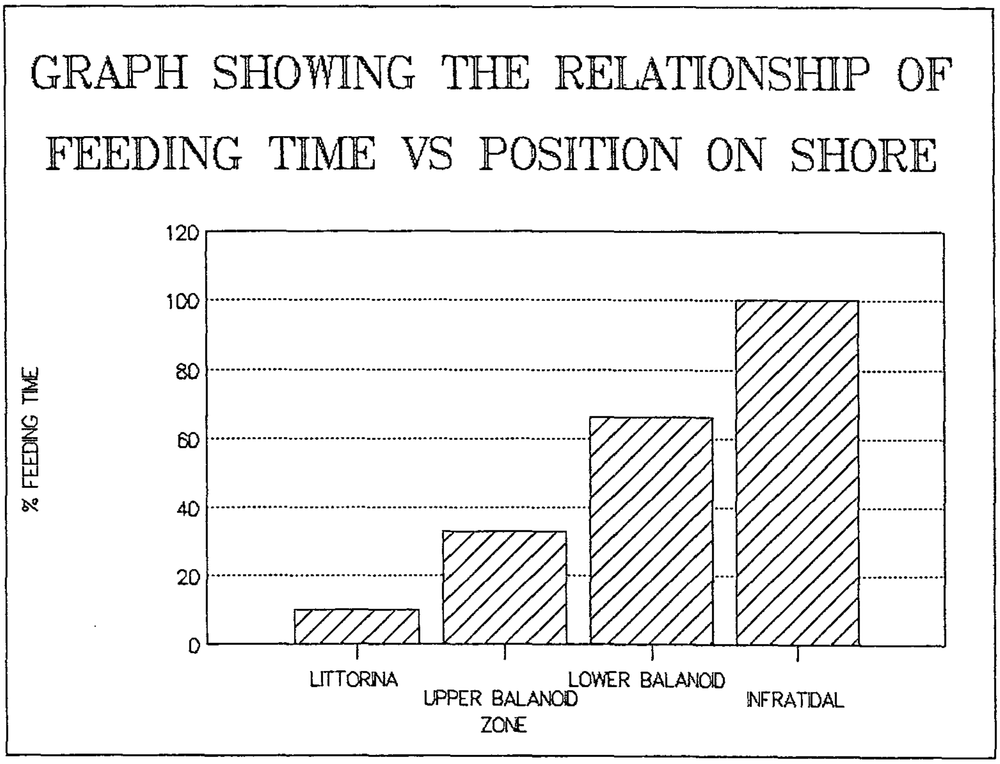
The obvious connection this is feeding time. The Littorina zone highest up is exposed for the longest period and the animals feeding time this zone is therefore far shorter than those animals in the infratidal zone whose food sources are constantly being replenished by the action of waves. The animals lower down the shore are therefore larger than those higher up.

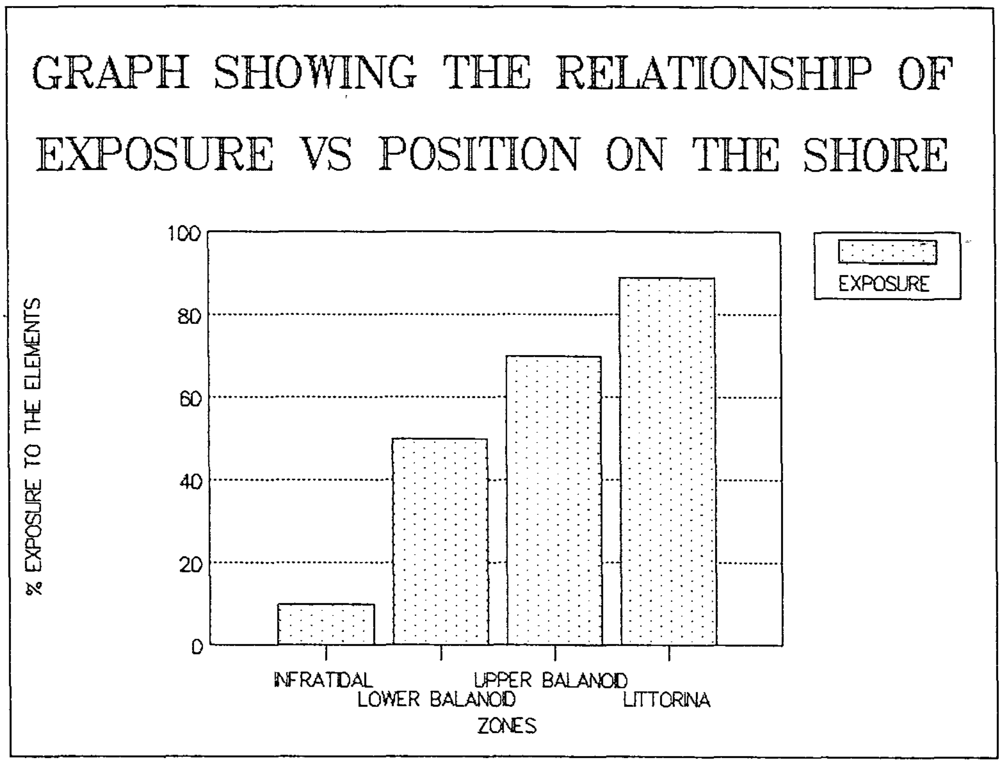
The oxygen levels in the infratidal zone are higher because of the action of waves. The algae in the infratidal zone were also photosynthesizing at a faster rate which was indicated by the abundance of bubbles that they releases when I swept my hand through the plants.

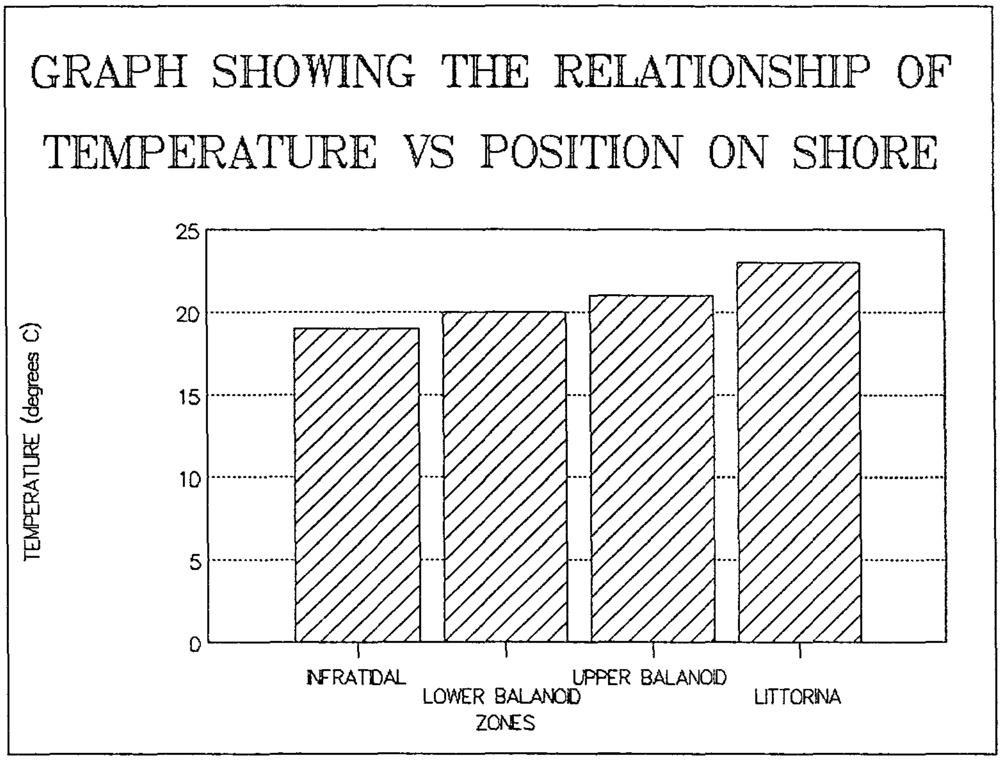
GRAPHS OF RESULTS

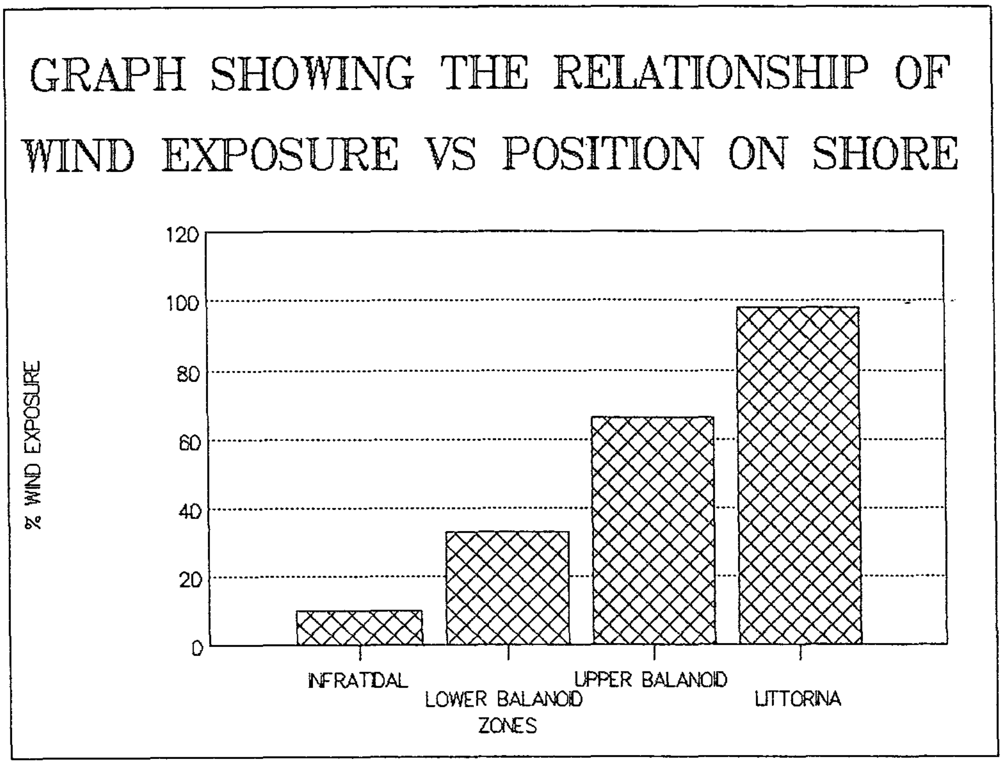


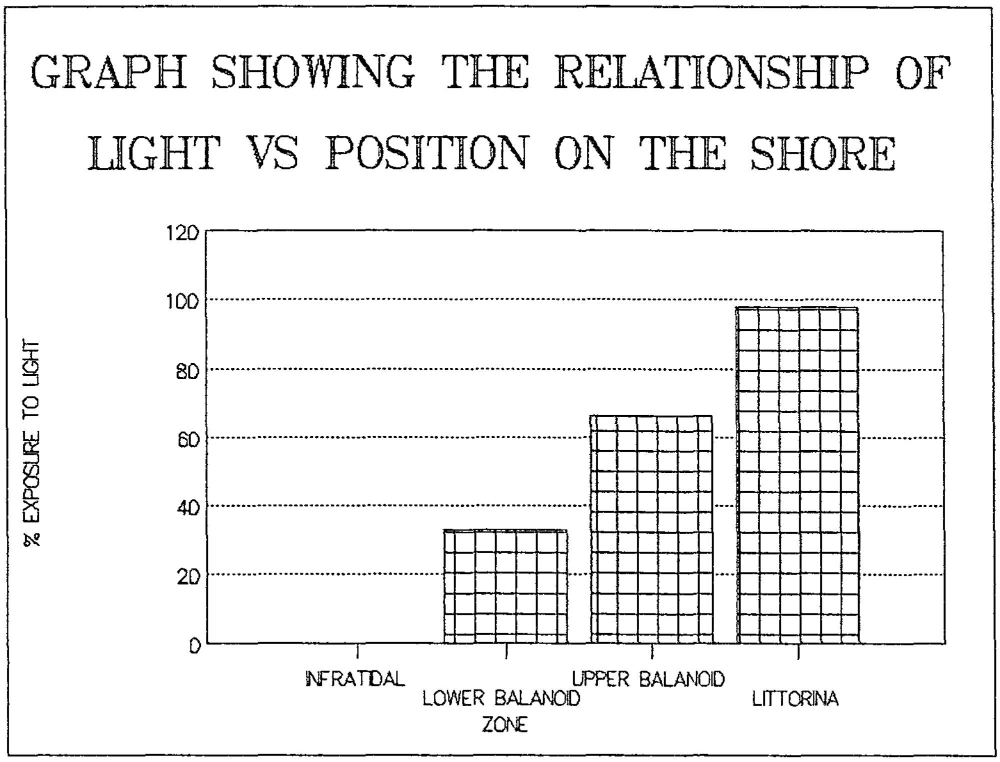

GRAPH SHOWING THE RELATIONSHIP OF
% OXYGEN VS POSITION ON THE SHORE
% OXYGEN
120
100
80
60
40
20
0
LITTORINA
UPPER BALANOID
LOWER BALANOID
INFRATIDAL
ZONES


GRAPH SHOWING THE RELATIONSHIP OF
FEEDING TIME VS POSITION ON SHORE
% FEEDING TIME
120
100
80
60
40
20
0
LITTORINA
UPPER BALANOID
LOWER BALANOID
INFRATIDAL
ZONE


GRAPH SHOWING THE RELATIONSHIP OF
EXPOSURE VS POSITION ON THE SHORE
% EXPOSURE TO THE ELEMENTS
100
80
60
40
20
0
EXPOSURE
INFRATIDAL
LOWER BALANOID
UPPER BALANOID
LITTORINA
ZONES


GRAPH SHOWING THE RELATIONSHIP OF
TEMPERATURE VS POSITION ON SHORE
TEMPERATURE (degrees C)
25
20
15
10
5
0
INFRATIDAL
LOWER BALANOID
UPPER BALANOID
LITTORINA
ZONES


GRAPH SHOWING THE RELATIONSHIP OF WIND EXPOSURE VS POSITION ON SHORE
% WIND EXPOSURE
120
100
80
60
40
20
0
INFRATIDAL
LOWER BALANOID
UPPER BALANOID
LITTORINA
ZONES


GRAPH SHOWING THE RELATIONSHIP OF LIGHT VS POSITION ON THE SHORE
% EXPOSURE TO LIGHT
120
100
80
60
40
20
0
INFRATIDAL
LOWER BALANOID
UPPER BALANOID
LITTORINA
ZONE

It is thus concluded that:

(a) The intertidal zone receives the most wave action.
The Littorina zone receives the least wave action.

(b) The Intertidal zone has a greater oxygen content in its water.
The Littorina zone has the least % oxygen content in its water.

(c) Animals in the Infratidal zone feed for the longest period.
Animals in the Littorina zone feed for the shortest period.

(d) Animals in the Intertidal zone are least exposed.
Animals in the Littorina zone are the most exposed.

(e) Temperature in the Intertidal zone is the lowest.
Temperature in the Littorina zone is the highest.

(f) Organisms in the Littorina zone are most exposed to wind and those in the Infratidal zone the least.

(g) Organisms in the Littorina zone receive the most light.
Organisms in the Infratidal zone receive the least light.

STUDY 1.1

A TRANSECT OF THE INTERTIDAL ZONE

HYPOTHESIS: The distribution of mollusca in the intertidal zone is due to the percentage exposure.

AIM: To prove or disprove the above hypothesis by collecting data and formulating a decision based on the relevant data that is collected from our study of the intertidal zone at Treasure Beach.

PRINCIPLE:

(1) Identify the abiotic conditions that are acting on the fauna and flora, specifically the mollusca phylum.

(2) Select a suitable stretch of the intertidal zone and stretch a piece of string from the spring high water mark to the infratidal zone.

(3) Start at the spring high water mark and measure off one metre. Place a 0,25m quadrant with the string as its centre on the line and count the number of mollusca enclosed by the quadrant. Record the number and the distance from the Spring high water mark.

(4) Repeat step 3 until the spring low water mark has been reached.

METHOD:

(1) Identified the abiotic conditions that were acting on the fauna and flora, specifically the mollusc a and recorded them in table form.

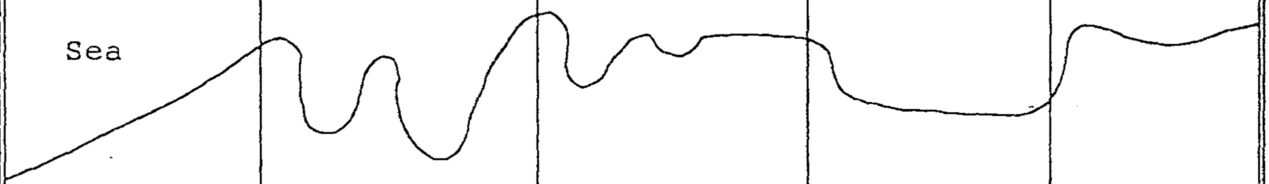
(2) Suitable stretch of the intertidal was selected but a transect was not constructed a piece of string.

(3) Started at the spring high water mark and measured off one metre. Placed a 0.25 quadrant on the mark and counted the number of mollusca that the square enclosed. We recorded

the number of mollusca, species and their distance from the spring high water mark in table form.

(4) Repeated step 3 until the spring low water mark had been reached.

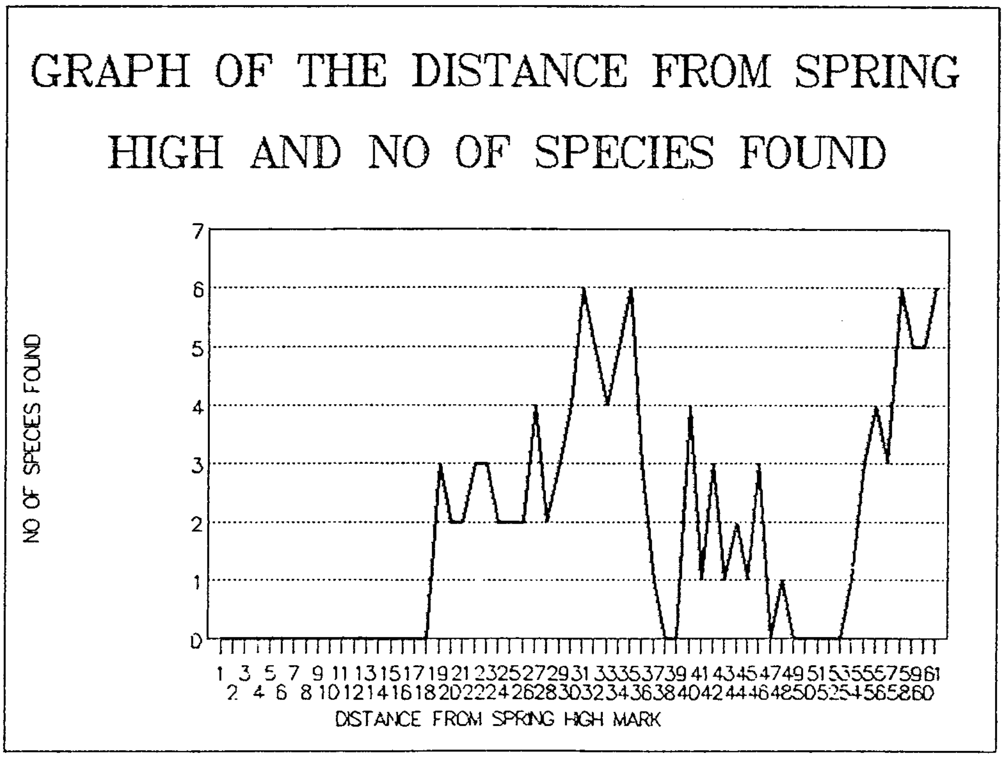
RESULTS: Displayed below.

	Infratidal Belt	Lower Balanoid	Upper Balanoid	Litorina Zone
	Algae & Red bait	Algae, Sponges, Mussels, Zooanthids	Barnacles, Tubeworms, Limpits.	Winkles, Oysters, Crabs
Sea  Conditions	at high tide			
Light	0 %	33 %	66 %	100 %
Salinity	No reading	No reading	No reading	No reading
Wind	10 %	33 %	66 %	98 %
Wave action	100 %	60 %	40%	10 %
Temp	19 °C	20 °C	21 °C	22 °C
Food	100 %	66 %	33 %	10 %
Conditions	at low tide			
Approxima	te %'s	are a tak	en as cor	ect!
Condition	's above	are not	necessaril	y
correct,	but are b	ased on m	y observ	ations
at Trea s	ure Beach	on that	day.	
ie Wave a	ction was	greatest in	the Infrat	idal
Zone at	the time!			

It is however noted and acknowledged that this may not be the case under normal circumstances.

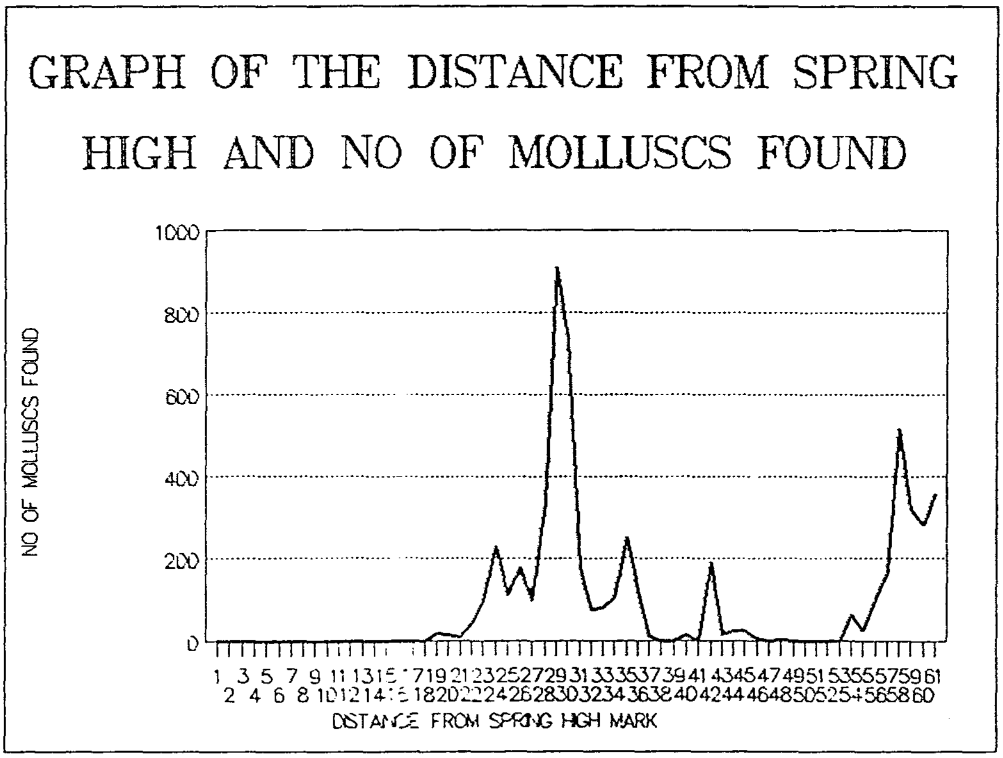
DISTANCE FROM SPRING HIGH	TOTAL NO OF SPECIES
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	3
20	2
21	2
22	3
23	3
24	2
25	2
26	2
27	4
28	2
29	3
30	4
31	6
32	5
33	4
34	5
35	6
36	3
37	1
38	0
39	0
40	4
41	1
42	3
43	1
44	2
45	1
46	3

DISTANCE FROM SPRING HIGH	TOTAL NO OF SPECIES
47	0
48	1
49	0
50	0
51	0
52	0
53	0
54	1
55	3
56	4
57	3
58	6
59	5
60	5
61	6



DISTANCE FROM SPRING HIGH	TOTAL NO OF MOLLUSCS
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	18
20	15
21	8
22	44
23	95
24	232
25	112
26	180
27	97
28	336
29	912
30	736
31	176
32	76
33	80
34	105
35	254
36	124
37	12
38	0
39	0
40	14
41	1
42	192
43	14
44	24
45	24
46	6

DISTANCE FROM SPRING HIGH	TOTAL NO OF MOLLUSCS
47	0
48	2
49	0
50	0
51	0
52	0
53	0
54	64
55	24
56	102
57	165
58	516
59	320
60	280
61	357



GRAPH OF THE DISTANCE FROM SPRING HIGH AND NO OF MOLLUSCS FOUND

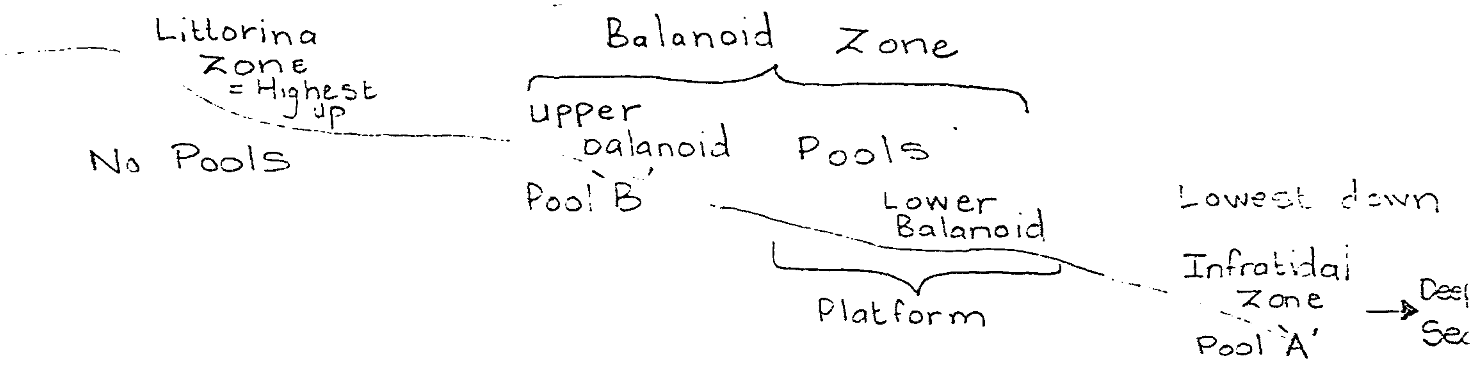
DISCUSSION:

The experiment was not carried out along a transect because our leader, Jonathan, felt that a truer representation could be obtained by moving around the rocky shore. This way we accounted for many mollusca which we would otherwise have missed eg. octopus. The graph clearly shows that the distribution of mollusca in the intertidal zone is not determined by their percentage exposure. I interpret exposure to mean "open to the elements" and not be submerged in water. No mollusca were observed for the first nineteen metres from the spring high water mark. This constituted the sandy shore, where conditions are extremely harsh with no water or food source available to sustain life here and it is thus understandable that no mollusca were observed. It is however clearly seen that mollusca occur in the four different zones with total contrasts in percentage exposure to the elements in each zone as shown. The Littorina zone experiences the greatest percentage exposure to the elements and the number of mollusca here is high, consisting of three species of snail which were concealed in crevices. The snails are, however, well adapted to survive in their harsh environment. They have very small feet which minimizes heat gain from the rock and small round shells which reflect heat and thus reduce the chances of desiccation occurring. It must be understood that numbers drop off sharply in the Balanoid zone due to experimental error - mollusca were concealed by the algae which was abundant in this zone. Many of the mollusca were thus concealed which made an accurate count almost impossible. The only solution would have been to repeat the method along numerous transects in order to obtain accurate results. Time, however, restricted us from doing this. Numbers swell in the infratidal zone where wave action is severe and exposure restricted, a total contrast to the conditions in the Littorina zone. The species which occur here, though, are far more diverse than those which occur in the Littorina zone. It is thus clear and justified to say that the hypothesis is false and that the distribution of mollusca is determined by their species and not their percentage exposure to the elements, although certain species were prevalent in each and every zone. There are, however, far more species of mollusca in the infratidal zone than the number of species in the Littorina zone. This does not affect their physical numbers because certain mollusca are specifically suited to survive in their specific and diverse environments and there numbers are thus high in each zone.

STUDY 3.1

A STUDY OF THE ROCK POOLS

HYPOTHESIS: The abiotic factors that prevail in a rock pool on the rocky platform influence the size and frequency of the life forms in that pool.



A = a deep pool near the sea B = shallow pool on the platform
C = deep pool near the sand D = shallow pool near the sand

GROUP ONE: Compare the contents of the pools A and B and fill in the necessary information in the tables below.

PRINCIPLE :

(1) Examine the profile of the rocky shore and draw it.
(2) Compare the physical contents of pool A (a deep pool near the sea) and pool B (a shallow pool on the platform).
(3) Record your results and observations from 2 in table form.
(4) Relate your results to the abiotic conditions which prevailed in the area.

METHOD:

(1) A profile of the rocky shore was drawn.

(2) The physical contents of pool A and pool B were observed and recorded in table form.

RESULTS:

ABIOTIC FACTORS	POOL A	POOL B
WATER DEPTH (CM)	120	10
WATER TEMPERATURE (C)	19	21
SUBSTRATE	SANDSTONE	SANDSTONE
AVAILABILITY OF LIGHT	POOR	GOOD
ARE PLANTS PRODUCING GAS?	YES	YES
DOES WATER FLOW IN AT LOW TIDE	NO	NO
MEAN HEIGHT OF ALGAE (CM)	10	5
RELATIVE NUMBER OF ALGAE	11	3
RELATIVE NUMBER OF ANIMALS	7	5
RELATIVE NUMBER OF HERBIVORE	4	1
RELATIVE NUMBER OF CARNIVORE	3	4
RELATIVE EXPOSURE TO AIR	NONE	NONE
SALINITY	NO READING	NO READING

POOL 'B'

NAME OF ANIMAL	SHELL OR TUBE	SESSILE OR MOTILE	DENSITY	AVERAGE HEIGHT (MM)	OPEN OR CLOSED	SOLITARY OR COLONIAL	FEEDING TYPE
ACORN BARNACLE	SHELL	MOTILE	HIGH	10	CLOSED	COLONIAL	FILTER
LIMPET	SHELL	MOTILE	FAIR	5	CLOSED	SOLITARY	GRAZER
OYSTER	SHELL	SESSILE	HIGH	15	CLOSED	COLONIAL	FILTER
PERIWINKLES	SHELL	MOTILE	HIGH	5	CLOSED	SOLITARY	GRAZER
ANEMONE	NO	SESSILE	LOW	25	OPEN	SOLITARY	CARNIVORE

NAME OF PLANT	COLOUR	LENGTH (MM)	SHAPE OF BRANCHES
BOSTRICHIA	DARK GREEN\BLACK	5	WIRY, CURLED UP
PINK CORALLINES	DUSTY PINK	50	FLAT, BRITTLE LOOKING

POOL 'A'

NAME OF ANIMA	SHELL OR TUBE	SESSILE OR MOTILE	DENSITY	AVERAGE HEIGHT (MM	OPEN OR CLOSED	SOLITARY OR COLONIA	FEEDING TYPE.
HERMIT CRAB	SHELL	MOTILE	LOW	10	OPEN	SOLITARY	SCAVENGER
ZOANTHID	NO	SESSILE	HIGH	5	OPEN	COLONIAL	FILTER FEEDER
ANEMONE	NO	SESSILE	LOW	15	OPEN	SOLITARY	CARNIVORE
URCHIN	SHELL	MOTILE	LOW	50	CLOSED	SOLITARY	CARNIVORE
LIMPET	SHELL	MOTILE	HIGH	5	CLOSED	SOLITARY	GRAZER
CHITON	SHELL	MOTILE	HIGH	10	CLOSED	SOLITARY	GRAZER
MUSSEL	SHELL	SESSILE	LOW	45	CLOSED	COLONIAL	FILTER FEEDER

NAME OF PLANT	COLOUR	LENGTH (MM)	GAS BUBBLES	DENSITY	SHAPE OF BRANCHES
SEA LETTUCE	LIME GREEN	60	NO	LOW	FLAT, LEAFLIKE
CODIUM	DARK GREEN\BLACK	50	YES	HIGH	TUBULAR
CAULERPA FILIFORMIS	BRIGHT GREEN	80	NO	LOW	FANLIKE

DISCUSSION:

Pool A (a deep pool near the sea) was situated in the infratidal zone. Pool B a shallow Pool on the platform) was situated in the upper Balanoid. Pool A was deeper than pool B and the temperature of its water was therefore lower because it had a smaller volume to surface ratio. The shallow pool is penetrated by light. The deeper pool does, however, have areas that light does not reach. Algae is certainly more common in the deeper pool. They released more bubbles than those higher up which is indicative that they are photosynthesizing at a faster rate than the algae in shallower pool. It is thus concluded that algae photosynthesizes better when it is submerged in a metre of water but exposed to light. There are more herbivores in the deeper pool because their food source (algae) is abundant. There are more carnivores in the shallower pool because algae is not as abundant here. Many animals in this area have developed carnivorous tendencies because of the shortage of algae here. No salinity reading was taken because no one was able to operate the hygrometer. It is however logical that the shallower pool would be more saline because evaporation would be higher here and as water was evaporated the salt would become more and more concentrated here. It is also noted that the specimens are far larger in the deep pool near the sea. It is due to the fact that food sources here are constantly being replenished by the action of the waves. They flush out the pools and replace them with nutrient rich water. Higher up, though, in the upper Balanoid the feeding time is restricted by the tides and thus the specimens are far smaller because their feeding time is limited. As they grow larger it is assumed that they migrate toward the infratidal zone because they are able to withstand the action of the sea and the food sources are far more abundant here.

Ex. Ex.

REPORT ON HALF THESIS: O.D.PHIPPS : THE USE OF A DATABASE TO IMPROVE HIGHER ORDER THINKING SKILLS IN SECONDARY SCHOOL BIOGRAPHY A CASE STUDY.

1. POSING THE PROBLEM:

The field of study was well defined and the specific objective clearly demsarcated.

2. SETTING:

The setting out of the thesis was systematically done and well done and well documented.

3. LITERATURE STUDY:

Good literature study was done to form a sound theoretical base.

4. RESEARCH MATERIAL:

The selection of research material was very well done and a lot of sound effort went into the collecting of evidence that higher order thinking had been established.

5. FINDINGS AND RECOMMENDATIONS:

The findings and recommendations regarding the study were frank and open.

6. FURTHER RESEARCH:

Further research could profit by using this pilot study.

7. EDITORIAL CORRECTIONS AND ADAPTATIONS:

✓ p. 3.14: changes : changed
✓ p. 4.18: ..handler, (comma out)
✓ p. 5: 16: ..first, (comma out)
✓ p. 5: 25: teachers: teachers´
✓ p. 11: 32: childs: child´s
✓ p. 22: 6: there = their
✓ p. 22: 25 + 28: Cagne (no such an author - the source has never been consulted) It is Gagné or Gagné and Briggs. A VERY BAD SLIP. REFERENCE NOT GIVEN.
✓ p. 25: 32: e.t.c. = etc.
✓ p. 25: 33: students, (comma out)
✓ p. 34: 18: suggest = suggested
✓ p. 37: 28:..who suggested, (comma out)
✓ p. 38: 27: Before the setting (the out)
✓ p. 38: 29: page 106 totally blank!!!
✓ p. 39: 11: challenged, (comma out)

✓ p.39: 30: ..on paper, (comma out)
✓ p.42: 8: ...used, (comma out)
✓ p.46: 10: ..Request = Requests
✓ p.47: 23: put = putting
✓ p.50: 30: wont = won't
✓ p.51: 12, 13, 14 : There was..Formulation error.,
✓ p.71: Battlefields ; Historic = battlefields; historic
✓ p.117: 18: overlapping = one word.

DR. W.J.SMIT

[signature]

24 JANUARY 1994.

Although Mr Phipps's analysis of the data on thinking skills is, as he acknowledges, subjective, his results indicate that higher order thinking skills related to comprehension, application and analysis, as set out in the second chapter of his study, were being employed by the pupils in their interaction with the database. His study is of great worth to those educators who are concerned with innovation and change in approaches to the teaching not only of Biology, but of other content-rich subjects as well.

Mr Phipps undertook this study and produced his dissertation with very little assistance apart from suggestions and guidance relating to the discussion of the research and to comment on written drafts.

Mr Phipps's writing is awkward in places and there are several errors of punctuation and style. The following typographical and/or grammatical errors need to be corrected before the thesis is submitted to the University :

x Abstract, pg ii, para 2 : clumsy grammatical construction - "Resnick...being effortful"

✓ Abstract, pg ii, para 4 : wrong tense - "query"

✓ Abstract and rest of study, pg ii, para 4 - be consistent with capitals - either "Higher Order Thinking skills" or "higher order thinking skills" - I would suggest the latter

✓ Chapter 1, pg 2, para 3, last sentence : plural of "skill" needed

✓ Chapter 1, pg 3, para 2 : form two sentences from this paragraph to distinguish between "...special skills" and "...models of familiar content"

✓ Chapter 1, pg 3, para 3 : wrong tense - "changes"

✓ Chapter 1, pg 5, last para : possessive apostrophe needed - "Most teachers lack..."

✓ Chapter 1, pg 6, para 1 : wrong tense - "will"

✓ Chapter 1, pg 6, last para : plural needed - "conclusion"

✓ Chapter 2, pg 7, para 1, para 3, pg 9 para 1, etc : omit the hyphen - "higher-order" or include the hyphen elsewhere in the study, a <u>careful check</u> is needed - same applies to references to "lower-order thinking skills" see pg 11 and "higher-order goals" see pg 12 and "problem-solving" see pg 16

✓ Chapter 2, pg 14, para 1 : overuse of the word "knowledge"

✓ Chapter 2, pg 22, last para : part of sentence omitted - "that are needed for these processes." ...?

Chapter 2, pg 25, para 3 : the word "the" is missing from the phrase "judge importance"

Chapter 2, pg 25, last para : etc. rather than "e.t.c."

Chapter 2, pg 25, last para : omit comma : "collected, be relevant"

Chapter 2, pg 26, para 1 : enlarge on "This" in the clause "This can be enhanced..."

Chapter 3, pg 31, para 2 : incorrect participle : "the advantage" should read "an advantage"

Chapter 4, pg 34, para 3 : omit extraneous commas - "... organisms, found there, to..."

Chapter 4, pg 35, last para : clumsy construction - "...divided in approximately half..."

Chapter 4, pg 39, para 2 : keep to use of plural of student - "the student would receive support"

Chapter 4, pg 39, para 3 : omit extraneous comma - "researcher's intention,"

Chapter 5, pg 47, para 2 : wrong tense - "put pressure"

Chapter 5, pg 51, para 2 : something missing - "...about how the densities of organisms..."

Chapter 5, pg 57, para 3 : wrong tense : "are able to associate ... and are able to relate"

Mr Phipps has demonstrated his ability to use the tools of research in this field and I recommend that he be awarded the degree (without distinction) subject to the completion of a paper for publication.

Yours sincerely

C.J.A. Marsh