Reading Competence and Advanced Level Physics

by

Dorothy Violet Fagan

A thesis submitted to the Institute of Education, University of London
for the Degree of Doctor of Philosophy

October 1996

READING COMPETENCE AND ADVANCED LEVEL PHYSICS

Language, for various reasons, tends to be a neglected area in the school physics curriculum. Discussion of "literacy" in the context of science teaching is limited, and many teachers are unclear about the issues involved. However, so-called "active reading" exercises have had an impact on the science curriculum up to GCSE level as part of a broader campaign for enhancing reading for learning. This has helped to highlight reading in science but without necessarily clarifying the issues or attempting to integrate results with what might be called "standard measures of progress".

This study uses reading exercises constructed around topics in the Advanced level physics course, to investigate reading among physics students. Evidence of student progress and achievement such as homework marks and the A level grade, are related to students' responses on the exercises, to obtain an objective assessment of the value of language-related activities.

Reasons for the choice of texts and methodologies are two-fold:
From the point of view of the physics teacher, to allow an investigation into the range of skills and abilities which students demonstrate on language-based material.
For the students involved, to make participating in the exercises useful and relevant to their studies.

Analyses are directed at looking at the text, task and responses individually from a linguistic as well as a pedagogic perspective, and more particularly at the relationships between the areas.

Connections between reading competence and achievement in physics are shown and suggestions are made on how teachers could encourage reading, monitor the reading competence of students and identify students with problems. Implications for future research into language in physics are also discussed.

Dedication

To my Mother and Father

In Memoriam

Acknowledgements

I would like to thank my supervisors Dr Arthur Jennings and Professor Jon Ogborn for their invaluable advice, patience and support; the teachers and pupils from the four schools in Nairobi involved in this study: Brookhouse, Braeburn Senior, Hillcrest Secondary and Nairobi Academy, for their co-operation and goodwill; and the physics teachers at Imberhorne School, East Grinstead and Michael Hall Rudolf Steiner School, Forest Row, who kindly read and commented on some of the passages.

This project could not have been completed without the enthusiasm and encouragement supplied in generous quantities by my husband Tom and my daughters Catriona and Antonia. I am grateful too for the moral support of my sisters and brothers Jean, Aubrey, Karen, Gail, Randal, David, Marylon , and my aunt Sheila.

CONTENTS

ABSTRACT 2
ACKNOWLEDGEMENTS 3
TABLE OF CONTENTS 4
LIST OF FIGURES 10
LIST OF TABLES 13

CHAPTER 1: INTRODUCTION 16
1.1..............Background to the investigation 16
1.2..............Language issues in the classroom 16
1.3..............Language in school physics 17
1.4..............Reading as part of scientific training 18
1.5..............Study skills 19
1.6..............Summary of classroom language 20
1.7..............Choice of problem and method 21
1.8..............Context of the study 22
1.9..............Organization of the thesis 22

CHAPTER 2: REVIEW OF LITERATURE 24
2.1 ....Introduction 24
2.2..............What is reading? 24
2.2.1 ....Psycholinguistic perspectives 24
2.2.2 ....Sociolinguistic aspects 26
2.2.3 ....Language and cognitive development 26
2.3..............What is learning and understanding? 27
2.3.1 ....The Constructivist view of learning in science 27
2.3.2 ....Seeing and believing – a cognitive psychologist's approach 29
2.4..............Learning from texts 29
2.4.1 ....Ways of encouraging active interrogation of text 30
2.4.2 ....The importance of "reflection" in reading 31
2.4.3 ....Reading and the "real world" 31
2.5..............The problem of assessment 32
2.6..............Special difficulties of science 33
2.6.1 ....Scientific concepts 34
2.6.2 ....Scientific language 35
2.7..............Summary 36

CHAPTER 3:THE PROBLEM AND THE RESEARCH QUESTIONS 37

3.1..............Introduction 37
3.2..............The Examining Boards' position 37
3.3..............The teachers' position 38
3.4..............Exploring the issue 39
3.4.1 ....The text 39
3.4.2...........The reader 40
3.4.3...........Purpose and outcome 42
3.5..............The pupil as a reader 42
3.6..............Summary of the argument 44
3.7..............The key guiding questions 45

CHAPTER 4:RESEARCH INSTRUMENTS AND METHODS OF ENQUIRY46

4.1..............Introduction to the research instruments 46
4.2..............Description of elements 46
4.2.1 ....Cloze Tests 46
4.2.2 ...."Traditional" comprehension tests 47
4.2.3...........Interpretive tests 48
4.2.4 ....Reading aloud (miscue analysis) 49
4.3..............Choosing the passages 49
4.4..............Introduction to the method of enquiry 52
4.5..............Structure of the enquiry 52
4.6..............The schools involved 53
4.7..............Arrangements made with teachers 54
4.8..............Summary of the research method 55
4.9..............Summary of chapter 57

CHAPTER 5: THE CLOZE TESTS 58

5.1 ....Reasons for using cloze 58
5.2 ....Cloze variables 59
5.3 ....An overview of the 3 cloze exercises in this study 60
5.4 ....ERRORS (Systematic and Random Uncertainties) 60
5.4.1 ....Readability 61
5.4.2 ....The students and the test conditions 62
5.4.3 ....The results grid 62
5.4.4 ....Criteria used in marking the results grid 63
5.4.5 ....Discussion of items 64
5.4.6 ....Performance and test reliability 71

5.4.6i ....Reliability 71
5.4.6ii..........Comparing total scores 72
5.4.7 ....Patterns in the results 73
5.5 ....TEST 8 TIME (How to go back in time) 76
5.5.1 ....Details of the exercise 76
5.5.2 ....The students and the test conditions 77
5.5.3 ....Readability 77
5.5.4 ....Marking 77
5.5.5 ....Discussion of items 78
5.5.6 ....Performance and reliability 83
5.5.7 ....Patterns in results 84
5.6 ....PROJECTILES (Investigating Free Fall) 89
5.6.1 ....Details of the exercise 89
5.6.2 ....The students and the test conditions 89
5.6.3 ....Selection of the items for testing. 90
5.6.4 ....The results grid 90
5.6.5 ....Discussion of items 90
5.6.6 ....Reliability and performance 92
5.6.7 .... Patterns in results 93
5.7 ....Comparing the cloze test results 95
5.8..............Summary discussion of cloze results 98

CHAPTER 6: READING ALOUD 102
6.1..............Introduction 102
6.2 ....Relevance to the teacher 102
6.3..............Choice of passage 103
6.4..............Aims of the READING ALOUD exercise 104
6.5..............Administering the test 105
6.6..............Data Recorded 105
6.7..............Results 106
6.8..............Reliability and performance 106
6.9..............Patterns in results 107
6.9.1 ....Hesitation rate and time taken 107
6.9.2 ....Reading rate and reading proficiency 111
6.9.2.i ....How question score relates to time taken 112
6.9.2.ii.........How question score relates to hesitations made 113
6.9.3 ....Relationship to A level score 115
6.9.3i ....A level score and time taken 115

6.9.3ii..........A level score and hesitations 118
6.10............Summary discussion of READING ALOUD results 118

CHAPTER 7: THE COMPREHENSION EXERCISES 121
7.0..............Introduction 121
7.0.1 ....Purpose of the chapter 121
7.1 ....TYPES OF FORCES 123
7.1.1 ....Details of the exercise 123
7.1.2 ....Relevance to the teacher 123
7.1.3 ....Mark scheme 124
7.1.4 ....Discussion of mark scheme 125
7.1.5 ....The results grid 126
7.1.6 ....Patterns in results 126
7.1.7 ....Scores in different tasks 127
7.1.8 ....How the questions are categorized 128
7.1.8i ....Language-based questions 128
7.1.8ii..........Physics-based questions 128
7.1.9 ....Looking at types of errors made 130
7.1.10..........Relationship with other results 132
7.1.11..........Summary of FORCES exercise 132
7.2 ....INTERNAL RESISTANCE 133
7.2.1 ....Details of the exercise 133
7.2.2 ....Selection of the passage 133
7.2.3 ....Relevance to the teacher 134
7.2.4 ....Mark scheme 134
7.2.5 ....Discussion of mark scheme 135
7.2.6 ....Exploring the questions 137
7.2.7 ....Exploring the results 139
7.2.8 ....Relationship with other results 140
7.2.9 ....Summary 141
7.3 ....DAMPED OSCILLATIONS 142
7.3.1 ....Introduction to the exercise 142
7.3.2 ....Relevance to the teacher 142
7.3.3 ....Selection of the passage and readability 142
7.3.4 ....The students and the test conditions 143
7.3.5 ....Mark scheme 144
7.3.6 ....Discussion of the questions 144
7.3.7 ....Exploring the results 146

7.3.8 ....Further item analysis 148
7.3.9 ....Relation with other exercises 149
7.3.10..........Discussion of exercise 150
7.3.10i.........Reliability 151
7.3.10ii........Assessment of passage 152
7.4..........HEAT RADIATION 154
7.4.1 ....Details of the exercise 154
7.4.2 ....Selection of the passage 154
7.4.3 ....The pupils and the test conditions 155
7.4.4 ....Relevance to the teacher 155
7.4.5 ....Exploring the questions 155
7.4.6 ....Mark scheme 157
7.4.7 ....Discussion of mark scheme 158
7.4.8 ....Exploring the results 159
7.4.8i ....Facility and Discrimination of Responses 159
7.4.8ii..........Relationship between responses 160
7.4.9 ....Relationship with other exercises 163
7.4.10..........Summary of HEAT RADIATION 164
7.5.............Conclusions from chapter 7 164

CHAPTER 8:COLLATED RESULTS AND ANALYSES 167
8.0.............Overview of chapter 167
8.1.............Teachers' assessments of pupils 167
8.2.............Factor analysis 170
8.2.1 ....Cloze exercises 170
8.2.2 ....Comprehension exercises 172
8.2.3 ....Exercise results and A level 173
8.2.4 ....Test and Homework scores 175
8.2.5 ....Exercise results and Test and Homework scores 175
8.3.............Summary 179

CHAPTER 9:CONCLUSIONS 181
9.1.............Introduction 181
9.2.............Overview 181
9.3.............Summary of results 182
9.3.1 ....(i) The text - responses interface 182
9.3.2 ....(ii) The texts - tasks - responses interface 183
9.3.3 ....(iii) The responses - A Level/ tests/ homework interface 187

9.4.............Review of methodology 188
9.5.............Suggestions for physics teachers 191
9.6.............Implications 194
9.6.1 ....The problem of text selection 194
9.6.2 ....Reading speed and performance 195
9.7.............Final remarks 195

BIBLIOGRAPHY **197**

Appendix 1....ERRORS exercise 199
Appendix 2....ERRORS results 200
Appendix 3....ERRORS Discrimination / Facility graphs 204
Appendix 4....TIME exercise 206
Appendix 5....TIME results 208
Appendix 6....PROJECTILES exercise 214
Appendix 7 ...PROJECTILES results 216
Appendix 8....READING ALOUD exercise 218
Appendix 9....READING ALOUD results 220
Appendix 10 ..FORCES exercise 222
Appendix 11 ..FORCES results 224
Appendix 12 ..INTERNAL RESISTANCE exercise 226
Appendix 13 ..INTERNAL RESISTANCE results 228
Appendix 14 ..DAMPED OSCILLATIONS exercise 229
Appendix 15 ..DAMPED OSCILLATIONS results 232
Appendix 16 ..HEAT RADIATION exercise 234
Appendix 17 ..HEAT RADIATION results 239
Appendix 18 ..Class teachers' homework and test results 240

LIST OF FIGURES

Fig 3.2	Variables relating to reader
Fig 5.1	Schematic to show how responses were assessed
Fig 5.2	ERRORS facility / discrimination - physics group
Fig 5.3	Facility / discrimination - english group
Fig 5.4	Facility/Discrimination physics group
Fig 5.5	Cluster analysis (complete linkage) on facility/discrim. of physics group
Fig 5.6	Facility/Discrimination of physics group showing clusters a - d
Fig 5.7	Cluster analysis (complete linkage) on facility/discrim of english group
Fig 5.8	TIME facility/discrim english showing clusters
Fig 5.9	Facility/discrimination PROJECTILES Items
Fig 5.10	Facility and discrimination of physics (P) and non-physics (N) items.
Fig 5.11	Ratio of non-physics / physics items against total score
Fig 5.12	A Level results / ERRORS scores
Fig 5.13	A Level results / TIME scores
Fig 5.14	A Level results / PROJECTILES scores
Fig 5.15	ERRORS / PROJECTILES
Fig 5.16	Scores on ERRORS / Scores on TIME
Fig 5.17	Scores on PROJECTILES / Scores on TIME
Fig 6.1	Facility and Discrimination of Questions 1-5
Fig 6.2	Number of hesitations made by pupils / time taken to read the passage.
Fig 6.3	Dendrogram showing the results of a cluster analysis on Fig 6.2
Fig 6.4	Scattergraph Fig 6.2 with clusters a-f identified.
Fig 6.5	Hesitation/time sgraph showing correct pronunciation of causal (ringed)

Fig 6.3 Dendrogram showing the results of a cluster analysis on Fig 6.2

Fig 6.4 Scattergraph Fig 6.2 with clusters a-f identified.

Fig 6.5 Hesitation/time sgraph showing correct pronunciation of causal (ringed)

Fig 6.6 Mean score on questions 2-5 per cluster

Fig 6.7 Mean A level grade per cluster

Fig 6.8 Graph to show total correct questions vs time taken

Fig 6.9 Question score / time taken with A level grade points of slowest group

Fig 6.10 Graph to show total correct question vs number of hesitations

Fig 6.11 As above, with the A level points of pupils with a high hesitation rate

Fig 6.12 A level score vs time taken to read passage

Fig 6.13 Cluster analysis (complete linkage) on A level / time taken data

Fig 6.14 A level / time taken scores to show clusters

Fig 6.15 A level scores vs hesitations

Fig 7.1 Facility / Discrimination (question number shown)

Fig 7.2 FORCES scores / A level points

Fig 7.3 Facility / Discrimination of INTERNAL RESISTANCE questions

Fig 7.4 Scores of Internal Resistance / A level

Fig 7.5 Facility / Discrimination of DAMPED OSCILLATIONS questions

Fig 7.6 Scattergraph of DAMPED OSCILLATION and FORCES

Fig 7.7 Scattergraph of DAMPED OSCILLATION and A Level scores

Fig 7.8 Facility / Discrimination of HEAT RADIATION Questions

Fig 7.9 Distribution of skills for each question in Fig 7.6

Fig 7.10 Schematic diagram to show relationships between responses

Fig 7.11	A level grades / HEAT scores
Fig 8.1	Mean homework mark vs mean class test score per pupil
Fig 8.2	A level grade point vs mean homework mark per pupil
Fig 8.3	A level grade point vs mean test mark per pupil
Fig 8.4	Vector representation of factor analysis of cloze exercises
Fig 8.5	Correlation of results of READING ALOUD
Fig 9.1	Schematic diagram of research framework
Fig 9.2	Model of analysis framework

LIST OF TABLES

Table 1.1	Types of classroom language
Table 4.1	How the Enquiry will be structured
Table 4.2	Summary of the Research Method
Table 5.1	Discussion of ERRORS items
Table 5.2	Pupil scores: ERRORS
Table 5.3	ERRORS: physics (P) english (E) Groups 't' tests.
Table 5.4	Distribution of Reading, physics & Grammar items - physics group
Table 5.5	Distribution of Reading, physics & Grammar items - english group
Table 5.6	Discussion of TIME items
Table 5.7	Pupil scores TIME
Table 5.8	TIME: Comparison between english (E) physics (P) Groups
Table 5.9	Discussion of PROJECTILES items
Table 5.10	Pupil scores PROJECTILES
Table 5.11	Summary of Reading Assessment results
Table 6.1	Facility and Discrimination of Questions 1-5
Table 7.1	Correlation between Questions 1 - 9
Table 7.2	Errors made in Question 3
Table 7.3	Correlation of responses to INTERNAL RESISTANCE questions

Table 7.4	Comparison of questions
Table 7.5	Correlation of responses to DAMPED OSCILLATION
Table 7.6	Item Analysis of Damped Oscillations
Table 7.7	Correlation of DAMPED OSCILLATIONS with other exercises
Table 7.8	Reliability of comprehension Exercises
Table 7.9	Results of teachers' questionnaire on comprehension passages
Table 7.10	Summary of skills relating to questions 1 - 9
Table 7.11	Correlations between HEAT RADIATION and other exercises
Table 7.12	Comparing reading level estimates with pupil performance
Table 7.13	Correlations between HEAT RADIATION and other exercises
Table 7.14	Comparing reading level estimates with pupil performance
Table 8.1	Correlation between Reading Exercises/Homework, Test marks & A level
Table 8.2	Correlation matrix for cloze exercises
Table 8.3	Factor Loadings Orthogonal Solution - Cloze
Table 8.4	Correlation matrix of comprehension physics and non-physics items.
Table 8.5	Orthogonal solution for physics / non-physics items.
Table 8.6	Correlation matrix for all exercises plus A level
Table 8.7	Factor Loadings Orthogonal Solution - Exercises & A level

Table 8.8	Factor Loadings Orthogonal Solution - 5 Exercises & A level
Table 8.9	Correlation matrix for A level, Homework and Test scores
Table 8.10	Orthogonal Transformation Solution A level, Homework & Test scores
Table 8.11	Correlation matrix for Reading Aloud / Tests / Homework
Table 8.12	Factor Loadings Orthogonal Solution - 6 Exercises/ Homework/Tests
Table 8.13	Correlation matrix using FORCES and OSCILLATIONS exercises sorted into physics and non-physics items
Table 8.14	Factor Loadings Orthogonal Solution FORCES and OSCILLATIONS
Table 8.15	Matrix for FORCES physics, non-physics, Homework & Test scores
Table 8.16	Orthogonal solution of FORCES physics, non-physics Homework & Tests

CHAPTER 1: INTRODUCTION

1.1 Background to the investigation

Several years of teaching physics in schools had made me concerned about the lack of attention given to language in this subject. For example, it was very apparent that material such as text books were underused at most levels of school physics and students' use of other complementary literature that should normally be available, in libraries and so on, was limited. Many physics teachers are aware that their students are reluctant to use text-books or read[1] in general. One teacher commented that because of this lack of "background reading" students found it difficult to relate what was being covered in class to "the real world".

It is not unexpected that teachers would agree about the desirability of students reading more around their subject, what seems to be in doubt is how seriously to pursue the goal of persuading students to read more. But, in raising this relatively simple point about reading one prises open the wider issue of *language*, which, far from being an irksome or obscure side issue, should be "a proper and central concern for all teachers", as Harold Rosen has emphatically pointed out (Rosen, 1972 #25).

This investigation is an attempt to examine the *language* element in physics teaching, working, for practical reasons, within the parameters of the A level curriculum.

1.2 Language issues in the classroom

Even a brief list of the activities which take place inside the classroom will reveal the extent to which language is nominally involved. One major focus of practical educational research has been the interaction between teacher and pupil in the classroom. Originally, the reason for this was the desire to improve teacher effectiveness by trying to define the characteristics of an ideal teacher. For many reasons this work was unsuccessful (Morton D Waiman quoted in Barnes, 1972 #26) but subsequently a shift in emphasis from categorizing teacher language to looking at pupils' language, initially by "naturalistic" studies, has pointed to the crucial role that language plays in learning. For teachers, this has called attention to the importance of perceiving how pupils' language is contributing to or inhibiting their learning. Douglas Barnes has argued that ways of helping teachers to arrange discussion and writing so that their pupils benefit from them, must be based on a

---

[1] This excludes "short-burst " reading which is defined as reading of 15 seconds or less.

In Hash symbols (eg #25) in references should be ignored throughout. It was not possible to prevent the programme from inserting them.

theory of learning which takes account of four aspects of classroom interaction: pupils' expectations, context of the situation, context of language use and learning outcome (Barnes, 1972 #26). What is clear from seminal studies in this area is that the study of classroom language encompasses more than linguistics and indeed intersects a number of disciplines, notably, *sociology* and *psychology.*

The language of the textbook is another key issue. In the early seventies Harold Rosen (Rosen, 1972 #25) was pointing out the inappropriateness of much of textbook language, and urging a radical change in the way textbooks are written. His main criticism was of the use of impersonal language which he said "looks at children across a chasm". Some children do take on chunks of this kind of language "as a kind of jargon", but for many "the textbook is alien both in its conventions and its strategies". The salient point of Rosen's argument is that the conventions of the textbook divorce the language of the subject from the child's experience so that only those pupils who are confident in the use of that kind of language will be able to take it on, and even then not in a way that allows the child's thoughts and knowledge to be reinterpreted and expressed. That physics students find reading texts so unpalatable may well be due to their alienation from the language of the textbooks on offer, which if true would mean that more than twenty years on, Rosen's criticisms are still valid.

1.3 Language in school physics

Catchphrases such as "every lesson is an English lesson", have been popular for many years, yet, subject teachers are often unaware of how exactly to assist their pupils' learning through appropriate language use. This is true on the whole for physics, but it has to be said that some Examination Boards have made an attempt to involve the language element by having a "comprehension" paper[2] as part of the A level examination, where pupils are required to read a passage and answer questions which relate directly to it. Unfortunately, preparation for this examination is often restricted to reviewing a few past papers. There is little evidence that other texts are discussed formally in class or indeed that reading is taken seriously as a learning activity in the widest possible sense.

It is understandable that content - orientated syllabuses make it difficult for teachers to find the time to cultivate reading and other related skills, except as a hasty attempt at examination preparation, towards the end of the course. Teachers hope that students will acquire these skills on their own, and indeed many will; but the desirability or possibility of encouraging students to acquire and practise reading related skills within the time

---

[2]University of London A Level Physics Examination is one example, the idea having been pioneered by Nuffield A level Physics

constraints of a heavy syllabus load is rarely discussed.

It is true to say that the hard-pressed teacher has very little guidance in this area, as Kempa points out in Assessment in Science (Kempa, 1986 #12), "Exam. Boards do very little to make explicit what they require by way of communication skills ". The absence of guidelines suggests widespread adherence to the assumption that the ability to read and write is an absolute value requiring no definition, scrutiny or indeed further attention, from teachers and examiners.

The journal *Physics Education* whose target readership is physics teachers and lecturers, has published only one article even remotely concerned with language, in the period 1989-1992. This article was a review of 5 A-level textbooks compared with respect to several criteria, including a section on the "*Use of language and quality of writing*" (Wellington, 1991 #28). The review gives a description of each book in terms such as "style is a friendly one", "the language level is good...with clear,well constructed sentences – few containing more than 40 words". However, in his concluding comments the reviewer says: "It should not be forgotten that A-level physics contains many difficult concepts, so a crude estimate of readability using a formula involving factors such as sentence length...is not appropriate. Measures of a book's readability ...are of little value in judging how 'understandable' a book is. Understandability, if there could be such a measure, would involve a 'fiendishly complex' set of factors"

It appears from this that one reason "language" is virtually ignored in school physics teaching is because the issues involved are seen as being too complex and, one concludes, hardly worth the effort of investigating.

1.4 Reading as part of scientific training

Traditionally, physics teachers are trained to be aware of the importance of developing the practical and mathematical abilities of their A level pupils. More recently, greater emphasis has been given to encouraging problem-solving strategies and computer competences. Reading, by contrast, has been and is regarded as largely a tacit skill which is never tackled directly. Yet, post-A level education relies heavily on written information and students will have to face a variety of literature, from stolid standard texts half a century old, to scholarly journals concerned with the latest controversies in the subject. It may include somewhere on the way lively, popular-magazine style articles and perhaps quirky, unedited communications from individual scientists.

Since the student's ability to understand and absorb this material greatly influences her or his success in the particular course of study, it would seem logical to try to make reading as specific and enjoyable task as early in the course as possible. A 1969 policy document *London Teacher* (Teachers, 1969 #53) suggests: "(At all levels) children should have available various types of material on the topic they are studying: reference books, newspapers, cuttings, periodicals, stories, biographies, documents and texts. (There should also be) provision for reading time."

If encouraging students to read is a genuine objective, then both the material and the time must be available to make this achievable. Yet, as Davies and Greene point out in Reading for Learning in the Sciences (Davies, 1984 #14), asking a student to read a chapter of a book is like asking him / her to do a practical without instructions.

1.5 Study skills

Although this chapter has attempted to point out the deficiency in concern for language in school physics, it has to be said that many schools do take the time to teach "study skills' in some form to older pupils, particularly those embarking on an A level course. It is presumably hoped that what is taught in a Study Skills course will be directly relevant to any subject, and a well-designed course will contain a large component of language related skills such as reading, note taking, use of a library and so on. The problems with prescriptive, general courses are that what is taught is to a great extent arbitrary and may well miss important skills which are relevant to some subjects and not others. Also, there is the question of the relevance of the material that is used for the course; does, say, reading a sociology text help a physics student to read a physics text book?

These criticisms are not meant to dismiss the idea of teaching study skills out of hand, but the rational solution is to try to satisfy the the needs of the individual student, which must to some extent, be dependent on the subject s/he is studying. There is a need to distinguish skills that can be taught independently, for example, using an index, cross-referencing, using a library and so on from other skills that are deeply embedded in the mores of a particular subject. The trend towards a workshop approach which is particularly favoured by institutes of higher education, shows an enlightened approach to satisfactorily combining content with process (Irving, 1985 #15). However, whether or not an adequate study skills course is offered, the relevance of looking seriously at language in school physics and investigating an aspect which might improve the quality of the learning experience, cannot be denied.

1.6 Summary of classroom language

Table 1.1 Types of classroom language

Medium	Teacher	Pupil	Other
Spoken	Exposition Instructions Questions Answers	Questions Answers Exploratory comments Pupil/pupil discussion	Speaker Video Visits Lectures
Written	Notes Questions Comments/marks Model Answers	Notes Answers Practical reports Investigations	Books, papers, magazines etc Syllabus Examinations Test Questions

In Table 1.1, I have tried to give a bare list of possible language activities. This could be refined to distinguish, for example, between formal and informal modes, interactive and "one-way" communications and perhaps static / modifiable language.

Most investigations of spoken language will require the investigator to be in the classroom for a significant amount of time because as well as characteristics of human speech that could be recorded such as pace, clarity, volume etc, other factors like gesture, position of speaker relative to the listeners, eye contact and distractions must be considered. As has already been mentioned and will be further discussed in chapter 2 work on spoken language in the classroom has benefited from the attentions of sociolinguists and psycholinguists, but, perhaps with little feed-back to the classroom teacher. There are areas where research on classroom spoken language could have direct and valuable impact. For example, it may be useful for teachers to have some guidelines for assessing pupil's grasp of material from spoken comments or answers and for improving their own verbal communications such as explanations and instructions. Ultimately, though, pupils will be examined by a written test on their knowledge and understanding of the subject, there being, so far at least, no oral elements in any A level examination. Hence, despite the exciting and rewarding work that could be envisaged being done on spoken language, it is the written mode of language use, in reading and writing answers to questions, in particular, that could have the most immediate significance to teachers.

1.7 Choice of problem and method

Since observations of classroom language and interaction must to some extent be intrusive these types of studies are fairly demanding in terms of commitment from the participants. Many teachers, seeing the value of socio- and psycholinguistic studies, would willingly give this co-operation, but it seems likely that teachers would be more interested if the focus of the research was directed at issues relating to their classes and teaching which caused them genuine concern. Related to this, is the fact that as I am a physics teacher and not a specialist in psychology, sociology or linguistics, I judged that it would be sensible to stay within an area which exploits my available skills and experience, whilst realising the potential for methods and ideas that other disciplines offer which can be drawn upon.

A study which looks at written language, particularly one which is concerned with material that pupils' read and / or write, has several advantages which can be summarized as follows:

- fairly non-intrusive and so encourages participation by teachers
- could be linked to established curriculum and hence seem more relevant to pupils
- could focus on "problem" areas in language which are of concern to teachers.

The desire to make the work relevant to physics teachers in general and to the participating pupils and teachers in particular was an important constraint on the type of research which could be done. The other main factor was that I did not start with a strong theoretical base of what was to be tested, but rather some hunches and ideas drawn from the literature about what would be interesting to find out about and how to do it. This type of pragmatic approach can be called **action research**, and I have referred in this thesis to the research methods which I adopted as characteristic of action research. Basically, if empirical educational research can be described in terms of a continuum between two extremes which are, either testees fitting in with the demands of the research instrument or the instrument adapting to the needs of the testee, then I would say I have opted for the latter.

Although the advantage of this type of approach was that I could produce material and methods relevant to the pupils and teachers concerned, the main disadvantage was that I lacked a "grand master plan" and a solid frame of reference for evaluating results. The danger of this was that I could be left without any valid results or results that were uninterpretable, however, on balance, I felt the chance was worth taking.

1.8 Context of the study

It should be pointed out that this work was carried out in Nairobi, Kenya where I lived in the early 90s. The pupils who participated were A level students at four schools in Nairobi whose physics teachers (and in two cases english teachers also) agreed to be involved. These four schools were chosen because they followed the British-style of curriculum and in fact modelled themselves closely on British (Public) Schools. My intention was that the results should be relevant to physics teachers in almost any english-medium school. More details of the pupils and the schools are found in 4. 6, but I would like to highlight three points:

- the wide variety of the mother tongues of pupils in this study is not so very different from some schools in Inner London, particularly Further Education colleges, that I have taught in;
- differences that were apparent to me were that the pupils in the Nairobi schools came from a more affluent background than most pupils I had taught in London. I believe that differences of a similar kind would have been found if the study had been carried out in Public Schools in the UK, so, to this extent I do not believe that the location was as lacking in relevance to British education, as it might seem;
- the small number of girls involved in the study. A maximum of six female physics pupils were involved out of a total of forty pupils (15%). Although girls are also under-represented in A level physics groups in the U.K, my guess is that a mixed A level physics group in London at that time would more typically have at least 30%[3] girls.

1.9 Organization of the thesis

The thesis consists of three strands which correspond to the headings below but which do overlap in some chapters:

Part 1 Framework of Enquiry (Chapters 1-4)

Gives the reasons for chosing the area of language in the A level physics curriculum; reviews the literature on issues concerning language and learning in science and expands on how possible suitable topics for study were evaluated before delineating the chosen research questions and the instruments by which the questions could be investigated.

3University of London A level Examination had the following numbers of female / male candidates : June '91 2563 / 6585, June '92 2556 / 6590, giving an average of 28% girls over these two years

Part 2 Implementation (Chapters 5-7)

Each of these chapters describes the materials and methods used for one particular type of investigation, the pupils involved and the test conditions. The results of each investigation are stated and discussed, together with a breakdown and exploration directed towards the terms of reference of the particular instrument used and a brief analysis of their usefulness and validity in terms of the research questions.

Part 3 Analysis (Chapters 8 & 9)

Collates and compares the results and discusses how these data relate to each other and other evidence collected. This information is studied to assess how far the results go towards answering the research questions. A critique of the methods and evaluation of the study complete the thesis.

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

The initial problem, and the concern of this chapter, is to establish what exactly reading involves, the relationship between reading and language and how ideas about these areas can be related to learning and understanding within a particular subject. The implications of reading assessment or at least, monitoring of development, will also be considered.

The subject of "language" is immense and so only a small fraction of the ideas related to reading and learning can be covered here. Taking as a starting point that language encompasses "words", "meaning" and "communication" suggests immediately that the subject spans several disciplines. Examples of these disciplines are linguistics, psychology and sociology. Vygotsky (Vygotsky, 1966 #5) proposed that the basic unit of language is *word meaning*. He argued that separating the study of sounds from the study of thought, "has little bearing on their function as human speech". Furthermore, Vygotsky points out that the primary function of language is as a means of *social communication*. Hence, there is a necessity for overlap between disciplines when investigating language and areas such as sociolinguistics and psycholinguistics have been called upon to look at language from these specific perspectives.

2.2 What is reading?

Superficially, reading is the decoding of written symbols. However, that reading involves much more than decoding is illustrated by the fact that different kinds of reading and different levels of fluency in reading are possible, which have been shown to rely to a very variable degree on the interpretation of visual symbols. The idea that reading is decoding of symbols is most applicable to beginning readers and even then is far from being the whole story. It is necessary, as it is with language in general, to review the issue of reading from several points of view.

2.2.1 Psycholinguistic perspectives

Before learning to read, a child has developed language competences through listening and talking. Whether or not this is a necessary precondition for reading is unclear, but by analysing the errors children make when reading it seems that "a child's attempt to *preserve meaning* is instrumental in determining what is actually read"(Rye, 1982 #16). Many reading teachers have more or less based their work on this premiss and a working hypothesis has emerged of reading being a "problem solving activity acquired through the use of several cueing systems"(Arnold, 1984 #18). Kenneth Goodman's three cueing systems quoted in *Making Sense of It* (Arnold, 1984 #18) comprise the above stated need to preserve meaning which he calls the *semantic level* (of reading), the decoding of the look of a letter to its sound, the *grapho-phonate level* and the child's use of the structure of the language, the *syntactic level.* The extent of the contribution of each level of cue depends on the fluency of the reader and the familiarity of the subject matter; a fluent reader faced with a passage whose content is familiar will make economical use of the grapho-phonate cues, as demonstrated by experiments which have observed the behaviour of the eye during reading. The eye certainly does not focus on every letter nor on every word, "there are influences on words which help the reader to predict what may be coming in a given sequence" (Rye, 1982 #16), which seems to justify Goodman's epigram calling reading being a *"a psycho-linguistic guessing game"* (Arnold, 1984 #18).

There seems to be a need to capture the relationship between two major aspects of language, speech/listening and writing/reading. Lunzer and Gardner (Lunzer, 1979 #17) cite De Saussure's classification of language as what the child *knows* and speech as what the child *does* which is echoed by Chomsky's *linguistic competence* and *performance.* Naturally, almost by definition, psychologists of the Behaviourist school reject the idea of *knowledge of language* distinct from what can be demonstrated by *language behaviour* . The basis for insisting on a theory which includes *knowledge* is that experience has not taught us all the sentences we could possibly say, and that children use language creatively after only a short exposure to adult language. Hence it is possible that we draw on a body of knowledge, which could be called the ideal form of language. "Normal speech consists of fragments, false starts, blends and other distortions of the underlying idealized form. Nevertheless as is evident from a study of the mature use of language, what the child learns is the underlying ideal theory" (Chomsky, 1972 #51).

If speech can be regarded as a sub-set of language, then for reasons which Lunzer delineates (Lunzer, 1979 #17). "the domain of written language exceeds that of spoken language – and tries to include it". In other words there seems to be a nested relationship between language, writing and speech. However, Lunzer also enumerates the disadvantages of written over spoken language, which include the absence of non-verbal behaviour and feedback, increased difficulty and that other important psychological point, the motivation which reading requires.

Some people find that reading requires more effort than listening to conversational speech. Certain psychologically defined personalities (extroverts, according to Freud/Eysenck's nomenclature) find reading more difficult to cope with than other personality types (introverts). There is a certain amount of evidence from brain physiology (Rowe, #40) experiments to support the theory of a distinction between the amount of external stimulation needed to maintain interest in academic tasks in different people, which might well correspond to the psychologically based differentiation between extrovert/introvert.

2.2.2 Sociolinguistic aspects

A useful way of beginning to look at the sociolinguistic aspects of language and thus, reading, is to consider the implications of *pupil expectation*. Of course, *expectation* has a psychological connotation in reading as noted above, in as far as playing the "psycholinguistic guessing game" involves predicting and so on. But, from the sociolinguistic viewpoint a pupil's expectations of what is being demanded of his/her language resources is a product of social and cultural conditions... "(expectations) have been set up both by the pupil's experience of language outside the classroom, and by ... particular experience of language in lessons" (Barnes, 1972 #26).

The effect of social class on language has been widely investigated, and Basil Bernstein has contrasted the language of middle class children and working class children. He recounts experiments with groups of seven-year-olds (Bernstein, 1990 #19) and suggests that the results show that middle class children are able to produce abstract connections between objects more readily than working class children of the same age. This, and other evidence led Bernstein to conclude that the language a child uses is highly dependent on his / her social class: "We found in general that the focus of the child's speech was more a function of the child's class background than the child's IQ."

Although there are criticisms of Bernstein's interpretation of his results, there is no dispute about the influence of social background on language. As Stubbs confirms (Stubbs, 1985 #7) "No critic of Bernstein has ever denied that there are social class differences in language, or that these differences are somehow related to educational problems faced by working class children. What is in dispute is the nature of the relationship.... it remains to be demonstrated that they are causally related".

It should be pointed out that sociolinguists distinguish between two aspects of language ability, which they call constitutive rationality and practical rationality, where the former is the "ceiling" of ability within which the latter operates, practical rationality being dependent on the context and the person's interest and preferences. This paradigm may be equivalent to the "deep" and "surface" processing proposed by psycholinguists.

2.2.3 Language and cognitive development

An interesting perspective by Jerome Bruner which has links with the sociolinguistic viewpoint (and also naturally, the psycholinguistic) suggests that cognitive growth is a result of skills transmitted by the culture. "If we are to benefit from contact with recurrent regularities in the environment, we must represent them in some manner...experience is coded and processed so that it may be relevant and usable...the end product of such a system of coding and processing is ...a *representation*" (Bruner, 1972 #33). There are three types of *representation*, enactive (motor responses), iconic (images of objects or events) and symbolic (words), listed in the order in which they develop in the child. Bruner contrasts the restrictions of the iconic mode of representation with the bountiful possibilities of language which provides, "not only a means for representing experience, but also for *transforming* it ...the transformational rules of grammar provide a syntactic means of reworking the realities one has encountered" (Bruner, 1972 #33). Bruner uses the results of experiments with children given a transposition task on a double classification matrix to show that, for the most part, children who did not find the language to describe the classification system of the matrix failed to perform the transposition correctly. From this he goes on to suggest that improvement in language, which might mean activation of language habits which the child already has, should aid this type of problem solving.

Bruner seems to be mainly interested in the technological aspects of culture and environment when he says: "What is significant about the growth of mind in the child is to what degree it depends not upon capacity but upon the unlocking of capacity by techniques that come from exposure to the specialized environment of culture", but that does not mean that "localized idiosyncrasies" (if social class can be thus categorized) are not also agents of influence on cognitive growth and thus implicitly, on language development.

2.3 What is learning and understanding?

Since in this thesis I am interested in language and specifically in reading in science education (especially A level physics) a review of relevant ideas connected with pupils' learning and understanding and the processes involved, is necessary here.

2.3.1 The Constructivist view of learning in science

Central to the Constructivist paradigm is the fact that a pupil in a science lesson is not a "blank sheet" in the Lockean sense but has many pre-conceptions about, for example, what things are and how they behave. To learn, the Constructivists propose, the child must make cognitive bridges between what s/he knows and what is being taught in the class. "Learning involves taking apart new ideas to build them into our own understanding" (Sutton, 1980 #31). Or, as Rosalind Driver (Driver, 1981 #41) puts it, "Learning science implies shifts in thought comparable to scientific revolutions (in a Kuhnian sense)". Although the images invoked by these two statements differ slightly, the use of metaphors linked with building, construction and "making connections" has been used to describe learning in the field of science education, and indeed elsewhere, both by Halliday and by Bourdieu (Solomon, 1984 #32). Together with the evidence for widely-held alternative frameworks of pupils' ideas in science, these are theories which teachers of science have had to take seriously.

A considerable body of research has considered various elements of Constructivist theories, notably, the actual ideas that children have about various phenomena, how the child switches from his/her alternative theories to those of standard science and also the nature, source and explanation of the alternative framework.

Empirical evidence suggests that pupils who are not successful in learning science have difficulty in forsaking the alternative framework. The difficulty is understandable since "the common metaphors and meanings of words which underlie many of these alternative frameworks cannot be obliterated even if they are at odds with science, because they are continually reinforced by everyday speech." (Solomon, 1984 #32)

Joan Solomon (Solomon, 1984 #32) has shown how pupils can be helped to switch from one cognitive domain to another, that is, from an alternative framework to a "scientific" framework, by using *verbal cues or prompts*. She tentatively concludes from this that pupils may have both types of knowledge simultaneously but that the less successful pupil just needs much stronger cues to switch into the right domain.

Looking more closely at the alternative frameworks that children have, there has been extensive investigation into the actual ideas which children hold about various phenomena related to the science curriculum which has alerted teachers to possible areas of conflict between children's "misconceptions" (or, rather, naive conceptions) and that which standard science tries to explain. Further studies (such as Joan Solomon's above) attempt to investigate ways of "bridging the gap" between the two domains. More recent work has centred on the "logic" of the commonsense domain, by examining the dimension which underlie alternative theories. Jon Ogborn (Ogborn, 1991 #42) has sought to find a theory of the content of commonsense conceptions, arguing that commonsense reasoning cannot be dismissed as "what we do when we are not paying careful attention", but that on the contrary, "in a sense, (commonsense is) the final arbiter in science". By delineating the key concepts which govern commonsense reasoning, Ogborn is able to show how scientific explanations do ultimately satisfy deeply-held criteria necessary to make "commonsense". Action at a distance, to take one example, is against commonsense which requires objects which affect each other to touch. Science offers the notion of a "field" to fill in the empty space which neatly [1] appeases our fundamental need for relating cause and effect.

---

[1] Nicholas Maxwell proposes that "simplicity and beauty" are strong but unarticulated criteria applied to the selection of scientific theories,(Maxwell 1976)

2.3.2 Seeing and believing – a cognitive psychologist's approach

There is an interesting parallel between the notion of two domains of knowledge about the world together with the need, in order to learn conventional science, to be able to recognise both domains, and Bruner's explanation of why young children can sometimes correctly predict the results of a liquid conservation task when the different shaped vessels involved are partly screened, but revert back to an incorrect answer when the task is repeated with the vessels in full view: "It is plain that if a child is to succeed in the conservation task, he must have some *internalized verbal formula that shields him from the over-powering appearance of the visual displays*...explanations from children who lacked conservation suggest how strongly orientated they were to the visual appearance of the displays they had to deal with" (Bruner, 1972 #33). At the early stage of cognitive development which Bruner is describing, the rules that govern "commonsense" seem to be different from those that follow later. Whether the rules are fundamentally different or merely more easily subverted by visual appearances is another matter, but one can't help but feel that when a pupil "understands" Newton's laws of motion, say, something along the lines of: the child having internalized verbal forms which shield her from the "over-powering appearance of visual displays", has taken place.

2.4 Learning from texts

The influential Bullock Report (Bullock, 1975 #23) gave rise to a number of other studies which have investigated the issue of reading in the curriculum. The Report isolated three levels of reading comprehension which are listed here to show what exists by way of general guidelines and which could be used as a basis for the present investigation.

How far these levels are relevant to physics education will be discussed later (2.5 and chapter 3):

(i) Literal comprehension: where the reader can pick out the main theme of a passage and sequence of events or arguments. Where the important words / sentences are recognised and the reader "knows" what the passage is about, can answer the questions what, where, whom, when relating to the text.

(ii) Inferential comprehension: at this level the reader can make inferences about the author's intentions, can answer how and why questions about the passage.

(iii) Evaluation comprehension: now the reader can weigh the value of what is read, consider the status of the information and its sources as well as the quality and cohesion of the arguments and relate these to any contrary information. In evaluating the type of material (persuasive, narrative, informational etc) the reader can also appraise its effectiveness.

The report suggested that reading for learning would be most effective when the reader became an *active interrogator* of the text rather than a passive receiver of words.

2.4.1 Ways of encouraging active interrogation of text

The Schools Council publication, *Effective Use of Reading*, followed by *Reading for Learning in the Secondary School*, both explore the methods by which subject teachers can help pupils interact more fully with reading material. The main motive behind each type of method is to try to involve the student in the text by asking him/her to perform specific tasks linked with the text. These activities have become known by the acronym DARTS (Directed Activities Related to Texts). For example, filling in gaps (cloze exercises), sequencing jumbled text, underlining key words or more complicated schemes involving creative writing and fantasy. The teacher's choice of technique to be employed will depend amongst other things on the nature of the text, the students involved and so on, as not all methods suggested will be useful for a given class or subject area.

As important as involving the student in the text is the possibility these methods afford of interaction with the teacher to monitor progress or generate discussion. Part of the problem for a teacher who wishes to set reading (homeworks or fill - in lessons seem to be the preferred times) is to evaluate how well the students have responded to the passage, if at all. In fact, difficulties with evaluation might well be a reason why reading is not taken very seriously in school physics.

Very recent work has demonstrated the potential for small-group work by students reading physics texts. Various types of small-group work related to the language of particular subjects have been devised and investigated in the past (Lunzer, 1979 #17). In general, the results have not supported the case for this vehicle of language development, at least, when the results are evaluated by "tests, or more importantly... assessed in the context of the normal work of the curriculum." (Koch, 1991 #30).

Intuitively, small-group work gives pupils a chance to talk about a subject, a chance so conspicuously lacking from normal classroom routine in secondary science (Woolnough, 1985 #11), and thereby articulate what they understand, in their own words. This instinctive feeling is supported by (amongst others) Wittrock's observation that "to comprehend what they read, learners invent explanations that fit their own logic" (Wittrock, #43). Wittrock goes on to recommend that "an external monitor is needed to control the learners' explanations". Koch and Eckstein (Koch, 1991 #30) have adapted the small-group technique to provide "peer feedback" for questions which students are asked to devise about passages of text that they have been assigned to study. There was a highly significant difference in test results between the three groups of students which the study set up (those who had devised questions as well as taken part in peer feedback sessions about the texts, those that had only devised the questions and a control group who were left to their own devices with the texts). The first group performed best on the post-tests. These tests were designed to "assess reading comprehension skills and not problem-solving skills" which the authors differentiate on the grounds that problem-solving skills require comprehension skills and elaboration (calculation) skills, so the post-test questions did not require any elaboration.

2.4.2 The importance of "reflection" in reading

Several writers have discussed the importance of developing the habit of reflecting on what is being read, that is, "going beyond what is being read in the local sense to what went before and what they already know" (Davies, 1984 #14). The crucial aspect of all DARTS, these writers say, is that they should encourage reflective reading. Reflective readers go back over the text to check for coherence, poor readers do not; thus, to improve the quality of pupils' reading one has to increase their willingness to reflect. A similar point in made by Donna Alvermann (Alvermann, 1991 #21). Using examples from artificial intelligence research and cognitive psychology she suggests that prior knowledge facilitates learning from text because the reader can use it "to fill the empty 'slots' of a partially completed schema". This would mean that part of the technique of learning from texts is for the reader to activate his or her prior knowledge related to that subject.

Davies and Greene's studies (Davies, 1984 #14) show that the quality of reflection rests on the reader's existing knowledge and concept of what is being read so there should be a *suitable match* between the reader's background and the content and level of comprehension of the text in order to enhance the prospect of students reflecting and thus reading effectively.

2.4.3 Reading and the "real world"

Joan Solomon argues that learning science involves linking two domains of knowledge, the "commonsense" domain and the classroom "scientific"domain (Solomon, #44). Assuming that most sections of physics text books of A level standard are written exclusively in the orthodox science domain, from Solomon's viewpoint, students who have not fully crossed the conceptual bridge to the standard scientific explanation of that topic will have their pre-conceptions challenged to a greater or lesser extent when reading such a text passage. This could be frustrating and disheartening for some students and it is easy to see why reading text books could become an irksome chore, to be avoided whenever possible.

Another point that should be clarified here is the role of *background reading* which teachers have mentioned (see 1.1) as being particularly healthy and desirable. There are obviously numerous uses for this type of reading, but part of what is intended is that students should read about scientific concepts at work in the real world; to reinforce the orthodox science view, to establish links with the student's personal life and stimulate motivation, etc. One could speculate on how this might relate to the Alternative Framework paradigm, particularly in the light of the suggestion that some pupils can be prompted to use the "correct" scientific language to describe a phenomenon with appropriate cues. Admittedly, in Joan Solomon's investigation the cues were provided by a teacher in a one-to-one interview situation, but, essentially, the teacher is prompting the pupil to use "scientific" language when the pupil seems trapped in the "commonsense" domain. There seem to be similarities with what reflective reading is supposed to achieve, although at a more sophisticated level than a 'prompt', and links with Alvermann's suggestion about the importance of activating prior knowledge. Assuming that DARTS are a means to the end of effective reading for learning, it may be that by involving the reader in the text the process of self-prompting is being developed which, ultimately, results in the reader being able to monitor and mine his/her own knowledge and thought processes relative to what is being read, a process known variously as metacognition (Alvermann, 1991 #21) or metacomprehension (Koch, 1991 #30).

2.5 The problem of assessment

Underlying most of the discussion so far, which has shown that reading is by no means a static skill but one that can and does develop with the cognitive growth of the child and an array of intrinsic and extrinsic influences, is the assumption that the flourishing of reading skills can be evaluated. That there is a need for objective evaluation of reading skills is undeniable and in some respects overwhelming, and may be the reason why, firstly, there is such a variety of reading 'tests' and, secondly, why none are free from controversy. The pros and cons of individual reading-assessment tests will be discussed more fully later (see chapter 3 and elsewhere) but the pervasive problem which is implicit in many of the arguments which have been given in this chapter, is that of *defining reading skills* separate from *understanding of the content* of what is being read, separate again, in some cases from other *related skills* such as problem solving. This is undoubtedly a consequence of the fact that reading can, though only to a limited extent, be assessed by having the subject *'just read.'* Although this is a valuable method (as will be discussed later – see chapter 6 READING ALOUD) listening to a pupil read does not exclude variables such as the interest and motivation of the reader to the passage, the response of the reader to the situation, and so on. Of course, there will be many instances where it is neither necessary nor desirable to separate the three, but it is unfortunately the case that many attempts to do so have been shown to be invalid or unreliable (Johnston, 1984 #37).

Assessing reading skills does not have an exclusively *summative* purpose, of course. There are plentiful reasons why it is important to monitor the development of reading skills (*formative evaluation*) at every stage although it is taken most seriously with beginner readers, and here the case for subjective judgements to do with, for example, how hard the reader appears to be trying, how much encouragement s/he needs, etc, has justified the use of qualitative elements in reading assessment without any deliberate attempt to 'fudge' the issue.

Looking again at the levels of comprehension suggested by the Bullock report (2.3) the scope for subjectivity on the part of the assessor is wide and for the purposes of norm-referenced testing would have to be explicitly defined in relation to the actual text and questions involved, and even then, it has to be said, the decisions made would be arbitrary.

The other important aspect of monitoring progress in reading is that of assembling *diagnostic* feedback. This is most usefully administered as part of formative assessment, particularly as the feedback may not be only be in terms of the pupil's progress relative to the instruction but evaluation of the course or programme of instruction (in more enlightened settings).

There are yet more aspects of assessment to do with such things as "maintenance of standards", but the upholders of standards in science education (i.e. Examination Boards) do little to go beyond the rhetoric of agreeing "about the importance of communication skills within the total framework of science process skills" and have made "few genuine attempts to evolve procedures and criteria for their assessment" (Kempa, 1986 #12).

2.6 Special difficulties of science

The difficulties that learning science presents are considered from the point of view firstly of concepts and secondly of the problems of communication. Essentially the two are intimately related, although it is possible to have concepts which are not structured with words, but, for example, in images. Gunther Kress has put forward a "grammar" of visual communication (Kress, 1996 #47) and indicates the power and expressiveness of the visual image. Kress also points out that increasingly in pupils' texts, images in the form of illustrations or photographs are used not as adjuncts to texts but *instead* of words. While acknowledging the importance of other visual media, I will look specifically at concepts and communication in the written mode, since this is still predominantly the method of communication of physics at A level.

2.6.1 Scientific concepts

Shayer and Adey (Shayer, 1981 #45) address the problems faced by children learning science, using as a model Piaget's theory of cognitive growth, which defines a sequence of stages through which the thought processes of a child develop. There are three main stages: 1 pre-operational, 2 concrete operational and 3 formal operational. Stages 2 and 3 are sub-divided into "early" and "late" stages giving a sequence like this:

1	*2A*	*2B*	*3A*	*3B*
	early	*late*	*early*	*late*
pre-operational	*concrete operational*		*formal operational*	

The important difference between the *formal* and the preceding *concrete* stage is the increase in the level of **abstraction** of the child's thinking process.

One example of the "qualitative change in complexity" of a child's thinking between the *concrete* and *formal* stages is the ability to cope with more than two variables. Shayer and Adey cite, amongst others, the example of the effect on the period of a pendulum's oscillation of changing both the weight and the length of the pendulum . Only "the formal thinker...knows that the fact that the two aspects are associated does not necessarily define their relationship, and that further evidence is required before a decision is made" (Shayer, 1981 #45).

Shayer and Adey's data show that by the age of 16 only 30% of schoolchildren in a mixed ability comprehensive school are likely to be capable of thought at the *early formal operation stage* and only 15% at the *late formal operation stage*. They go on to classify the major components of the physics curriculum in terms of Piaget's stages and it becomes clear that the physics curriculum, even before A level, requires pupils to be able to think at the formal operation stage, for a high proportion of topics.

One conclusion which Shayer and Adey draw from their work is that teachers could try to adapt the curriculum for the different cognitive levels of the children in their classes so that the content matches their pupils' capabilities. Alternatively, they discuss studies which investigate interventions which attempt to produce "cognitive acceleration" in pupils. The results of these and other studies (Project, 1993 #46) suggest that pupils' cognitive development can be assisted to become capable of using higher level material. In other words, the pupil can be "modified" to suit the curriculum rather than vice versa.

Vygotsky's observations of children's development of "scientific concepts"[2] (Vygotsky, 1966 #5) have some resonance with the Piagetian model of developmental stages where he says "a concept is... a complete and genuine act of thought that cannot be taught by drilling but can be accomplished only when the child's mental development itself has reached the requisite level". In a way Vygotsky postulated that all instruction (in "scientific concepts") contributes to "cognitive acceleration" since instruction "activates large areas of consciousness". In other words, he says "a pennyworth of instruction ...(gains) a small fortune in development". The implication from Vygotsky's work is that without instruction of the kind given in schools, children's cognitive development would not progress at all.

One further point made by Vygotsky (Vygotsky, 1966 #5) is particularly significant to this study. His experiments showed that eight-year-old school children could answer questions on "scientific concepts" better than "spontaneous concepts". He concluded that the child became conscious of everyday concepts relatively late whereas concepts learnt in school are usually presented on a verbal level so that "it starts its life in a child's mind at the level that his spontaneous concepts reach only later." Vygotsky summarized this by saying *"the development of the child's spontaneous concepts proceeds upwards, and the development of his scientific concepts downward, to a more elementary and concrete level."*

This seems to me to make a very good case for encouraging "background reading", indeed, for reading in general. Vygotsky's whole argument about the nature of "scientific concept" formation suggests that concepts cannot be "swallowed whole" from the teacher. Thus, scientific concepts are not static but subject to modification and growth in the mind of the child. The individual child has, in effect, to recreate the concept using any means at his / her disposal, and this of course includes reading.

2.6.2 Scientific language

Halliday and Martin's linguistic analysis of scientific language (Halliday, 1993 #10) started from the point of view that "it would not be possible to represent scientific knowledge entirely in commonsense wordings; technical terms are not simply fancy equivalents for ordinary words and the conceptual structures and reasoning processes... are highly complex and far removed, by many levels of abstraction, from everyday experience". However, they add, "it is often made more difficult than it need be". They took as their task to distinguish whether the features which make a particular passage

[2]Vygotsky uses the term "scientific concept" to refer to concepts "learnt in school". He calls these "systematic" or "non-spontaneous" concepts as opposed to "spontaneous" concepts which arise naturally, without instruction. He gives "brother" as an example of a "spontaneous" concept and "slavery" as an example of a "scientific" concept.

difficult to understand are "motivated" or not, that is, whether there is some good reason for the passage being written the way it is.

The problem, Halliday and Martin found (Halliday, 1993 #10), was not so much the vocabulary, the "technical terms" of science themselves, but the "complex relationships they have with one another". In other words, it is in the *grammar* of science rather than the vocabulary where the difficulties lie. Halliday gives seven main headings for considering the special difficulties of scientific English. One of these is considering the *lexical density* of a clause. Lexical density refers to the number of lexical or content words (the rest being grammatical or structural words) in a clause. The greater the lexical density count, the more difficult the clause will be to understand. This Halliday illustrates by comparing informal speech which typically has a lexical density of 2, and extracts from the journal *Scientific American* which had lexical densities of 13.

Identifying the grammatical and lexical words in a passage is relatively easy even for a non-linguist, but some of Halliday's other categories such as *syntactic ambiguity* are slightly trickier for the non-specialist to recognise. Nevertheless, linguistic analysis could be a useful tool and although Halliday and Martin's book was published after the passages had been selected and the data collected for the present research, there was an opportunity to review the data using some of these ideas.

Clive Sutton (Sutton, 1992 #13) points out in his discussion of language in school science how powerful and pervasive the use of metaphor in science is. He suggests that figurative expression quickly become literalized but by "striving to reactivate the dormant metaphors" teachers can help pupils to "enter imaginatively into the various systems of speech and thought". By this means, Sutton goes on to say, a pupil can make associations with what is being taught to what is already known which are relevant to him or her individually. Hence, a word "can become a possession - a part of that person's competence, not just something belonging to the teacher and textbook writer."

2.7 Summary

This review of reading and understanding has sought to establish the baseline issues from several disciplines and attempted to give a perspective of how they interrelate and are relevant to physics students. That is not to say that what has emerged is a clear picture, or the essence of the matter. What has been offered can be mostly categorized as interesting observations matched with penetrating insights that cannot be ignored, which, in some cases, appear to be paradoxical.

CHAPTER 3: THE PROBLEM AND THE RESEARCH QUESTIONS

3.1 Introduction

The problem concerns written language in the context of A level physics. That language should be a central concern has been argued in chapters one and two. Leaving aside those with a strong belief that language is not of major importance in this subject, at least at A level, there are many teachers who do not deny the significance of language but who suggest that on a practical level little can be done in this area. Teachers generally agree that students benefit from reading in and around their subject, but despite this very little emphasis is placed on the importance of reading or other language related skills and teachers are given almost no support or guidance on how to promote reading or an awareness of language. This chapter attempts to scrutinize the reasons why this might be so and discusses the kinds of questions which could be asked in order to make an empirical investigation of the problem.

3.2 The Examining Boards' position

As has been pointed out 'language' or 'communication skills' in various guises are given honourable mention in all physics syllabi and many Boards have included comprehension papers in their examinations. The lack of any explicit delineation of the language issues which should concern physics teachers and concrete advice or recommendations on how to tackle them may be due to:

- difficulty of definition;
- reluctance to be too prescriptive;
- assumption that there is not really a problem;
- assumption that pupils automatically develop the necessary language skills as they progress in the course;
- assumption that nothing effective can be done.

It is true that language is deeply connected with all our learning and understanding (see chapter 2) and at first sight making statements about what one expects of language skills in a subject area is at the same time trivial and astonishingly complex, but there is very little evidence that Examination Boards have made any attempt to analyze the situation. Analysis does not necessarily mean starting from first principles. Studies such as the Bullock Report have done more than put language on the agenda, they have tried to establish a framework on which subject 'experts' could build (see 2.3).

Regarding the reluctance to being too prescriptive: naturally, one should not stifle the creativity of teachers, who, after all, know best their students' needs, but this is an area where subject teachers, perhaps physics teachers particularly, do feel at a loss and in need of some helpful guidance.

The three assumptions mentioned in the list have to be looked at seriously. They may be closely connected by the unexpressed and possibly subconscious, rejection of the significance of language in learning in general or particularly in physics which makes further discussion or examination of "problems" irrelevant. To deal with the second assumption: it is true that some students do acquire excellent language skills in the course of developing their competence in physics, and most physics teachers can give examples of students who have read and understood very advanced material because it happened to be a topic that the individual was interested in, but the question surely is – why not more? That this question is not posed bluntly, might well be due to education policies or politics[1] but may also be based on the second assumption that *nothing effective can be done* within the constraints of time, workload, etc, etc. In spite of the work carried out since the Bullock report specifically looking at reading and other aspects of language in science there seems to be widespread adherence to the view that physics is excused from using methods concerned with language that may well apply to other science subjects, because "physics contains many difficult concepts"[2] which implies that language is a tiresome hindrance that is best ignored in order to get to the essence of the subject.

3.3 The teachers' position

If teachers are ambivalent about their pupils' language skills this is entirely understandable given the Examination Board's equivocal stand. The natural consequence of this is that students, recognizing the *low priority* language is given, learn to avoid being concerned with language and are then confused when exhorted to "read more" and subsequently examined on reading ability, as in comprehension papers.

Having decried the lack of guide-lines, it is possible that even if they were available little would be done in the classroom unless teachers are convinced that paying attention to language did not impinge unduly on an already heavy schedule. The crucial question for the

---

[1]of the types which favour an elitist approach.

[2]Jerry Wellington discussing why readability formulae should not be applied to physics texts (Wellington, 1991 #28)

teacher considering adopting any new initiative would be: is it worth it, in terms of time and trouble?

3.4 Exploring the issue

What is actually involved in this issue of reading in physics? To investigate the parameters and key players one could consider a possible scenario such as:

A teacher selects a passage of text for pupils to read independently.

The teacher's choice of ***text*** is clearly important. No less important and linked in the mind of the teacher to the choice of text is each individual ***reader***. Implicit in the activity is the idea of ***purpose***, not only why the passage should be read but also what kind of ***outcome*** is expected to show that the reader has read and understood the material adequately.

3.4.1 The text

Assuming that the teacher has some degree of choice over which particular passage to select, some of the variables which might influence the teacher's decision are summarized in Fig 3.1.

TEXT	Appearance: lay-out, diagrams etc Subject matter: relevance to course, depth & scope Purpose: why read it ? Style of writing Challenging / motivating / difficulty features

Fig 3.1 Variables affecting selection of a passage

Visual presentation is a complex topic and attempts to improve clarity, attractiveness and to some extent "understandability" of text are not always as straightforward as might be assumed. In fact, some studies on the use of diagrams (Reid, 1990 #34) point to the fact that even these are not beneficial to every pupil. For various reasons teachers may wish to re-write or re-format the text so the quality of the final version presented to pupils, particularly when photocopied, may well be quite different from the version originally seen by the teacher. Short of discarding all diagrams and re-typing text in identical format, it is a difficult variable to control systematically. Some qualitative discussion of the visual presentation and any diagrams that are included in the text should be included to keep track of these variables and which may have significance in interpreting results.

It is possible to make a decision regarding the suitability of the subject matter of a text fairly objectively by relating it to the published syllabus of the course and treatment of the topic in class, but closely woven with this is the sense of purpose: why should the pupil read this particular passage, and what will reading the passage achieve? (see 3.4iii)

The style of writing could be simply categorised for the purpose of broad identification and comparison, e.g. news magazine, science journal, humorous etc. or could be more deeply analysed on linguistic grounds as discussed in chapter 2. The question of "difficulty" of the language arises here. Could the language be made simpler while conveying the meaning adequately? How does one decide?

The fifth variable tries to encapsulate the special features of the writing. Clearly, the writing should be pleasantly challenging otherwise there is little point in asking pupils to read it. But what are the features that make it challenging and is it the case that these very features could cause problems with some readers? Similarly, motivation is not a feature of a text but affect a possible response to the text by an individual student. Can these motivating factors be identified and are there less positive reactions which other students will have to the same material?

3.4.2 The reader

Whether they realise it or not, teachers will have made assumptions about their pupils as readers which to a greater or lesser extent will depend on how long they have known the pupils, how frequently they see them and what kind of interaction they have had with them. It is possible that the assumptions are based on no tangible evidence relating to the particular pupils but on a hypothetical standard which the teacher has in mind.

Constructing a set of variables relating to the reader is not quite as straightforward as with the text, but an attempt has been made in Fig 3.2

	Willingness to read in general
	Willingness to read physics related texts
READER	Reading skills
	Facility with subject matter
	Turn-on / turn-off stimuli & responses

Fig 3.2 Variables relating to reader

The first point to be made is that the factors relating to the reader seem very interdependent. For example, it is likely, but not necessarily true, that a pupil who is a keen reader of novels, say, and also studying physics will more readily read material relating to physics than another pupil who reads very little for pleasure. Certainly, **attitude** to reading, which is entailed in both the first two points has psychological links which are diverse.

The assessment and quantification of pupil's reading skills are very much a part of the primary school curriculum but at secondary level only really continue to be of interest to teachers of special needs pupils, i.e. those pupils who have difficulty reading. Currently, in the UK at least, most children learn to read by following one of a number of "reading schemes" which eventually lead to independent reading. During the course of the scheme pupils will be assessed. This assessment could be merely a statement of where the child stands in the scheme at a particular time, if the scheme itself is taken as the yardstick of reading progress. Other forms of testing include word recognition and cloze testing. A common product of the tests is to assign the child a "reading age", usually in years and months, which sets the pupil's reading skills in the context of what is considered "normal" or "average" for the assigned age which may be above, below or on par with the the child's chronological age. Once a pupil has become a competent reader, which is taken to be when s/he has graduated from the reading schemes, reading assessment is not practised so systematically. Apart from english lessons in the secondary school, it is theoretically possible for a student to have avoided reading anything more lengthy than a paragraph or two at a time until s/he reaches A level.

The facility a child has with a subject or a particular topic within that subject is not easy to define. Being good at something or finding something easy or difficult could have some relationship to an "objective test of knowledge" assuming such a test exists, or some other form of performance indicator, but also depends on the child's perception of how well or badly s/he has done in other things, how highly the activity rates in importance or interest, and to some extent the child's own confidence in his or her own ability in that particular field. An assumption is made here that a pupil being interested in a subject will mean that the child is as interested in the written presentation of this subject i.e. reading about it, as in any other manifestation of his/her interest, which won't always be true. Consider the statement "I enjoy tinkering with cars". It would be rather risky to assume that therefore, "I must be an avid reader of anything connected with cars". A more cautious proposition would be "I may well be interested in reading articles relating to modifying, adjusting or repairing cars", which relates to the outcome which the reader requires. (see 3.4 iii)

The last item on the list in Fig.3.2 tries to embrace other factors which might be shaping the pupil as a reader. Seemingly disparate items such as the angle at which the topic is approached or style of presentation, the questions which are posed, the number of pictures or presence of certain words might have motivating effects or quite the opposite as far as the student is concerned. For example, a passage about Bernouilli's principle is one thing, a passage about Bernouilli's principle applied to the carburettor, is quite another. The link with carburettors may appeal to the car enthusiast, but the pupil who does not know what a carburettor is or the more extreme case of the pupil who feels alienated by car mechanics may have a totally different response. This does not mean that there is trouble lurking behind every piece of lively writing which tries to use "everyday examples" to illustrate the principles of physics. In the example given above, the whole passage is unlikely to be about the single subject of carburettors; other, more reassuring examples of the effect are likely to be included in any general textbook or article which may attract the pupils whose interest is not aroused by cars.

3.4.3 Purpose and outcome

In setting a passage for reading the teacher must have a reason why a reading exercise is chosen and some objectives in mind as to what pupils will gain from reading the chosen passage. In the context of the physics classroom, the purpose will involve some aspect of reading for learning. Possible objectives of a reading exercise could be:

- describe / explain a new section of work
- reinforce / revise ideas or topics
- examine interesting examples or illustrations of uses of particular phenomena
- connect classroom teaching with everyday life, make "cognitive bridges"
- practise independence / self-reliance in learning
- develop reading skills

One could reasonably expect some tangible form of outcome from any of these objectives and in some cases these would be open to assessment. Just as in other forms of classroom learning, assessment of some form must be built into the task. The danger of this is that the purpose of the reading exercise becomes completing the evaluation. However, if one of the intentions that the teacher has is to build reading and independent learning skills the sense of purpose and onus of (self) assessment has, eventually, to be transferred to the reader.

3.5 The pupil as a reader

Having introduced the issue in broad terms, some of the troublesome areas and specific problems have already become apparent but it is important to return to the central concern, which is the pupil. The argument is essentially about the pupil as a reader: the interaction of the pupil and the text. Certainly, as suggested above, there are things which can be said about the text which are independent of the pupil and various data can be collected about the pupil which are unrelated to the particular text. But, to investigate the pupil as a reader the prime target must be the response of the reader to the text.

Spontaneous verbal or written reactions to reading the text are possible, but are also of questionable value. The reader's response will somehow have to be elicited, usually, but not always[3], this will mean some sort of interrogation of the reader. The physics teacher is usually interested in the learning of physics which has supposedly taken place, but finding out *anything* about the pupil as a reader must originate from looking at the reader's responses to the text by interrogation of some sort. It is difficult to envisage alternative methods of enquiry apart from listening to the pupil read, as mentioned before. or possibly physiological monitoring of the reader's reactions. Leaving aside physiological measurements and given that listening to pupil's read has only limited power to interpret pupil's reading, it is mostly through various methods of interrogating the reader that an enquiry into the pupil as a reader can begin.

Although the two overlap, the two main options for interrogating the reader are setting:

- "Open-ended" questions
- Specific tasks.

Open ended questions could be factually related, such as,"what was the passage about?". Alternatively, the pupil could be asked what they thought of the passage, which would be more a "feelings-related" question. The difficulty with open-ended questions is that some pupils may find it difficult to give a complete or adequate answer without further probing questions, or without resorting to copying extracts from the passage.

Giving pupils specific tasks would seem to be more promising, because a variety of tasks could be set which may stimulate interest and motivation to complete the questions, even if one particular question caused difficulty. There is also the possibility of comparing the responses to different kinds of tasks and in this way open-ended questions could be used as *one of the tasks*. It should become clear to the pupils involved that they are reading for learning and understanding and that the **tasks they are asked to perform will reflect their reading and comprehension of the passage**. This process has come to be known as "active reading" [4], and the exercises comprising passages of text and series of tasks, are called "active reading exercises".

---

[3]Miscue analysis assesses the reader's response to reading on the "grapho-phonate" level by the number of hesitations made when the child reads aloud. See chapter 4

[4]There are objections to the term "active reading" based on the premise that there is no such thing as "passive reading". However, I am using the term "active reading exercises" to refer specifically to the kinds of exercises which involve the pupil is some sort of concrete activity as well as reading

3.6 Summary of the argument

In order to look at the problem of reading from the point of view of the physics teacher, as discussed so far, it has been suggested that pupils should be:

- given suitable texts to read
- asked to complete tasks related to the material read (active reading exercises).

Clearly, there will be questions that can be asked about the texts and about the pupils, but the research questions must chiefly look at how responses to the text are elicited from the students and the methods by which this is done. The questions should reflect the aspirations of the teacher, but must be posed in a way which makes them suitable for a classroom-based investigation.

Given that there is a gulf of varying dimensions between a pupil's and a teacher's concept of what a particular task or question related to a written passage requires, this study proposes to examine the clues from the language and to a certain extent the *culture* of the subject which may clarify this relationship. Culture here means those influences and constraints which may affect pupil or teacher behaviour particularly in relation to the use of language, for example, in the construction of a mark scheme. The rationale for every mark scheme will unavoidably include factors which are not just dependent on the "quality of the language and the physics". How an item is "weighted" will depend on how important the answer is judged to be and influences on the teacher which might include the type of group, the school, the Examination Board and so on, may well be crucial.

The next section (3.7) gives the five main areas which will be addressed by the end of the study. Not every exercise will necessarily cover each of the five sections and each exercise will enable questions to be posed slightly differently, to exploit the qualities of that particular task.

The main types of tasks chosen will be grouped together so that each chapter will contain exercises which involve similar kinds of task. Each chapter will discuss the research questions to be posed and how they are to be addressed. Explicit questions based on some or all of the following **key guiding questions** will be stated and rationalised in each chapter.

3.7 The key guiding questions

Question 1

Can results from the active reading exercises help the teacher to distinguish different facets of a pupil's reading skills?

Question 2

Can active reading exercises help to measure pupils' reading skills and how could this be useful to a physics teacher?

Question 3

Can the results of active reading exercises give the teacher feedback on choosing suitable texts and suitable tests for specific purposes?

Question 4

Do the results of active reading exercises relate to or reflect the pupil's progress or achievement in the subject in general?

Question 5

How do the results of active reading exercises used with non-science A level students compare with those of physics students and are there any implications in the comparisons relevant to physics teachers?

CHAPTER 4: RESEARCH INSTRUMENTS AND METHODS OF ENQUIRY

4.1 Introduction to the research instruments

As has been pointed out there is a significant body of work concerned with the effective use of reading for learning, the underlying features of which concern encouraging reflective reading by using active reading exercises on texts which the teacher wishes the student to use. This requires the selection of suitable passages and adapting them into particular types of exercise which the students complete in one way or another, depending on the exercise.

4.2 Description of elements

The following sections introduce the types of exercise that may be relevant to this study, in order to illustrate the scope of the research instruments. A more extensive discussion of what the exercises claim to offer as well as previous work on how they can be analyzed and interpreted will be given in the chapters in which the exercise are fully reported (Chapters 5 - 7).

4.2.1 Cloze Tests

Of the numerous exercises available of the "active reading" type, the most useful from the point of view of measuring reading ability is the "cloze test". In a cloze test words are deleted from a passage, either on a regular basis, eg. every seventh word, or, key words are deleted which are selected by the test-giver.

Cloze tests are widely used in the teaching of reading at the primary level and teaching EFL and there is a significant body of research covering the validity and reliability of this method of testing, to the extent that cloze tests are now used as **standard tests of reading**, superseding other methods in certain cases. If at least two cloze tests are given, at the beginning and end of the investigation, it should be possible to firstly, establish a baseline for students' reading ability and secondly, to assess students' progress. There are some additional practical reasons why cloze-type tests should be investigated in as far as they could be **useful to teachers of physics**:

- Broadly speaking, any passage can be used for cloze testing.
- The test is easily made up (i.e. words deleted), and marked.

- Suitable cloze passages can be used with non-science groups or other science groups, for comparative purposes.
- If passages are selected which do not depend excessively on specific subject knowledge then there will be less discrimination between physics students from a content point of view, which possibly makes the exercise a better **test of reading**

Cloze tests are highly suitable for statistical analyses; a large number of "questions" (i.e. blanks for students to insert responses) can be generated from a relatively short passage. For example a single side of A 4 paper which can easily accommodate 500 words of text will provide approximately 70 "questions" (student responses) using a deletion rate of 1:6, every seventh word deleted. Methods of item analysis can be applied to the results.

Furthermore, it is possible to classify the causes of any errors in order to predict what kind of problems the students are facing with each part of the text; this will have very useful consequences for a study such as this.

Theory (Rye, 1982 #16) suggests that different kinds of information can be elicited from students' responses if, instead of regular deletions, specific words are deleted. Both these methods are fairly easily adapted for class use.

Delving further into the realm of "standard reading tests", many american tests of this type now include multiple choice cloze exercises using specific passages which have been extensively tested. This is obviously an interesting line of study but it is difficult to see how the use of a standard passage, which deliberately avoids being subject bound, could fit into the remit of this study. Multiple choice cloze in itself is an interesting idea but much more difficult to prepare than standard cloze and thus not so realistic for a classroom teacher.

4.2.2 "Traditional" comprehension tests

The most widely used comprehension test is an exercise which asks the student to "read the passage and answer the questions". Comprehension passages are also used as measures of reading competence and some of them have been "standardized" in the way that cloze exercises have been. However, as far as subject based exercises are concerned careful selection of the text and design of the questions makes it possible to test specific aspects of students' understanding and use of language. It is also possible to grade questions in terms of difficulty or cognitive level which helps testers discriminate between students. So, in terms of formative assessment, comprehension testing of this kind has obvious advantages. As these tests are so common at least one exercise of this type must be included in this study not only to assess the intrinsic strengths/weaknesses of this kind of exercise but also in order to gauge how students' perform, relative to the other tests.

The important point for this study to address is how to distinguish various types of question/answer in order to reveal exactly which skills are being tested and thereby investigate the relationship between the "language" and "understanding" elements as suggested in the research goals and questions in the previous chapter.

There is a certain amount of variety as to where questions are given and this has been the subject of research in the past (Johnston, 1984 #37). In general it has been found that questions located at the beginning (particularly at the start of a chapter in a book) tend to restrict rather than encourage understanding of the text. The reason for this seems to be that the reader is focussing exclusively on the questions asked when reading so that the context of the passage and other points which were not asked about, are missed by the pupil. However, differences between questions incorporated *in the passage* and questions set at the end of the passage are not so clear and may be worth investigating.

There is also a case, particularly in physics, to investigate how questions which are posed in (albeit subtly) different ways are answered. This could mean questions which approach the same point from different angles, or, a question which, say, asks for written explanations of a concept which another question asks about by way of a calculation. This is actually quite important to teachers of physics as there is often an assumption that once a student is able to perform a certain type of calculation, use a formula, provide the correct units and whatever else is deemed to be involved, the student is judged to "understand" that particular concept. This assumption is dubious, to say the least, but the weakness lies in the apparent absence of alternative ways of judging understanding that are perceived as "valid" by physics teachers.

4.2.3 Interpretive tests

Many kinds of interpretive exercises are possible and are recommended by proponents of active reading in order to involve students in the text they are reading. For example, students could be asked to explain particular diagrams in words (or vice versa); identify which sections cover certain ideas, or explain the meaning of particular passages. Which particular variety is used depends on the students, the nature of the passage and the specific purpose of the exercise. Although, intuitively, all the activities suggested seem to be useful and interesting, one suspects that this approach is rarely used with A level students and hardly ever in science subjects, even though diagrams tend to be extensively used in science.

The question of whether interpretative-type exercises have a role to play in teaching A level physics can only begin to be answered by looking at how students respond to them. More interesting, from the point of view of this study, is to ask what the particular strengths of these tests are from students' and teachers' perspective, and how the results relate to other indices of student ability.

4.2.4 Reading aloud (miscue analysis)

Reading aloud to a teacher is commonly used with early readers in primary schools as a way of encouraging readers by giving them individual time with the teacher. It can also be adapted to **assess** reading ability. In this case, the teacher notes the number of stumbles, hesitations, mispronunciations or missed words (miscues) which a child makes in a (carefully selected) passage. There is a good deal of argument in the literature concerning the accuracy of this method of assessing reading and especially how the results of miscue analysis relate to other forms of reading test. Unfortunately, there is little published about the applicability of miscue analysis to older children who do not have particular learning difficulties.

How relevant an exercise involving miscue analysis is to the hard-pressed subject teacher, given that even ten minutes with each student and considerably more time to assess students' responses afterwards can be difficult to organize, is a fair question. However, having individual contact with a student gives the tester an opportunity to measure parameters, such as time taken to read the passage; to ask the student questions about the passage and find out the student's first language, etc. So, as far as this study is concerned there are obvious attractions to investigating miscue analysis and it is possible that the method does have definite strengths which could be applicable to at least some students or learning situations.

Thus, it was decided to investigate a variety of kinds of exercise, for the purpose of comprehensively covering a range of language tasks, skills and contexts that could be relevant at this level and to ultimately relate the results of the exercises back to the research questions.

Further details and relevant theoretical issues will be discussed individually for each exercise contained in chapters 5 to 7 since these are important influences on the analysis of results.

4.3 Choosing the passages

Four main criteria are applied to the choice of the passages on which the exercises are based.

(a) **Content**; the topics on which the exercises are based are directed by the teachers involved with the study (see sections 4.4 & 4.5). The reasons for this are that the work should fit in as far as possible with natural progression of what the teacher is doing in class and also to make it as relevant as possible from the teacher's point of view in order that the exercise is likely to be used with the students and not be put off to an indeterminate future date. Having said that the content was determined by the teachers it was agreed that some of the topics chosen should fall into the category of "extension material" or "background reading", that is, not strictly on the syllabus but closely enough related so that students could perceive their relevance. The reason for this was partly to broaden the horizons and, hopefully, interest of the student and also to allow a greater variety of styles to be included (see d)

The other important constraint on choice of topic was that two of the exercises (first and last) were to be used with non-science students, so, in these two cases careful attention was paid to choosing passages which were accessible to a broad range of readers, although the content was quite clearly "scientific", which was felt to be unavoidable to be true to the aims of the research. The non-science[1] students were members of the first year english literature A level group from two of the schools. The purpose of including these students was to compare their results with the results of the physics students to identify similarities and differences in language use (see Research Question 5).

(b) **Language level**; it is important in a study such as this to keep track of the level of difficulty of the language of the text that make up the exercises. It should be stressed that the area of assessing reading difficulty, for example using readability formulae, is not without controversy as has been hinted at in previous chapters. To try to keep things in perspective it is helpful to remember that **readability formulae** claim only to be guides to text difficulty. They are designed to predict text difficulty from variables such as sentence length and syllable count (depending on which test is used) and these variables have been found to be very significant contributors to how difficult a text is perceived to be. In fact, cloze tests, as outlined above have been found to be very useful measures (as opposed to predictors) of text difficulty and it would be interesting to compare findings from both readability formulae and cloze tests where possible.

The need for objective indicators, such as readability formulae, is apparent from research which shows that individual teachers assessment of text difficulty is remarkably flawed (Harrison, 1982 #35); whereas pooled teacher assessment correlate more closely with results predicted from formulae and other methods such as standardized reading tests and cloze procedures. In the absence of a sufficiently large group of teachers with whom to assess the text (numbers greater than ten are suggested), readability formulae remain the viable alternative.

Several formulae are suitable for use with upper secondary texts and the following were selected in order to compare and gauge difficulty: Fry, Flesh and SMOG. A breakdown of readability test results will be given with the results of each analysis of an exercise.

---

[1]One of the students in this group was not a non-scientist since he also studied A level chemistry.

A novel way of classifying texts has been described by Davies and Greene in Reading for Learning in the Sciences (Davies, 1984 #14). They suggest that passages of science text can be distinguished into seven types or "frames". Each frame has certain characteristics or "slots" which a text of that type should correspond to. When examining a passage one tries to decide which of the seven "frames" the passage most closely fits. Then by looking closely at each sentence of the passage one assesses how much it conforms to the definition ascribed and how much is "residue" (i.e. does not fit in with the specifications). If there is an excessive residue or many of the "slots" have not been filled, it might mean that the wrong label was given to the passage. But it appears that passages which do contain a lot of residue yet where "slots" are not adequately filled, are more difficult to understand.

(c) **Interest**; when considering text to be selected for individual exercises, it is obviously important to look for material that is clearly written and takes an interesting approach in dealing with the subject matter. Part of what is intended in this study is to present reading as an interesting activity and it is therefore an obligation to provide the best material that is available for the prescribed topic and level.

One restriction on the scope of material and to some extent the type of exercise that could be offered was the relatively small range of books and periodicals available in Kenya (see 4.6). For the purpose of constructing the exercises, texts could be imported from the UK, but it would be difficult to organize a "library search" or similar type of activity for students which assumes a broad range of suitable material.

How interesting a passage is judged to be is obviously a matter of opinion, but since published material is being used, choice is restricted by and in a way, reflective of, the standard of material on offer. As textbooks vary in how different subjects are handled and as other publications are also considered, there is reason to believe that for each topic area material which students will find interesting can be identified

(d) **Style**; there is a certain amount of variation in style between textbooks, and, indeed, with different sections of the same text, particularly when several authors are involved, and this should be reflected as far as possible in the choice of passages. There is however, a great difference between textbook styles and that of science magazines and science features in newspapers and news magazines and a taste of this kind of variety should be incorporated to enrich the reading experience.

More specific details of the passages chosen with respect to all the criteria mentioned above together with others as appropriate will be given in the chapter where each exercise is reported and analyzed in depth.

4.4 Introduction to the method of enquiry

It was intended that the elements of the research instruments would be administered to a group of students over the course of an academic year, which for practical reasons would be the first year of the A level course. As many of the exercises lend themselves to statistical analysis, as large a group of student "subjects" as was feasible to administer was hoped for. Since class sizes tend to be small and (for reasons given later) not as stable as one would wish, four schools were approached with the request to participate. In the event, all these schools agreed to be involved and a maximum of approximately forty physics students took part in the investigation.

Since one of the research questions concerns the comparative response of non-science students the english literature A level teachers in each school were also approached. It transpired that with the exception of one school, class sizes in this subject were very small, with a greater tendency to fluctuate than the physics classes, so the sample size of non-science students was much smaller than the physics group (>30), but still large enough to warrant statistical analysis.

4.5 Structure of the enquiry

The table which follows gives the sequence of events which will constitute the enquiry related to the factors which are pre-cursors to each stage with the relevant reference to where these factors are discussed ("input" column) and the tangible products of each stage of the enquiry ("output" column)

Table 4.1 How the Enquiry will be structured

STRUCTURE OF ENQUIRY

INPUT		Sequence		OUTPUT
Considerations governing preparation of instrument Ch 2,3,4 &Ch 5-12	→	PREPARATION OF INSTRUMENT	→	Exercises (found in appendices) discussed in Ch 5-12
Possible target groups determined by nature of goals and research questions	→	ADMINISTRATION	→	Details of schools, students, teachers Ch 4
Exercises marked and results tabulated	→	DATA COLLECTION	→	Data spread-sheets given for each exercise individually Chapters 5-12. This includes breakdown of items and classification of items
Collated results from exercises & other marks e.g. classwork, homework, exam results	→	DATA ANALYSIS	→	Qualitative and quantitative analyses of data, presented in terms of how far research questions answered
Reference made to goals & key questions (Ch3) in light of analyses and theoretical consideration regarding instrument	→	CONCLUSIONS	→	Consideration of the analyses in terms of how far they answer the research questions critique of method; further suggestions

4.6 The schools involved

Four private secondary schools located in Nairobi, Kenya, agreed to be involved in this study, and are referred to as Schools W, X,Y & Z. All schools in Kenya are fee-paying, but vary considerably in the amount of fees charged. Schools W, X,Y & Z are known as "high cost" in local terms and model themselves more or less on british public schools. The schools are all english-medium and although there are boarding facilities, most children are day-scholars. It is fair to say that the majority of the students have been educated at english-medium schools for all their school life, whatever their mother tongue.

In terms of facilities, the laboratories are adequately equipped and do not suffer from deficiencies which might be expected to affect students' performance. All the schools have impressive examination records, and, as in the private sector in the UK, examination success is an unquestioned priority for students and staff. The availability of books and magazines related to the subject is perhaps not what one would expect in the UK, although students are provided with a set text[2], and a few other text books are generally kept for reference purposes, in the laboratory / classroom.

Three of the schools follow the Cambridge Overseas A level syllabus and one school the London Overseas A level syllabus for the physics course. Since the introduction of the core curriculum in A level physics, a large section of the content should be common to both courses.

A significant proportion of the students in this study were from expatriate families, and because of job relocation and so on there was a higher rate of student turnover than one might expect in A level classes in the UK which could affect the study to some extent. A maximum number of about forty physics students and thirty non-science students were involved in total.

It was assumed, for the purposes of this study, that the students were effectively a homogeneous sample in that the actual school the students attended did not contribute to how they performed. At least, no allowances were made for differences in schools in as far as marking or administering of the exercises was concerned. Any observations made as to any *de facto* differences that could be significant to this study will be discussed later, either in the individual exercise concerned or in the concluding chapters of the thesis.

4.7 Arrangements made with teachers

The goals of the study were initially discussed with the teachers who taught the A level physics classes in each school, and if interest was shown, a brief explanation of the research instruments was given and a selection of exercises which would fit in with his/her scheme of work was offered. It was made clear that the students' work would be marked and returned to the teacher as soon as possible. Teachers were asked about their proposed scheme of work for the year so that suitable exercises could be made up. Teachers were requested to provide a copy of their mark records at the end of each term and, eventually, the final A level grade that his/her students obtained. The feasibility of seeing students on

[2]Usually A level physics by Tom Duncan

an individual basis (for READING ALOUD) was discussed and all teachers agreed that this could take place during practical sessions when individual students might be excused.

Arrangements were made with english teachers in three of the schools which had reasonably sized A level literature classes, whose students, it was hoped, could participate in two of the exercises, the first and the last to be administered. Again, a description of the goals and methods of the study were given as well as an outline of what their students would be asked to do and how much class time would be required. The response from the teachers of english was also favourable, although, as will be seen later, only one school's english groups managed to complete both exercises.

4.8 Summary of the research method

Table 4.2 shows the exercises that were used in the order in which they are described in the thesis, the students involved in each exercise and the research questions each exercise addresses.

As described in section 4.6 schools are designated W, X,Y and Z. This was done because schools do not follow the same scheme of work, so not all the exercises were done by all schools. Furthermore, two exercises were also given to non-science students and this is shown in the table.

Question numbers in the right hand column of Table 4.2 refer to Key Guiding Questions (see 3.7). It is clear that some of the Research Questions such as Q1 which covers "facets of reading skills" are addressed by all the exercises whereas others such as Q5, differentiation between science and non-science students, are addressed by only two exercises.

Table 4.2 could be a useful reference for assessing how successfully different exercises provide evidence which contribute to the investigation of each of the Key Guiding Questions.

Table 4.2 Summary of the Research Method

Exercise	*Students*	*Aspects investigated*	*Research Questions addressed*
ERRORS cloze with regular deletions	W,X.Y,Z science and W,X non-science	Measuring reading ability Comparing items Comparing science/non-science	Q1, Q2 Q3 Q4 Q5
TIME cloze exercise regular deletions	W,X,Y,Z science non-science X,Y	Measuring reading Measuring understanding Comparing items Comparing with non-science Comparing other results	Q1 Q2 Q3 Q5
PROJECTILES cloze with selected deletions	W,X,Y,Z science	Measuring understanding Comparing items	Q1 Q3 Q4
READING ALOUD miscue analysis	W,X.Y,Z science only	Measuring reading Measuring understanding Comparing items Comparing with other results	Q1 Q2 Q4
FORCES interpretation of text using diagrams & description	W,X,Y,Z science only	Measuring understanding Comparing items	Q1 Q3 Q4
INTERNAL RESISTANCE answering questions about the text	W,X,Z science only	Comparing items	Q1 Q3 Q4
DAMPED OSCILLATIONS questions on & interpretation of text	W,X,Y,Z science only	Measuring reading Measuring understanding	Q1 Q3 Q4
HEAT RADIATION text completion diagram completion questions on text	School Y science only	Measuring understanding comparing items	Q1 Q3 Q4

4.9 Summary of chapter

This chapter introduced the elements of the research instrument and described the proposed method of enquiry by looking at the:

- characteristics of active reading exercises in particular relation to how they could be relevant to teachers of physics
- criteria used in selecting passages to form the basis of the exercises
- structure of the enquiry with reference to the research questions
- pupils involved
- location and circumstances in which the investigation was carried out
- actual arrangements made with teachers.

CHAPTER 5: THE CLOZE TESTS

5.1 Reasons for using cloze

Cloze tests require the testee to fill in a word which has been deleted from a passage of prose. Cloze exercises are widely used by reading teachers to test the reading ability of primary school children and also to assess the level of difficulty of texts, either supplementing, or replacing, readability measures (see Chapter 2). Standardized cloze passages are also used as achievement tests for EFL students. There have been suggestions (Lunzer, 1979 #17) that giving pupils cloze passages of science texts could encourage active reading in science, since the process of filling in a cloze gap requires the text to be closely interrogated. By setting cloze exercises as part of this study, it is hoped that the process of how science text is interrogated by pupils can be scrutinized. The aim of the analyses will be to address the research questions as follows:

Question 1 Distinguishing facets of reading skills

What are the strategies needed to find missing words and can these be linked to facets of pupils' reading skills? Are there certain words in a passage which are especially useful in assessing pupils' strengths / weaknesses in particular areas?

Question 2 Measuring reading skills

Is it possible to use cloze exercises to measure pupils reading skills objectively; and could this could be useful to a physics teacher?

Question 3 Choosing texts and tests

Regarding readability of texts, how do results of cloze tests compare with other forms of readability assessment? Would it be useful to know who needed extra help to cope with certain texts and what that help could be?

Question 4 Physics achievement

What do the results of cloze tests on passages of physics text tell us about a pupil's understanding of physics? How do the results compare with conventional tests of physics knowledge and understanding?

Question 5 Comparison with non-physics students

Assuming cloze passages can be selected which are suitable for both science and non-science students can assumptions about the differences between these students be tested convincingly and do the results have any implications for physics teachers?

5.2 Cloze variables

The first factor to consider when setting a cloze test is deciding the passage to be used. The choice will depend on who the targeted testees are and the purpose of giving the test. The passage selected should have an appropriate readability which can be assessed initially using standard reading index methods, and content which is relevant to the groups taking the test.

Deciding the frequency of the gaps is obviously a key problem. Research indicates that intervals of greater than ten words do not increase comprehension; and that greatest difficulty is found when every second or third word is deleted (Rye, 1982 #16). Within these constraints, when a regular deletion method is used a deletion rate of every seventh word[1] is often chosen.

Cloze can also be used to assess aspects of a text that students find difficult.

Rye's system is to classify each wrong / inappropriate answer into four types of error:

type 1 : synonyms of words which do not significantly alter meaning

type 2 : syntactically appropriate but semantically inappropriate, same grammatical class as original

type 3 semantically acceptable, syntactically unacceptable; inappropriate in terms of tense, person, case & number or different word class.

type 4 unacceptable semantically and syntactically.

Thus, for any cloze test there would be effectively 5 scores per child, the total percentage correct as well as a percentage score for each of the error types 1-4. The error types are listed in terms of "seriousness" so children's reading ability can be compared in each of the categories. Rye argues that this system is particularly useful when comparing students with similar test scores. If student A has a relatively high number of type 1 errors whereas student B has a low number of type 1, but a higher proportion of type 4 errors, student B would be judged to be the poorer reader.

---

[1]This seems to be the preferred interval for cloze tests conducted with ESL students; another area where cloze tests are widely used. (Brown, 1989 #39)

This method can also throw light on a student's particular reading tactics, for example a competent reader who scores poorly overall, may be making mostly type 1 errors, which are not so "serious", but nevertheless can be improved with specific remedial exercises.

If the deletions are not regular, then the criteria by which words are selected for deletion must be established. Specific omissions of key words in a text are used for tests involving testing of knowledge or understanding of the content of a passage.

One further point is that the size of the gap should preferably be consistent in order that no further clues are given to the reader. This is difficult to avoid when passages are photocopied from textbooks and words 'whited out', but this may affect how the results are interpreted.

5.3 An overview of the 3 cloze exercises in this study

The first and second exercise discussed in this chapter (ERRORS and TIME) were also the first and last test given to pupils in the investigation. They have the format of the 'reading test' with regularly spaced omissions. These two tests were also given to english literature A level students (most of whom did not study a science subject at A level) as well as the physics students. The purpose of doing this was to look specifically at reading skills and to see how far examining the cloze exercises could answer the research questions, particularly research questions 2 and 5 (see section 5.1 and 3.7). The second[2] cloze exercise PROJECTILES had selected omissions, in order to look more specifically at the subject content of the passage with the aim of addressing research questions 1 and 5. PROJECTILES was given to the physics pupils only.

This chapter contains a section relating to each of the cloze exercises which describes:

- type of cloze, purpose, choice of passage, testees
- comments on the results grids, analysis of the task, breakdown of results, reliability
- analysis of *prima facie* results
- discussion of detectable patterns with reference to the research questions

Finally, there is a summary of the findings of the cloze tests together with a discussion of their implications and how they relate to what is known of pupils' performance in other tests and their final A level grade.

---

[2] The second test to be administered to the pupils, although the third cloze to be described in this chapter.

5.4 ERRORS (Systematic and Random Uncertainties)

This exercise (found in **Appendix 1**) takes the form of a cloze-type test with every seventh word deleted, which as mentioned above is a commonly used frequency. Exceptions were made when it was considered that the absence of the seventh word would be confusing, impossible to guess at or unnecessarily difficult. For example in the first paragraph, the item "-0.2A" should strictly speaking be omitted, however in this case the word following was deleted for the sake of simplicity. The passage was selected from an A level text book with the following criteria in mind:

- suitable in style and content for students starting an A level physics course
- of general interest to non-physics students who had in the recent past studied science.

Although the passage contains technical language, the context should be recognisable to students who had previously taken secondary school science, i.e. the problem of errors occurring in scientific observations. It was felt that very little previous knowledge was required to satisfactorily comprehend this passage although knowing that "ammeters" are connected in "series", and about the "period of oscillation of a pendulum" would clearly help. It is true that one of the reasons for selecting this passage was that physics teachers would be instructing their students on various practical techniques at this early stage in the course, although it is unlikely that any quantitative evaluation of error would be made and in any case this was unnecessary for understanding the passage which avoids the use of mathematical / statistical terminology.

The reasons for this selection procedure were that it was intended that the work should appear relevant to the participating physics students, but also be accessible to non-science students of similar age and ability, so that a comparative study of reading and comprehension could be made as well as establishing a base-line for the abilities of the physics students.

5.4.1 Readability

The intact passage was examined for readability by collecting the following data and applying three readability tests. Fry, Flesch and McLaughlin's SMOG[3]

Average sentence length/ 100 words	= 4.98
Average number of syllables/ 100 words	= 164
Average number of words per sentence	= 20.1
Number of words of 3 or more syll./ 30 sentences	= 93

---

[3] For details of these readability tests see Readability in the Classroom (Harrison, 1982 #35)

Results:

FRY READABILITY GRAPH:	GRADE 12 or 17 YEARS
FLESCH FORMULA :	48% (40% difficult 55% fairly difficult)
McLAUGHLIN'S SMOG:	17.5 YEARS

These scores indicate that the passage should prove challenging reading for first year A level students. However, the frequent repetition of the key words "systematic", "accuracy" and "uncertainties" each with 4 syllables, increases the overall syllable count without necessarily increasing the complexity of the text.[4] Since two of the methods above involve syllable count, this might give rise to an unjustifiably high readability score. Despite these relatively high scores, the passage was by far the most informative and interesting on this particular topic of any of the text books that were available at the time, and suitable too in terms of length; filling approx 1 side of A4 paper using a 12 point font.

5.4.2 The students and the test conditions

This exercise was given to the four participating physics (phy) groups in schools W, X, Y & Z and two groups of first year english literature (eng) A level students in schools W and X. The students were told that each "gap" in the text corresponded to a single missing word and they were asked to write in what they thought this word might be. As far as possible, the size of each gap was uniform, so that the area of empty space gave no clue about the word required. There was nothing else to indicate where a word should be added.

Some of the groups did the exercise in class and it was reported that 20 minutes were needed for most students to complete the work. The physics groups at schools X and Y were given the exercise to do at home.

5.4.3 The results grid

Students' responses were entered on a results grid. There were 77 responses in all, and answers were marked thus:

1 for a correct response; - for an omitted item; 0 for an inappropriate response.

Grids for each of the groups involved can be found in **Appendix 2**. The total number of correct responses per item are listed in the far right column, and the total per student in the bottom row labelled "Total". In some cases close synonyms of the correct answer were listed separately in the student's total. However, this proved cumbersome when handling the data and the total of correct and close synonyms were combined.

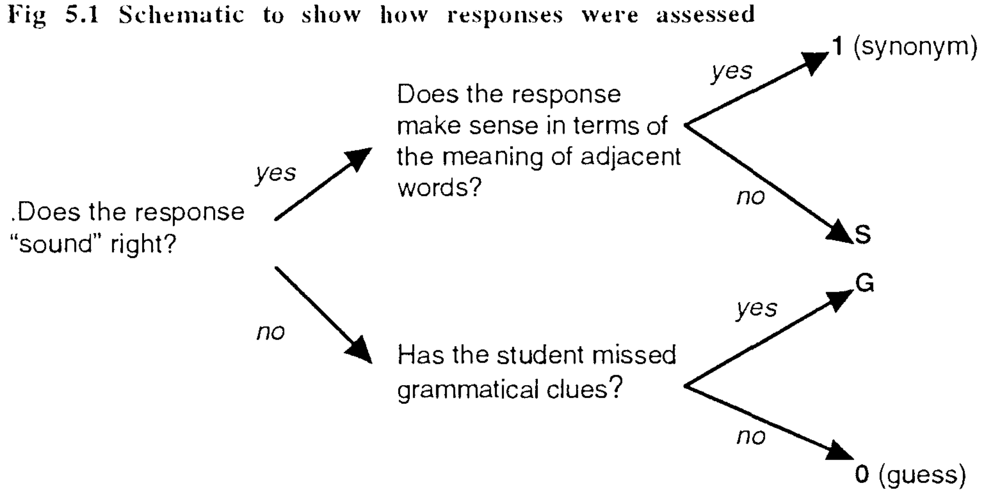
---

[4] Although this is not accepted by Harrison (Harrison 1982)

5.4.4 Criteria used in marking the results grid

The literature regarding cloze is often written from the point of view of a teacher of english, who is quite rightly concerned with the literary appropriateness of words in terms of mood and style. A teacher of english may justify rejecting a response, which although correct semantically and syntactically, does not match exactly the word used by the author of the piece (a type 1 error). However, whether this is appropriate in a science text is not so obvious, as it seems unlikely that the students involved will recognise these subtleties as a priority when selecting a word to fill a gap. A pertinent example might be this: when talking about non-accelerating motion in a physics class, the words uniform, steady, constant and regular are used interchangeably and a teacher will possibly have encouraged students to recognise that these words mean the same thing in this context. It would therefore seem absurd to say that a student who chooses the adjective "constant" to qualify "velocity" in a cloze test should be penalised just because the author happened to write "uniform". For the reasons given above synonyms are not listed separately as an error. An attempt was made to sort the errors into errors of meaning (S) or grammar (G). The following schematic (Fig 5.1) shows how students responses were assessed:

Fig 5.1 Schematic to show how responses were assessed



Some of the grids show errors categorised in this way, but the system was abandoned and most grids show 1 for the correct response or a suitable synonym, 0 for a wrong answer and - for a blank. The question of exactly what each response requires from a pupil and the strengths or weaknesses which can be shown by each correct or incorrect response is approached by examining each item in detail.

5.4.5 Discussion of items

Each cloze item is discussed in terms of a number of features which give clues about the correct response. These are:

1) The **facility** and **discrimination** of each item. Facility means the proportion of pupils who answer the item correctly, i.e. number of correct responses/total number of pupils. Discrimination indicates whether or not the item was answered correctly by pupils who obtained a high score overall (high discrimination). Low discrimination suggests that the answer may be guessed. The method used for finding the discrimination of the cloze analysis was the point biserial correlation coefficient (Crocker, 1986 #9) which shows how closely performance on an item scored 0 or 1 relates to total test score. A comment on the *predicted* facility or discrimination is made and the actual values are listed as "FacPhy", "DisPhy" facility and discrimination for the physics groups and "FacEng", "DisEng" representing the facility and discrimination of the english group.

2) Each item is categorized as either **lexical (L)** or **grammatical (G)** according to the definition given by Halliday and Martin (see Chapter 2) which is based on whether it is a content or structural word.

3) How the correct response ~~are~~ is thought to be found or the kinds of strategies or information a pupil might use to find the correct response. These are designated:

grammar where the linguistic structure of the sentence suggests the class of word

physics where familiarity with the subject matter is implied or necessary

reading where the word required repeats, elaborates or follows logically from information supplied by the passage or is consistent with the content of the passage.

Table 5.1 shows each cloze item in the order it appears in the passage, and where the same word is deleted more than once, each occasion is given a numerical index, eg systematic1, systematic 2 etc.

Table 5.1 Discussion of ERRORS items

ITEM	Fac Phy	Dis Phy	Comment	Fac Eng	Dis Eng
SYSTEMATIC L	0.91	0.02	A predictably easy item for both groups as the gap occurs just beneath the identical word in the title. Low discrimination for the physics groups since nearly everyone got it right. Significantly better discriminator though only marginally less easy for the english group where some students may not have noticed the words of the title Reading	0.87	0.49
RESULT L	0.34	0.38	Similar difficulty for both groups but slightly more discriminating for the physics group. "Occur" or "be" were substituted which makes sense of the first phrase but clashes with the "being" of the second phrase. Grammar	0.33	0.15
FAULTY L	0.40	0.29	The author's choice is an odd word to use and synonyms in the context of the passage such as skewed/biased/shifted were accepted, even so the facility is rather low. The reader needs to be aware of how a systematic uncertainty will affect the reading. physics	0.2	0.06
WHICH G	0.89	0.56	A fairly easy item which can be predicted from the grammar, a better discriminator of the english group. Grammar	0.8	0.85
ALL1 G	0.83	0.32	This word qualifies "time readings", grammatically the alternatives are none or some but logically, given that the clock is running fast, only "all" is suitable. Reading	0.6	0.52
AN G	0.91	0.41	Easily predicted from the grammar, and both groups largely found the correct answer . A significantly better discriminator of the english group. Grammar	0.93	0.7
WILL1 G	0.91	0.46	Alternatives are conditional "may", "can" etc. Follows the logic and grammar of the previous sentence. Better discrimination for the english group. Reading/Grammar	0.67	0.73
TOO G	0.77	0.38	Follows the sense of the sentence but could be perceived as technical by english group. Results for english group suggest correct responses here are linked with previous missing word. Reading/physics	0.67	0.71
SYSTEMATIC2 L	0.51	0.36	Seems dependent on the word calibration; possibly guessable from the context of the paragraph but too daunting for the english group. Moderately difficult for the physics group but much harder for the english group with low discrimination in both cases. physics	0.2	0.44
FOND L	0.29	0.36	May be difficult for a student to write "fond" in a passage like this and problematic to find an alternative which satisfies the constraint of "of assuming" which follows. Colloquial english	0.07	0.19

MUST G	0.66	0.45	Sense of sentence suggests "must" rather than alternatives "may / could" although these are justified grammatically. Reading	0.87	0.49
S0 L	0.86	0.45	Completing the phrase relies on recognising the expression more than the particular meaning. Fairly easy but a particularly good discriminator of the english group. Grammar / Colloquial english	0.8	0.85
INT01 G	0.40	0.44	This appears to be a simple item to predict on the basis of the grammar but it had a low success rate for both groups, as the favoured alternative "in" was not accepted. Grammar	0.4	0.17
THE1 G	0.94	0.60	Definite article is called for by the subsequent phrase, so "an" cannot be accepted. High facility for both groups but a negative discrimination with the english group. Grammar	0.8	-0.12
READING1 L	0.94	0.23	Fairly easy to predict from the sense of the sentence and synonyms such as taking / seeing / viewing were accepted. Ease of guessing may account for low discrimination among physics group. Reading	0.8	0.85
AS G	0.97	0.59	Easy to predict from the grammar. Surprisingly high discrimination for the physics group. Grammar	1	-
IS1 G	1.00	indeterminate	Highly predictable item on the basis of the sentence structure. Grammar	0.93	0.03
AFFECT L	0.74	0.43	Connects "parallax error" with "his readings" which seems guessable from the context. This seems true for the physics students but the poor facility and discrimination for the english group suggests that the connection is not obvious. Reading/ physics?	0.33	0.28
SAME1 L	0.83	0.52	Finding this key word relies very much on having understood the passage so far or realising through previous knowledge the effect of parallax error on readings. The very low facility and discrimination found for the english group suggests that they are not in general reading the passage for meaning beyond the immediate context of the cloze omission. Reading /physics	0.27	0
ESTIMATE L	0.20	-0.01	Difficult to guess exactly as there are no context clues, "detect" was a popular substitution, but this was not accepted since the subsequent part of the sentence says that it can be revealed. However this reasoning can be sustained if "difficult" is substituted in the next space although the description which follows in the next sentence indicates a simple enough procedure. Don't know	0.27	-0.06
SIMPLE G	0.46	0.23	This adjective contradicts the "difficult" in the first phrase, so there may be a tendency to endorse that view by substituting "complex" etc . Interestingly, this was easier and more discriminating for the english group who may not be so aware of possible contradictions. Reading	0.67	0.5

PLACED L	0.77	0.28	A suitable verb is fairly easy to guess. Unexpectedly high discrimination for the english group. Grammar /physics	0.73	0.62
FLOWING L	0.97	0.59	Highly predictable from the grammar and context. Highly discriminating for both groups. Grammar / physics	0.93	0.7
NOT1 G	0.89	0.55	Guessable from the grammar. Grammar	0.73	0.45
A1 G	0.97	0.59	Very predictable from the grammar Grammar	0.93	0.7
USE L	0.86	0.40	Predicted from the grammar and context. High discrimination for english group Grammar/physics	0.73	0.85
NOT2 G	0.89	0.13	Very predictable from grammar. Seems guessable by physics group but very discriminatory for english group Grammar	0.8	0.85
REDUCING L	0.69	0.26	Follows from the message of the paragraph, but the first word of a sentence and might be more difficult to predict accurately. Low discrimination for both groups Reading	0.53	0.45
USING G	0.74	0.58	Obvious from the sentence structure. Both groups found it easy, but there was good discrimination. Grammar	0.73	0.85
THE2 G	0.94	0.40	Seems very easy, "some" was accepted too. Much higher discrimination for the english group. Grammar	0.8	0.7
NEVER G	0.43	0.27	To distinguish this from the alternatives "sometimes" or "always" the sense of the rest of the sentence has to be understood. By inserting "without" at the next cloze gap it is possible to sustain the correct meaning. Reading/physics	0.07	0.12
WITH G	0.37	0.06	This or "without" can be predicted from the grammar. Grammar	0.33	0.17
UNCERTAINTIES1 L	0.89	-0.17	Should be obvious from the structure of the passage. High discrimination with the english group, negative discrimination for the physics group. Reading	0.53	0.65
THE3 G	0.91	0.65	Easily guessable from the grammar. Unexpectedly high discrimination for both groups Grammar	0.87	0.61
PRECISELY L	0.43	0.48	Fairly easy to predict correct word or close synonym from the meaning of the sentence. Surprisingly low discrimination from english group Reading	0.4	0.21

A2 G	0.97	-0.09	Guessable from the grammar. Surprisingly high discrimination with english group & negative discrimination with physics group. Grammar	0.87	0.8
MIGHT1 G	0.91	0.30	Simple grammatical considerations suggest "will" but someone with experience of the situation will recognise that "might" is more appropriate. Grammar/ physics	0.73	0.58
SEVERAL G	0.91	-0.07	Guessable from the grammar Grammar	0.33	0.24
EACH G	0.17	0.11	Guessable from the grammar. Surprising low facility for both groups even though "every" was acceptable. Grammar	0.93	0.7
MIGHT2 G	0.91	0.56	Predictable from the meaning of the sentence Reading	0.93	0.7
THE4 G	0.94	0.69	Easily guessed Grammar	0.93	0.7
THE5 G	0.94	0.69	Easily guessed Grammar	0.87	0.72
BE G	0.91	0.51	Easily guessed Grammar	0.8	0.49
PERIOD L	0.80	0.71	This would appear to be dependent of previous knowledge. Hence is surprising to note that both groups did equally well physics	0.67	0.21
THERE G	0.86	0.67	Fairly easy to guess Grammar	0.67	0.21
ON G	0.69	0.27	Appears easily guessable but a surprising low facility for the english group. May seem too simple? Grammar	0.2	0.27
MAY G	0.91	0.62	Conditional may not be obvious to the non-physics pupil. In fact english group have a high facility for this item. Grammar	0.8	0.54
SAME2 L	0.74	0.65	Seems straightforward from the meaning of the sentence Reading	0.8	0.21
UNCERTAINTY2 L	0.49	0.42	Predicted from the content of the paragraph. Far less easy than expected even for the physics group Reading	0.33	0.55
TO1 G	0.89	0.73	Seems guessable, but in fact quite a high discrimination Grammar	0.8	0.85
POSSIBLE G	0.43	0.30	Implied from previous sentence, not all that obvious. Unexpectedly does not discriminate Reading	0.47	0.37
GREAT G	0.51	0.34	Predictable from the grammar. Grammar	0.6	0.51
WILL2 G	0.91	0.58	Guessable Grammar	0.8	0.63

ERROR L	0.91	0.58	Easy to predict Reading	0.73	0.7
READINGS1 L	0.74	0.61	Fairly easy from the sense of the passage Reading	0.8	0.7
PRECISE L	0.89	0.82	Easily predicted from the sense. Surprisingly high discrimination for both groups Reading	0.73	0.67
ONLY G	0.29	0.30	Seems easily predicted from the grammar, but both groups found it difficult Grammar	0.33	0.52
READINGS2 L	0.69	0.65	Very predictable from the meaning of the passage and maybe slightly easier for the physics group. In fact easier and more discriminating for the english group Reading	0.73	0.79
TAKEN L	0.29	0.20	This word should be easier for the physics students. Surprisingly difficult even for physics group physics	0.13	0.2
FIGURES L	0.69	0.61	Again, should favour the physics group. Much easier this time for physics group. english group have almost identical facility and discrimination as previous item physics	0.13	0.13
OF G	0.60	0.58	Easily predicted from grammar . Slightly lower facility than expected Grammar	0.6	0.42
QUITE G	0.69	0.52	Fairly easy to predict from the grammar Grammar	0.67	0.3
A3 G	0.80	0.72	Easily guessable from the grammar. Surprisingly high discrimination for physics group Grammar	0.87	0.55
MEASURING L	0.66	0.50	Needs some experience so could favour physics students physics	0.4	0.25
HOURS L	0.69	0.57	Fairly easy to predict from the meaning Reading	0.53	0.63
INTO2 G	0.51	0.50	Guessable from the grammar. Unexpectedly difficult for english group Grammar	0.33	0.1
BOWL L	0.63	0.65	Easy to guess from common sense meaning Reading/Grammar	0.47	0.58
STICK L	0.74	0.66	Easy to guess from grammar and meaning Reading/Grammar	0.47	0.71

OCCUR L	0.51	0.36	Dictated by grammar and could be fairly difficult to predict. Very good discrimination for the english group, suggesting that this grammatical clue more obvious to higher scoring students Grammar	0.53	0.79
A4 G	0.77	0.69	Seems very obvious from the grammar. Lower facility for english group suggests some pupils may be confused by the size of the gap. Grammar	0.53	0.54
THE6 G	0.77	0.66	Guessable from the grammar, but a high discrimination for the english group again Grammar	0.6	0.73
TO2 G	0.86	0.86	Guessable from the grammar. High discrimination for both groups Grammar	0.67	0.61
SOME G	0.20	0.23	Requires careful reading of the whole sentence so should be slightly harder but more discriminating. In fact it is difficult and not at all discriminating. for both groups Reading	0.27	0.22
LEVEL L	0.80	0.81	Experience of subject possibly helps here, should discriminate. physics	0.53	0.58
SAME3 G	0.69	0.68	Depends on understanding the sense of the sentence. Probably easier for physics students. Good discrimination for both groups. Reading	0.47	0.69
READINGS3 L	0.83	0.83	Should be obvious from the meaning of the sentence, although perhaps more obvious to physics group. High discrimination Reading	0.60	0.66
READING2 L	0.77	0.62	See above. High discrimination for both groups Reading	0.40	0.62

Of the 77 items 33 were judged to be "lexical" and 44 "grammatical".

When looking at the information needed to fill in each cloze gap, 11 words did not seem to fall neatly into one category and hence two categories are listed for these words, giving a total number of 88 possibilities which break down as follows: Grammar 42 / Reading 28 / physics 14 / Idiom 2 / Don't know 1

Interestingly, only seven words of the fourteen "physics" words in the above table rely **only** on a background physics knowledge, which seems to support the use of this passage for non-physics students.

In trying to select words which might be useful pointers to particular skills, it would be best to choose words which most clearly involve one process only and which discriminate well across both groups. This procedure will be discussed in 5.4.7.

5.4.6 Performance and test reliability

According to Rye (Rye, 1982 #16) the following guide can be used to assess the level of a student's reading.

Comprehension Level	*Frustration*	*Instructional*	*Independent*	
Percentage Cloze Scores	*0*	*40*	*60*	*100*

These scores are based on the principle of "author's word only" correct. Marking synonyms correct increases the average score which could make the use of the scale above questionable. The main problem with accepting synonyms as far as the published research is concerned is the introduction of subjective value judgements for individual items. This is a problem for large studies where several people are involved in marking, it is obviously easier to keep track of consistency in a smaller study such as this. Furthermore, there is evidence that the longer the cloze passage and the more deletions there are, the closer the results become between the two methods of marking. Also, the intermediate figures above are only approximations given that other studies have proposed "instructional ranges" varying from 44 - 57 to 41 - 61. Accepting this uncertainty as inevitable, it nevertheless seems reasonable at this stage to use 60% as an indicator of a student's ability to read a passage independently, unless there is evidence from subsequent findings in this study that this figure is not valid.

Table 5.2 Pupil scores: ERRORS

COMPREHENSION LEVEL	FRUSTRATION (0-40%)	INSTRUCTIONAL (41-60%)	INDEPENDENT (61-100%)
ENGLISH GROUP	9 (26%)	7 (21%)	18 (53%)
PHYSICS GROUP	3 (9%)	3 (9%)	29 (82%)

The majority of science students (29 / 35) score over 60 % i.e. they are reading the passage **at or above the notional independent level**. This is also true for just over half of the non-science students (18 / 34). This appears to justify the use of the particular passage and indicates the level of difficulty which can be used with the science students. Provided the results are valid[5] and reliable (See 5.4.6i), then these results could indicate to a teacher which students need assistance with reading passages of this standard, particularly when the relative numbers of grammatical errors are considered.

5.4.6i Reliability

Reliability statistics refer to the consistency or reproducibility of the data and reliability coefficients show the correlation between scores on two parallel tests (Crocker, 1986 #9

[5]valid: that the individual's or group's score on other related tests correlate well

page 115). In the case of Cronbach's alpha and similar reliability coefficients such as the KR21, individual items in a given test are treated as "parallel tests" and hence give an indication of the *internal consistency* of the test. Values of alpha approaching unity show the greatest degree of consistency .

Two estimates of the reliability (coefficient alpha and KR21) of the test based on the variance of the composite scores were calculated and values in excess of 0.90 (max 1; min 0) were found. This was true for the english and physics groups considered individually as well as the whole population. The KR21 coefficient which gives a lower estimate of reliability if item facility varies, was found to be 0.93 for the whole group.

Reliability coefficients tend to be be higher for objective tests than subjectively marked tests and cloze tests are fairly objective. However, it is normally expected that increasing the range of ability of testees will increase the true score variance and hence the reliability coefficient; this has not happened in this case.

A possible interpretation of these reliability statistics is that common factors are affecting item performance systematically, even across the heterogeneous group. The most obvious factors which could be involved are reading skills and knowledge of content. Making the assumption that content knowledge is not uniform across the whole population in that the physics students will be more familiar with the subject matter, performance on the test may be more dependent on the reading skills of the student, which is, of course, the usual reason for using cloze tests.

5.4.6ii Comparing total scores

The facility and discrimination of each item was compared for the physics group and english group using paired t tests. Items were sorted into the categories investigated i.e. lexical / grammatical and reading / grammatical / physics strategies. The **difference between the physics and english group was found for the facility and discrimination of each category.** Table 5.3 shows the differences in means in 10 categories investigated in the exercise as well as the facility and discrimination overall (i and ii). Results which are statistically significant with a probability of 0.05 or less are shown in bold type.

Table 5.3 ERRORS: physics (P) english (E) Groups 't' tests.

Category	Difference in means	Probability
i Facility Overall	**0.1136**	**<0.0000**
ii Discrimination Overall	-0.0507	<0.1520
iii Facility Lexical Items	**0.1636**	**<0.0000**
iv Facility Grammatical Items	**0.0755**	**<0.0007**
v Discrimination Lexical Items	-0.0264	<0.6344
vi Discrimination Grammatical items	-0.0544	<0.2545
vii Facility Reading Strategies	**0.2546**	**<0.0000**
viii Facility Grammatical Strategies	**0.1554**	**<0.0003**
ix Facility physics Strategies	**0.0157**	**<0.0040**
x Discrimination Reading Strategies	0.0432	<0.2617
xi Discrimination Grammatical Strategies	**0.3010**	**<0.0000**
xii Discrimination physics Strategies	0.0343	<0.6327

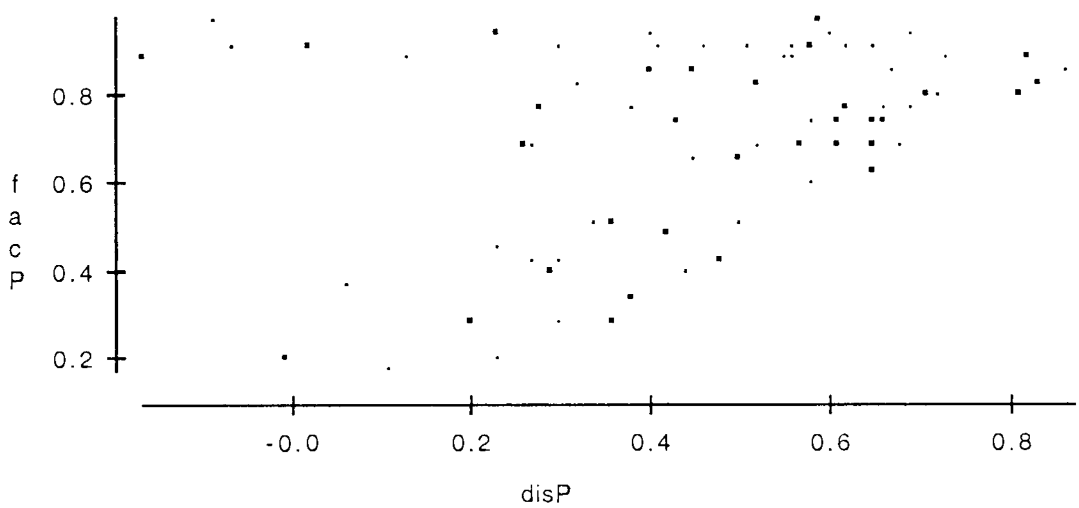
The purpose of performing these paired t tests was to see at a glance where the main differences were between the groups for the different categories of items, as well as the performance overall.

A subject-biased passage would favour students studying the subject, everything else being equal, so it is not surprising that the overall facility is greater for the physics pupils, but there are also significant differences between the scores of the english and physics group in the grammar, reading **and** physics categories suggesting that the difference in performance cannot be explained only by the presence of subject-specific words. It is noteworthy that the significant differences are mostly in *facility* , that is, the items are easier for the physics pupils but the discrimination is approximately the same for both groups. The exception to this as Table 5.3 shows is the discrimination of grammatical strategies (xi) is higher in the physics pupils. This may point to less successful guessing by the lower scoring pupils in the physics group suggesting perhaps that higher scoring physics students have better "grammatical strategies" than lower scoring physics students, a difference which is not so noticeable among the english students.

5.4.7 Patterns in the results

The facility and discrimination of each item were plotted on a scattergraph, Fig 5.2 and Fig 5.3 show the plot for the physics group and the english group respectively. In each figure the cases in bold show Lexical items. **Appendix 3** gives enlarged versions of these figures with each word plotted. For both groups most of the items are found in the top right quadrant which shows high facility and high discrimination, and very few items with medium facility and low discrimination which is consistent with the high reliability of the test. We know that facility in general is higher for the physics group but in Fig 5.2 the bottom right quadrant is empty indicating that difficult words did not discriminate this group. Compared to the english group, lexical items for the physics group tend to be shifted right and up, that is, lexical words tend to be easier and more discriminatory for the physics group.

Fig 5.2 ERRORS Facility / Discrimination - physics group (lexical items bold)



Looking at the four quadrants of the above plot (high discrimination[6] / high facility, high discrimination / low facility, low discrimination / high facility and low discrimination / low facility) in terms of the distribution of items classified as reading, physics and grammar (Table 5.4), we see that items classified as reading or grammar are mainly easy and these items tend to have high discrimination; whereas physics items tend to be easy and have low discrimination. Low discrimination can result from excessively high facility, in that, if most pupils get an item correct there can be little discrimination. This does not seem to be true here and the alternative explanation that there is a tendency for pupils to guess these items seems reasonable.

[6] "high" denotes >0.5; "low" <0.5

Table 5.4 Distribution of reading, physics & grammar items - physics group

	Discrimination Low (<0.5)	Discrimination High (>0.5)
High Facility (>0.5)	8 Reading 6 physics 13 Grammar	15 Reading 5 physics 23 Grammar
Low Facility (<0.5)	5 Reading 4 physics 6 Grammar	(Empty)

For the english group, Fig 5.3 shows there is an observable shift downwards as the overall facility decreases in comparison with the physics group and also a shift in the lexical items from top right to bottom left, showing that lexical items are not only more difficult for this group but more likely to be guessed.

Fig 5.3 Facility / Discrimination - english group (Lexical items bold)

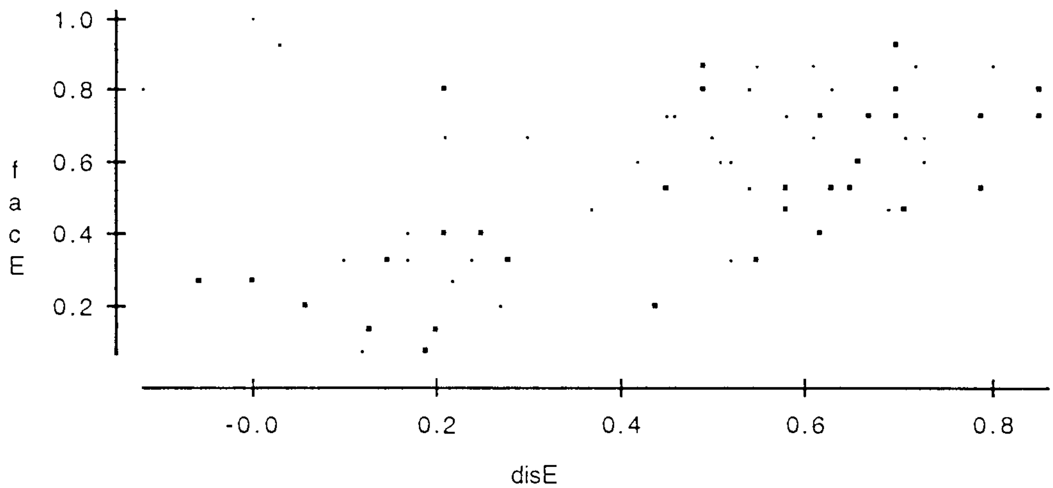


Table 5.5 shows the distribution of items classified as needing Reading, physics and Grammar strategies for the english group.

Table 5.5 Distribution of Reading, physics & Grammar items - english group

	Low Discrimination	High Discrimination
High Facility (>0.5)	3 Reading 2 physics 9 Grammar	14 Reading 6 physics 22 Grammar
Low Facility (<0.5)	6 Reading 7 physics 9 Grammar	5 Reading 3 Grammar

The top right and bottom left quadrants are virtually identical to the physics group. Apart from the transposition of reading items from the top left to bottom right quadrant, which indicates that reading items are more difficult and discriminatory for the english group.

5.5 TEST 8 TIME (How to go back in time)

5.5.1 Details of the exercise

This exercise was the last one to be administered. It took the form of a cloze test so that a comparison could be made with other cloze exercises particularly the first exercise, ERRORS. This exercise has approximately every seventh word removed, however, there were some occasions when the frequency was changed. In one case this was because the seventh word was split between one column and the next which could have looked as if two words had been erased.

The prose passage on which the exercise was based was a complete article from Time magazine of 20th May 1991, chosen because the subject was likely to appeal to young people as it was linked to aspects of cosmology which were fashionable at that time.

Unlike other passages, the article was photocopied and enlarged[7] to retain the magazine format and to double the area of the original article, i.e. 2 sides of A4 paper. This meant that the words deleted in the passage left spaces large enough for the student to fill in the missing word on the page itself. Two unfortunate inconsistencies arose from using photocopies of the original article in this way. Firstly, the colour picture which was an eye-catching feature of the original article, did not reproduce well in the photocopy and the visible impact together with any benefit this might have given some students, was considerably reduced. Secondly, the size of the blank spaces could not be kept uniform as the words were simply "whited out" of the original article so that the size of the gap available could provide the reader with clues about the missing word.

This was the second Time magazine science article provided in this study, the first being the passage which formed the basis of the oral exercise Reading Aloud. However, in Reading Aloud the student read the text directly from the magazine and not from an enlarged photocopy.

To summarize the differences between the magazine copy and the photocopy:

- semi-gloss paper / matt paper
- off white background colour / white background colour
- 10 point font size / 14 point (approx) font
- colour illustration of model and photograph of scientist / black & white reproduction barely visible
- clear copy, smudge free / some spotting of toner which affects overall appearance though probably not the legibility of individual words.

---

[7] School X physics group did not have an enlarged version of this test.

5.5.2 The students and the test conditions

This test was administered to all the participating physics students and english literature students. As explained above, the idea was to compare the first and last test of the series, in terms of the yardstick of the cloze test. Individual performances of physics students could be evaluated and a picture of the results from the two sets (physics and non-physics) could be obtained. As far as I am aware, all participants were given the exercise under test conditions, i.e. in class time with no opportunity for conferring.

5.5.3 Readability

Before this article was chosen an assessment of the reading difficulty in terms of the standard tests as shown in 5.4.1 was made. The passage was divided into 100 word sections and each complete section (8) was included in the word analysis, The following results were obtained:

FRY READING AGE	=15 YEARS
FLESCH READING EASE	=58% (55%=fairly difficult; 65%=standard)
SMOG READING AGE	= 16 YEARS

These results suggest that this article is easier to read than **ERRORS** (the first cloze test) which in turn was slightly easier than the previous Time article which was the subject of READING ALOUD (chapter 6). Taking the Fry estimate, there is a difference in reading age of 3 years between this text and the passage used in READING ALOUD.

The article was chosen because it was to be used with both science and non-science students and the subject matter seemed likely to appeal to both groups without being too technical. The simpler style compensates for the difficulty of the concepts being discussed which included the possibility of time reversal given certain theoretical conditions put forward by two models involving "wormholes" and "cosmic strings". The article is much longer than previous passages which on the one hand will yield a larger sample of words for analysis, but on the other may prove daunting to some students who may not finish the test for a number of reasons, not necessarily connected with lack of competence.

5.5.4 Marking

The deletion of every seventh word (apart from the exceptions mentioned above) gave altogether 123 possible responses. All correct responses or close synonyms were awarded 1 mark. The results were compiled into a spreadsheet grid where the correct response is shown as **1** an incorrect response as **0** and no response -. The grids of results of this exercise are given in **Appendix 5.**

5.5.5 Discussion of items

Table 5.6 Discussion of TIME items

ITEM	Fac Phy	Dis Phy	Comment	Fac Eng	Dis Eng
THE1 G	1.00	*	Easily predicted from the grammar G	0.96	0.45
THE 2 G	0.90	0.33	Leaving a blank is possible but not allowed. Could account for difference with above. G	0.92	0.29
BREADTH L	0.98	0.04	Depends on physics (or general) knowledge. . P	0.88	0.21
AS G	0.93	0.08	Simple prediction. "Even" favoured giving lower facility for english group G	0.81	-0.02
OTHER G	0.88	0.21	"First" also allowed. R	0.65	0.08
DIFFERENCE L	0.41	0.06	"Fact" was popular but not allowed. Picking up the element of contrast in this word requires close reading of the phrase. Low discrimination perhaps surprising. R	0.46	0.23
ANY G	0.78	0.26	"A" but not "the" allowed. G	0.69	0.25
RIGHT1 L	0.98	0.23	Continues the sense of the phrase. Surprisingly easy with low discrimination R	0.92	-0.02
TRAVEL1 L	0.54	0.29	Small space, "go"accepted. G	0.58	0.29
BACKWARD L	0.95	0.07	Seems very easy from the sense of the phrase. Negative discrim in english group puzzling R	0.92	-0.13
LAWS L	0.93	-0.16	Variety of words accepted, except those that sounded awkward.This might account for the negative discrimination in physics group R	0.85	0.20
GO G	0.88	-0.04	Seems more dependent on sense of paragraph than grammar R	0.77	0.19
EQUALLY L	0.83	0.37	Can be predicted from the grammar G	0.46	0.42
TIME1 L	0.88	0.00	Very much from the sense of the sentence. Not as difficult as might be predicted but low discrimination. R	0.62	0.20
YET G	0.85	0.16	Predictable from the meaning of the phrase, but clumsiness of the repetition may put off some. R	0.92	0.21
TIME2 L	0.90	-0.11	From the meaning of the sentence.Some physics students wrote "body" (moving) which would be more familiar. R	0.92	0.01
IF1 G	0.20	0.15	Difficult since sense of whole sentence must be comprehended. R	0.31	0.45
ALLOW/PERMIT G	0.39	0.06	Follows the logic of the passage. Fair discriminator for english group but poor for physics R	0.38	0.44
A1 G	0.63	0.41	Grammatically necessary G	0.88	0.44
PHYSICIST L	1.00	*	Some sort of scientist should be obvious from the meaning R	0.85	0.33

WITH G	0.98	0.09	Predictable from the grammar G	1.00	*
PAST1 L	0.78	0.28	Very dependent on understanding paragraph R	0.69	0.63
IF2 G	0.61	0.17	Grammar suggests "if" or "though", small space may be confusing G	0.81	0.22
CALCULATION S L	0.90	0.01	Variety of alternatives such as theory allowed resulting in good facility but poor discrimination R	0.92	0.21
JOURNAL L	0.78	0.03	Easily predicted R	0.73	0.25
MACHINE L	0.37	0.04	Relys on previous hearing of "time machine" Not exactly physics but background knowledge. P	0.46	0.24
CONCEPT L	0.90	-0.25	"Idea" / "theory" accepted, but not equation which may account for negative discrimination for physics group R	0.73	0.32
DISTORTED L	0.15	0.21	Difficult to guess without background knowledge, so low facility not surprising P	0.12	0.19
OBJECTS L	0.44	0.29	Background knowledge would help but probably easy to guess from next phrase P/R	0.46	0.29
SPEEDS L	0.93	0.16	Depends on next phrase. Seems obvious to physics group but mostly the high scoring english pupils R	0.73	0.59
IS1 G	0.83	-0.03	Seems easy from the grammar. physics groups results suggest that some high scoring students missed this. G	0.92	0.38
TACK L	0.73	0.02	Relys on sense of sentence. R	0.69	0.37
AND1 G	0.90	-0.10	Suggested by the grammar. Negative discrimination apparent for physics group G	0.81	0.62
TIME3 L	0.85	0.13	Possibly easy to guess from the following word (machine) but follows the gist of the passage. R	0.92	0.40
THE3 G	0.85	0.26	Simple grammar. Easily missed which might be the case for pupils searching for meaning G	0.81	-0.22
TRAVEL2 L	0.68	0.38	Possibly "wormhole" puts off some, theme of travelling carries on from previous column R	0.58	0.34
THAT G	0.88	0.13	Simple grammatical connection. Guessable G	0.85	0.43
CORE L	0.93	0.18	This may depend on knowledge of the subject, but can be helped by reading the next sentence. R/P	0.81	0.09
INFINITE L	0.85	0.18	Anything "large" accepted. Background knowledge would help but probably guessable from the grammar P/G	0.50	0.22
HOLE'S L	0.46	-0.29	Seems easy to guess from the context. Low facility may be due to confusion about the grammar (apostrophe) Negative discrimination for physics group might reflect this. R	0.31	0.25
WARPED L	0.39	-0.19	Difficult to guess accurately. Some inkling of subject needed. Surprising difference in discrimination P	0.27	0.30

SMALLER1 L	0.78	0.22	Can be guessed from sub-atomic particle R	0.46	0.24
LEAD L	0.71	0.16	Grammatical connection but implied in the meaning R/G	0.46	0.51
UNIVERSE1 L	0.54	0.24	Good candidate for guessing consistent with meaning R	0.58	-0.04
INSTANTLY L	0.37	0.35	Grammar suggests a point in time, differentiating from "eventually" needs appreciation of the gist of the passage and / or subsequent phrase. R	0.42	0.30
SPECIAL L	0.49	0.10	Context suggests this qualifier R	0.54	0.30
PAST2 L	0.66	0.30	Depends on understanding passage R	0.50	0.59
THIS G	0.78	0.02	Simple grammar guessable G	0.85	0.28
MUCH G	0.93	0.37	Guessable grammar. G	0.81	0.23
SURVIVE L	0.93	0.02	Implied from meaning. High discrim for english group suggests that understanding the meaning is a major factor in discriminating in this group. R	0.65	0.76
HOLE L	0.95	0.22	Guessable. R	0.96	-0.16
SMALLER2 L	0.90	0.08	Implied from meaning. Another example where understanding the message discriminates english gp well. R	0.77	0.62
A2 G	0.88	0.33	Guessable from grammar. G	0.77	0.22
OF G	0.88	0.20	Guessable from grammar G	0.92	0.30
MEANS L	0.78	0.35	Depends on reading rest of phrase R	0.58	0.46
PROPPING L	0.80	0.17	Predicted from context. High discrimination for english group R	0.65	0.56
GOT G	0.83	0.11	Grammatically predictable G	0.81	0.31
COULD L	0.83	0.20	Grammatically guessable G	0.85	0.23
SIMPLER1	0.66	0.08	Depends on subsequent phrase but should be guessable R	0.58	0.34
WORM HOLES L	0.78	0.49	Good level of comprehension of passage seems needed R	0.77	0.51
LIGHT1 L	0.76	0.20	Guessable from context. Fair discrimination for english gp R	0.77	0.43
A3 G	0.59	0.07	Very obvious from grammar. Missed by some high scoring english pupils G	0.69	-0.01
MAY G	0.80	0.21	Should be obvious from the grammar. High discrimination for english group G	0.77	0.55
AT1 G	0.78	0.36	Obvious from the grammar G	0.73	0.20
CASE L	0.51	0.28	Not so obvious but relys on grammar G	0.46	0.06
THE4 G	0.54	0.35	Grammar suggests definite article or adjective (eg high) G	0.77	0.39

UNIVERSE2 L	0.41	0.06	From the context of passage. Better facility and discrimination for english group R	0.50	0.31
RIGHT2 L	0.32	0.14	Difficult. Possible to justify omitting the word. Correct response depends on understanding a complex sentence. R	0.27	-0.01
THIN L	0.49	0.07	Guessable from string R	0.62	0.41
SURVIVED L	0.51	0.55	Subtle, obtained from "original state" which follows R	0.62	0.26
COOLING L	0.32	0.33	No apparent clues, either background knowledge or guess P	0.19	0.26
THESE G	0.76	0.58	From the grammar, marked difference in discrimination G	0.88	0.14
AND2 G	0.83	0.70	Same as above G	0.96	0.35
TONS L	0.61	0.40	Unit of mass P	0.69	0.38
LENGTH L	0.73	0.44	Confusing unit. But good facility P	0.85	0.20
GRAVITY/REGI ON L	0.46	0.42	Next 3 words require physics knowledge which most pupils will not have completely, likely that predictions are made on inferences in the passage P/R	0.58	0.25
SPACE1 L	0.49	0.33	P/R	0.27	0.02
LENS L	0.27	0.42	"Field "was allowed here which accounts for relatively high facility P/R	0.54	0.20
SOURCE L	0.71	0.49	"Source" strictly speaking is a physics word, but does occur further in the paragraph. "Object" was allowed which probably improved facility Almost identical for 2 groups P/R	0.69	0.50
IN1 G	0.68	0.58	Simply predicted from grammar. G	0.77	0.40
EACH1 G	0.56	0.36	From the context. R	0.73	0.18
END L	0.66	0.59	From the context. Quite good discrimination R	0.62	0.64
SIGNIFICANT L	0.71	0.35	From the context. Easily guessed R	0.81	0.13
THE5 G	0.66	0.60	Easy grammar. Note high disc for physics group G	0.88	0.25
LENGTHS L	0.46	0.37	This and next word are given by the context. R	0.58	0.54
LIGHT2 L	0.61	0.57	Much easier than word above R	0.85	0.47
AT2 G	0.63	0.58	From grammar. High discrimination for physics group G	0.81	0.43
LIGHT3 L	0.68	0.42	Connection between light & rays made earlier in the paragraph. But physics knowledge will make this obvious R/P	0.77	0.39
THE6 G	0.78	0.63	Simple grammar. High discrim for physics gp G	0.81	0.38
IS2 G	0.76	0.57	Fairly high discrimination for simple grammatical word G	0.96	0.45

SET LS	0.63	0.46	Exact word difficult as it is an unfamiliar colloquialism Synonyms accepted R	0.58	0.18
SPACE2 L	0.76	0.59	Very much from the sense of the passage R	0.85	0.29
SPEED L	0.68	0.39	Connection with light made Good discriminator of english. R	0.62	0.62
TWO G	0.83	0.64	Deduced from description so far. High discrimination R	0.85	0.60
THE7 G	0.73	0.48	Grammatical. Slightly higher discrim for english group G	0.81	0.51
EXACTLY L	0.51	0.37	See above G	0.77	0.69
RAY L	0.63	0.54	See light3 above A better discriminator in this case R/P	0.65	0.65
THE8 G	0.71	0.56	Simple grammar Surprising discrim for english group G	0.81	0.81
LIGHT4 L	0.76	0.54	From the context. Good discriminator R	0.88	0.71
IT G	0.66	0.64	Grammar. High discrimination G	0.85	0.58
FOR L	0.46	0.41	Harder grammar. Lower facility but lower disc for Phys gp G	0.62	0.54
MAKE L	0.76	0.60	From context Good discrimination for physics R	0.73	0.37
AND3 G	0.63	0.38	Guessable grammar G	0.69	0.41
DO G	0.46	0.54	Context. Fairly difficult but good discrimination R	0.46	0.55
EACH2 G	0.73	0.63	Grammatical Surprisingly high discrimination G	0.77	0.69
LIGHT5 L	0.71	0.55	Context High discrimination R	0.88	0.71
WORK L	0.29	0.25	From context but unusual usage might be confusing R/colloquialism	0.38	0.36
THE9 G	0.63	0.51	Grammar G	0.77	0.52
BELIEVE L	0.61	0.63	Difficult context. Surprisingly high facility and discrim R	0.62	0.55
BUT G	0.61	0.70	See above R	0.65	0.58
IN2 G	0.59	0.57	Seems easy from the grammar Low facility/h.discrimination G	0.23	0.41
PHYSICS L	0.51	0.71	Difficult.context. Low facility but good discrim R	0.46	0.55
ACTION L	0.29	0.53	Difficult to see cause/effect link. Very low facility favours low scoring english pupils Medium discrimination for phy R	0.12	-0.08
IF3 G	0.24	0.46	Complex context Good discriminator of english group contrasting with previous item G	0.27	0.61
SCIENCE L	0.49	0.54	From context High discrim R	0.54	0.63
PAST3 L	0.54	0.72	Careful reading to avoid "future" Good discrimination R	0.58	0.64

AT3 G	0.56	0.73	Easy grammar. High discrimination G	0.73	0.68
SEEMS G	0.39	0.75	Quite hard grammar Note higher discrimination for physics group. G	0.23	0.48
MUST G	0.54	0.53	Quite hard grammar. See comment above G	0.50	0.49
IDEAS L	0.59	0.71	From context High discrimination R	0.65	0.63
BE1 G	0.59	0.64	Predictable grammar High discrimination for english G	0.65	0.63
IN3 G	0.51	0.56	Last two grammatically predicted Quite high discrimination G	0.54	0.63
BE2 G	0.61	0.65	See above G	0.65	0.63

The items in this test can be broken down as follows:

grammatical 49 / lexical 73

reading 68 / grammar 48 / physics 16 / idiom 2[8]

The proportion of grammatical/lexical words is almost the opposite to that found in ERRORS where grammatical items were more numerous than lexical and grammar exceeded reading

There seems to be a noticeable trend with the english group that reading-related words, particularly where important meanings are conveyed, have a high discrimination whereas very simple grammar related words seem to be overlooked and frequently have a negative discrimination. This suggests that higher scoring students are reading the passage for meaning at the expense of missing "obvious" grammar words which are noticed by lower scoring students.

For the physics group, discrimination tends to be greater for the grammar words although this is only really apparent in the second half of the test. Negative discrimination which occurs earlier in the exercise tends also to be with grammar words, suggesting that high-scoring physics pupils in common with the english group are missing simple grammar items at first. To some extent physics students seem distracted by their previous knowledge. One example is the word following "Einsteinian" which in the text is "concept"; several physics students wrote "equation" which was not really satisfactory.

5.5.6 Performance and Reliability

Table 5.7 Pupil scores TIME

COMPREHENSION LEVEL	FRUSTRATION (0-40%)	INSTRUCTIONAL (41-60%)	INDEPENDENT (61-100%)
ENGLISH GROUP	4 (15%)	3 (12%)	19 (73%)
PHYSICS GROUP	3 (9%)	9 (26%)	23 (65%)

8 Same definitions as for ERRORS

A higher proportion of the english group achieve the independent level, but approximately the same proportion of both groups are reading the text at the instructional level or better.The proportion of physics students reading at the independent level is lower in this exercise than in ERRORS (82% Independent); whereas the proportion of english students reading at the independent level is greater here than in ERRORS (53% independent).

There are two major variations between the two exercises, these are:

- Type of passage. The TIME passage is a fairly sophisticated piece of journalistic copy from a news magazine targeting a general, educated though non-specialist, adult readership, whereas, the ERRORS passage is taken from an A level physics textbook.
- Timing of the two tests. Almost a full academic year had elapsed between the time of the ERRORS exercise and TIME, during which, presumably, english literature A level students would have spent a good deal of time and effort reading various passages of text.

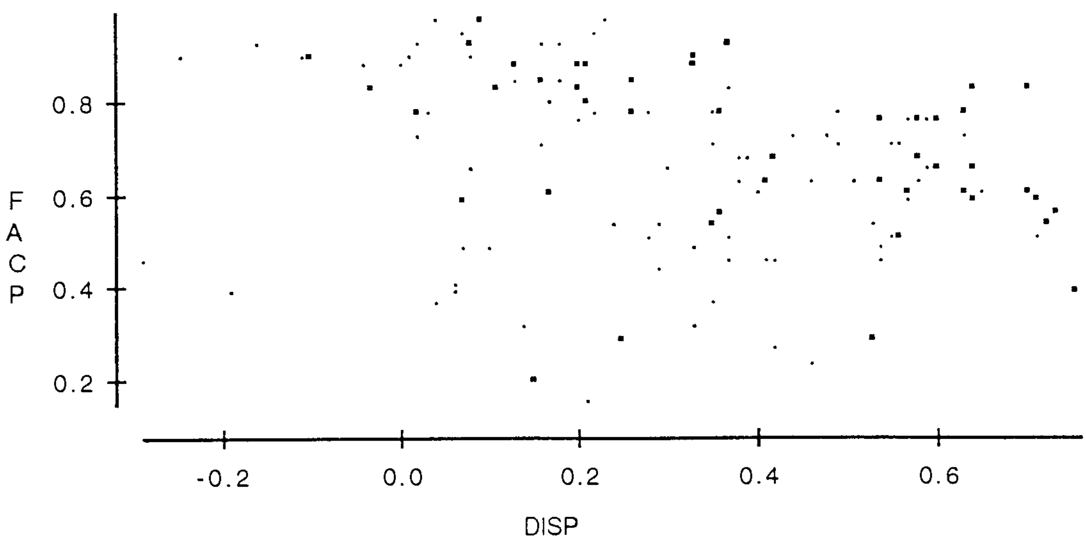
So, on the one hand english literature students might be expected to be "better readers" in general terms at the end of the first year of the A level course, but part of the explanation for the apparent improvement in their performance might be due to the difference in style and content of the material of the passage.

This cloze test, like ERRORS, has a **high reliability.** Coefficients of reliability (Cronbach's alpha) were calculated and found to be 0.950 for the physics group and 0.934 for the english group.

5.5.7 Patterns in results

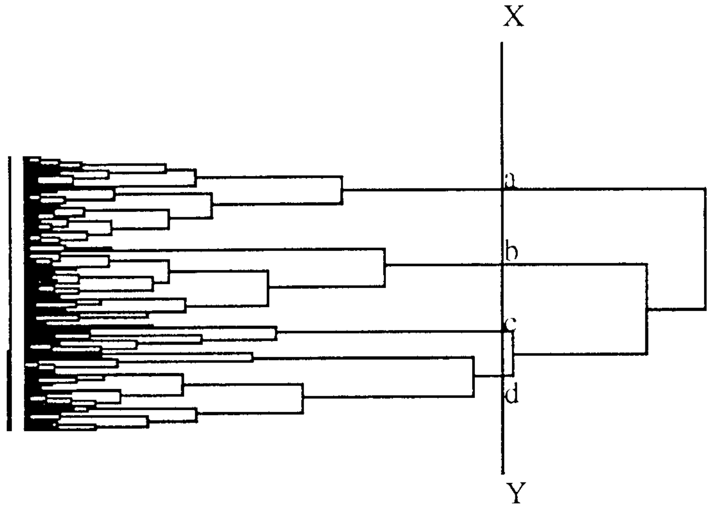
Fig 5.4 shows the facility and discrimination of the answers of the physics pupils. Items which were deemed grammatical are shown in bold and lexical items in plain type.

Fig 5.4 TIME Facility/Discrimination physics group (grammatical items bold)



The scattergraph (Fig 5.4) seems to show that grammatical items fall in two main areas (high facility, low discrimination and medium facility, high discrimination). A cluster analysis was performed in order to investigate this further, the results of which are shown in Fig 5.5.

Fig 5.5 Cluster analysis (complete linkage) on Facility/Discrim. of physics group



Axis XY in Fig 5.5 shows the level at which clusters were considered and four clusters labelled a - d have been identified. To show the items that they correspond to another scattergraph Fig 5.6 has been drawn.

Fig 5.6 Facility/Discrimination of physics group showing clusters a - d

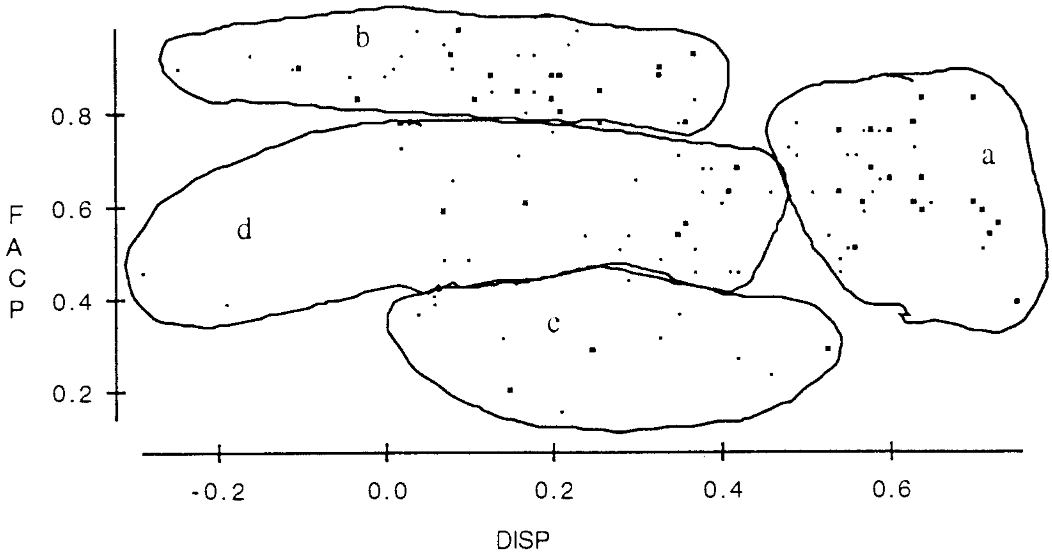


Fig 5.6 suggests two main clusters of grammatical items, one with high facility and low discrimination (cluster **b**), the other with lower facility and higher discrimination (cluster **a**).

About half of the grammatical items are located in cluster **a**. In order to investigate why these particular items might have a greater discrimination the item number[9] of the points in the scattergraph were monitored. The results showed that cluster **b** contains items which occur earlier in the test. In fact, no item higher than 60 (less than halfway through the test) appears in this group and most are within the first 50 items. Whereas cluster **a** contains items which occur much later in the test, most occurring after the 100th item. This could illustrate the comments made above about the two types of strategies which seem to be used by this group for dealing with Grammatical items.

It is also possible that as the test is fairly lengthy, some pupils are not performing so well towards the end due to what might be called "test fatigue". To look at this more closely, t tests were performed on:

(a) the facility of the first half of all items versus the facility of the second half and

(b) the discrimination of the first half versus the second half of the items.

The results were as follows:

- facility of **first half** of items **significantly greater** than second ($p<0.01$)
- discrimination of **second half significantly greater** than first ($p<0.01$) .

This could mean that the second half of the exercise is more difficult or that some pupils do not try so hard, and hence their overall score is low, which would account for the relatively high discrimination of the second half. The comments made at the end of 5.5.5 could also supported by the t test results. That is, it is the grammatical words of the second half of the exercise which are effectively providing the discrimination between the pupils because the higher scoring students solve the trickier "grammatical puzzles" but the lower scoring students do not.

The same procedure of cluster analysis was carried out for the results of the english group to see if the grammatical items were located in any particular cluster and the result of the cluster analysis is shown in Fig 5.7. Again, the axis XY in Fig 5.7 indicates the level at which clusters were considered and the branches on the dendrogram labelled a - f identify the six clusters which are shown on the the scattergraph of the Facility/Discrimination of the english group's results. The resulting scattergraph is shown in Fig 5.8.

---

[9]In order of occurrence in the cloze test.

Fig 5.7 Cluster analysis (complete linkage) on Facility/Discrim of english group

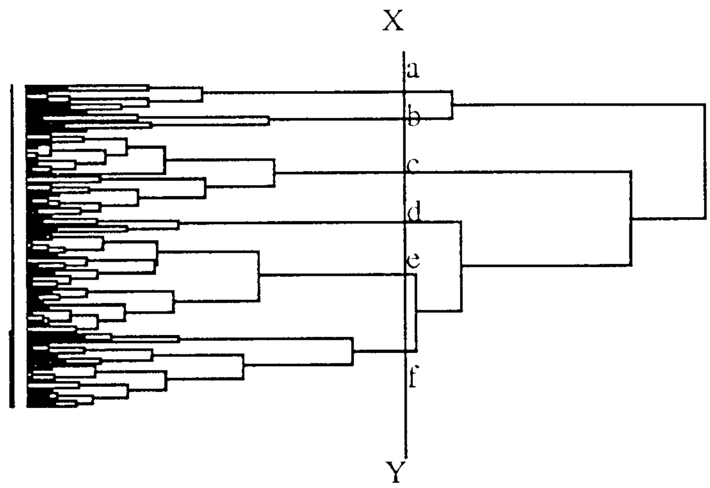
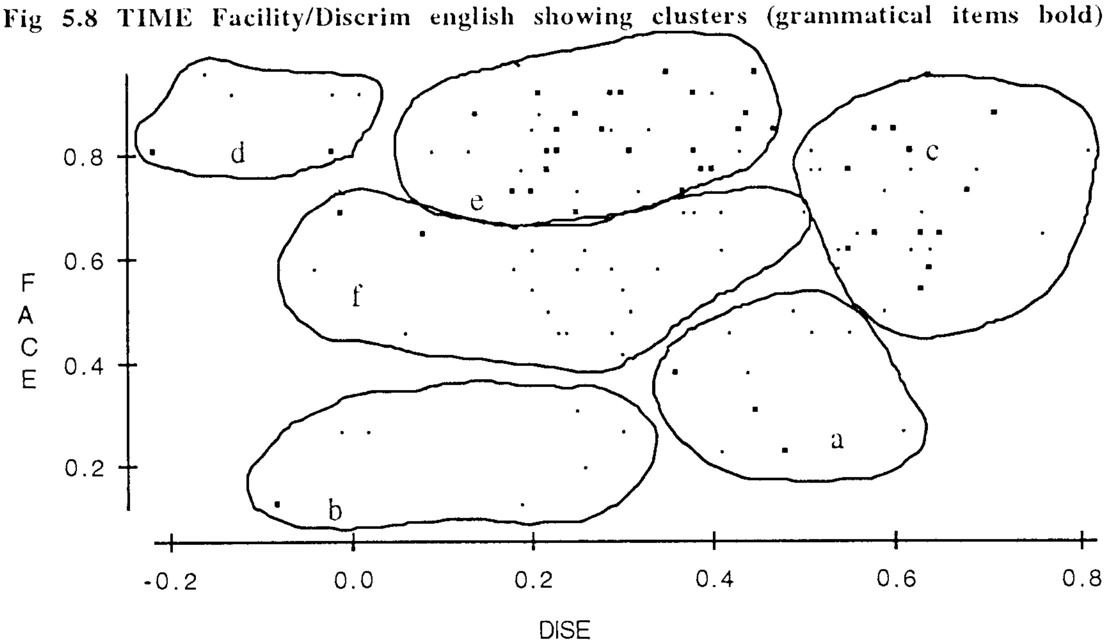


Fig 5.8 TIME Facility/Discrim english showing clusters (grammatical items bold)



The grammatical items are concentrated in clusters **c** and **e**, in a pattern similar to that found for the physics group. However. the range of distribution of the discrimination for the english group is from 0.2 to 0.6 which is slightly narrower than for the physics group, 0.0 - 0.8. This seems to reinforce the suggestion that grammatical items are items are answered more consistently (i.e. with less variation) by the english group throughout the exercise.

Scores between the groups were subjected to paired t tests testing in each case the hypothesis that english group scores are greater than physics group scores. The results shown in Table 5.8 and categories shown in bold type are statistically significant ($p<0.05$).

Table 5.8 TIME: Comparison between english (E) physics (P) Groups

Category	Difference	Probability
Facility Overall	0.0016	0.8932
Discrimination Overall	**0.0405**	**0.0749**
Facility Lexical Items	0.02671	0.1018
Facility Grammatical Items	**0.0220**	**0.0389**
Discrimination Lexical Items	**0.0680**	**0.0079**
Discrimination Grammatical Items	0.0244	0.4715
Facility Reading Strategies	0.0225	0.1480
Facility Grammar Strategies	0.02792	0.1905
Facility Physics Strategies	0.0129	0.7634
Discrimination Reading Strategies	**0.0697**	**0.0348**
Discrimination Grammatical Strategies	0.0037	0.9115
Discrimination Physics Strategies	0.0727	0.4459

Although the overall facility of the passage was just about the same for both groups the Grammatical items were easier for the english group. Overall, the passage was a better discriminator of the english group, particularly it seems, the lexical items. The reading strategies required also discriminated the english students better than the physics students.

5.6 PROJECTILES (Investigating Free Fall)

5.6.1 Details of the exercise

This exercise (found in **Appendix 6**) was designed to be given to physics students fairly early in the A level course[10] when they would normally be covering basic mechanics. It was assumed that the students would have background knowledge of the topic so that most of the technical words would be familiar, the formulae recognizable and the skills involved in interpreting diagrams / graphs, well rehearsed. As before three readability tests were carried out on the passage and the results were as follows:

FRY	= grade 7 (12 years)
FLESCH	= 71%(75%=fairly easy; 65%=standard)
McLAUGHLIN'S SMOG	= 16 years.

In general, the passage comprises short sentences so both Fry and Flesh scores indicate low-grade difficulty . However, the SMOG score is higher as the number of words of 3+ syllables is relatively large, eg acceleration, stroboscope, gravity. As these key words are repeated several times they may not necessarily increase the difficulty of the passage. The calculations above were made using the convention cited in *Teaching Language and Study Skills in Secondary Science* (Bulman, 1984 #48) whereby "a word is a string of letters or characters delimited by spaces". Thus, a formula such as $s=1/2at^2$ is counted as one word, with each component as one syllable (6 syllables). Similarly, with quantities such as 4.9 m s^{-2} counted as one word[11] with 7 syllables. This practice also accounts for the high score on the SMOG scale, and contributes to the syllable count, which, nevertheless, is not particularly great overall.

5.6.2 The students and the test conditions

The exercise was given to the four physics groups (schools W,X,Y and Z) and the students were asked to insert a single word wherever they thought one had been omitted. It transpired that all groups were given the work to do in class; approximately half an hour was allowed which seemed to be sufficient for most students to complete the work.

---

[10] PROJECTILES was the second exercise administered

[11] The spaces between units are ignored as they are a convention of presentation.

5.6.3 Selection of the items for testing.

The length of the passage is approximately 690 words and there are 22 omissions which students were asked to fill. Words selected for deletion were:

i) reasonably well spaced, to provide sufficient context on both sides of the omission.

ii) a mixture of word types i.e. physics related and non-physics related

All the items selected were thought to be important elements in terms of comprehending the sense of the sentence; it was not a deliberate motive in this case to test the student's knowledge of grammatical structures. Half of the items are thought to be **physics-related**, the remainder (11) were thought to be **non-physics** items. The criteria for differentiating a physics item from a non-physics item were:

a) non-physics items were words that students who were not science specialists could at least guess at.

b) if a word was described in the text, even if it appeared to be a "science" word, it was called a non-physics word, since this gave non-scientists a fair chance of finding the answer.[12]

Under the item results the student's total of correct responses and below this, the physics, semantic and grammatical errors are given.

5.6.4 The results grid

Each student's response is noted in the answer grid in the following way: a response which is identical to the word in the original text is denoted by 1 only, all other responses are given in full with an additional symbol, either 1, P,S or G. 1 indicates that the word was accepted as a close synonym, P a mistake which shows a misunderstanding of physics, S a non-physics related semantic error and G a grammatical error.

Under the item results the student's total of exact matches, with an additional figure showing the number of acceptable synonyms, if any. Below this, the physics, semantic and grammatical errors are given. Results grids for all the students who took the test (41) are in **Appendix 7**.

5.6.5 Discussion of items

The items are discussed in a similar way to those from ERRORS and TIME. Although items are not classified as grammatical or lexical since most of them were selected as content words. The items are, however, described as physics. or non-physics, based on the criteria given in section 5.6.3 An additional column states the types of error which pupils made.

---

[12] This criterion proved to be questionable (see section 5.6.7)

Table 5.9 Discussion of PROJECTILES items

Response	Comment	Error Type	Facility	Discrim
PICTURED (non-physics)	Despite the intention of classifying non-exact responses, this proved difficult to carry out with this word as I found it impossible not to allow "photographed" "recorded" or "illuminated". There seemed to be no reason to prefer "pictured" at all and nothing to distinguish a preference for any particular alternative		1.00	
TIME (non-physics)	Initial reaction is to find a specific interval of time, but since that is not given, one should settle for the variable "time." Many students made a guess at a suitable time interval, this was deemed an S type error. "Seconds" was also an S error. "31 Hz" (from fig 1) or "Hz" were P type errors as these seem to confuse physics knowledge.	S, P	0.41	0.30
INCREASES (physics)	Responses with inappropriate endings G,"decreases" "changing" P since they show incorrect or incomplete physics knowledge. "Accelerates" is the right idea although strictly it is the ball which accelerates not the speed. 1	G, P	0.78	0.40
ACCELERATION (physics)	Only 2 incorrect responses which contained inappropriate physics eg "displacement", "velocity"; "half" which refers to the formula given immediately above, hence, semantic error	S, P	0.90	0.27
RELEASE (physics)	"Rest" was thought to be a suitable synonym. "Zero" did not really convey the full meaning and thus an S error. "When" was an unexpected response which is tenable only if there was no full stop after rest. G.	P, G, S	0.71	0.62
TIME (physics)	14 pupils omitted this item. Most errors were trying to qualify "t" in some way and were deemed S errors	S	0.49	0.27
ESTIMATED (non-physics)	"Determined" & "Measured" were counted as synonyms but "gradient" or "read from graph" were thought to be grammatical errors. Repeating formula was an S error	G, S	0.73	0.44
CONSTANT (physics)	"changing" was a P error."gradient' or "straight line" G "half" S	P, S, G	0.59	0.41
9.8 MS -2 (physics)	All wrong answers were physics deemed P	P	0.37	0.52
MORE (non-physics)	"Greater" was an acceptable synonym. Other errors S	S	0.66	0.41
CURVED (physics)	"Parabolic" acceptable synonym "Straight" or "circular" P errors other qualifiers such as "regular" S	P, S	0.41	0.30
GRAVITY (non-physics)	No incorrect responses - 2 blanks only		0.93	0.48
HORIZONTAL (physics)	Contradictions of horizontal such as "vertical' or "curved" are flaws in interpreting the graph hence P. Variations of "start" or "begun" impede the grammar, so G. Other responses do not convey enough meaning, S	P, G, S	0.32	0.49
LEVEL (non-physics)	"Horizontal" & "parallel to table" acceptable synonyms		0.88	0.13

STROBOSCOPE (non-physics)	Little excuse for looking for synonyms here, so "light","multiflash" not accepted. S errors	S	0.63	0.51
SAME (non-physics)	No wrong responses (1 omission) Too easy.		0.95	0.44
REGULAR (physics)	"Constant' acceptable synonym Other incorrect responses misinterpret last sentence of paragraph hence S. This item has a very low discrimination given its reasonable facility which suggests that many of the answers are guesses.	S	0.63	0.15
9.8 MS-2 (physics)	Incorrect unit P "g" and incorrect quantities S	P, S	0.54	0.51
HORIZONTAL (non-physics)	Clearly given in text so incorrect responses S	S	0.95	0.34
STEEPER (physics)	Problems with interpreting photograph are P	P	0.29	0.49
SIDEWAYS (non-physics)	"Horizontally" a suitable synonym. Other errors P	P	0.83	0.31
GRAVITY (non-physics)	No errors		0.98	0.24

5.6.6 Reliability and performance

The reliability of the test was less than for the other cloze tests with alpha calculated as 0.7. This may be due not only to the lower number of items (less than a third of the number of ERRORS) but also to the lower discrimination of the items in general. It was noted that the reliability decreased when the synonym scores were added to grids. As the reading assessments predicted, the text posed no particular difficulty and only 6 items had a facility less than 0.5.

Table 5.10 Pupil scores PROJECTILES

COMPREHENSION LEVEL	FRUSTRATION (0-40%)	INSTRUCTIONAL (41-60%)	INDEPENDENT (61-100%)
PHYSICS GROUP	**1 (2%)**	**12 (29%)**	**28 (68%)**

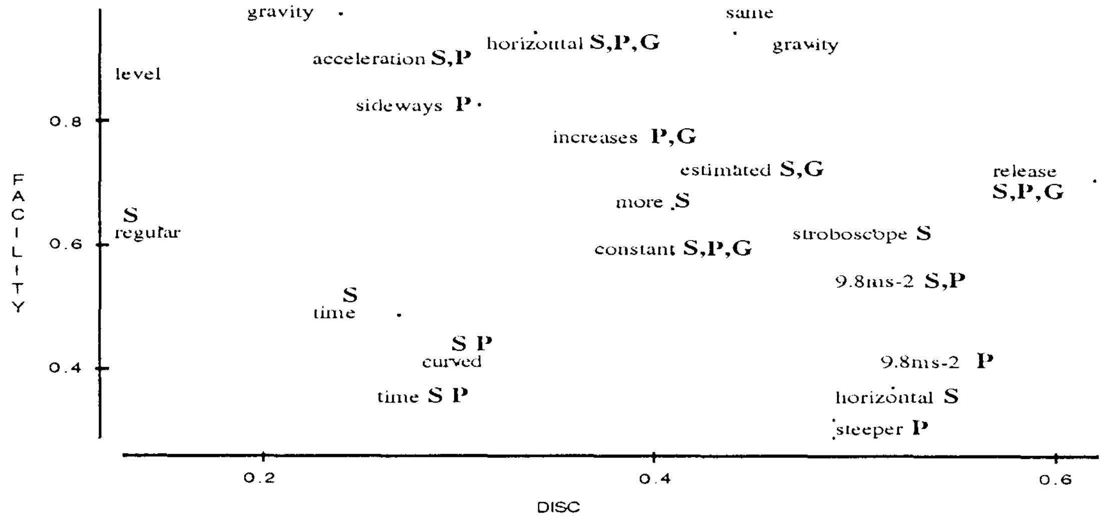
Less than one third of the pupils read this text at the instructional level or below. Interestingly the proportion of students reading at the independent level is approximately the same as for TIME (65%) but lower than for ERRORS (82%). This conflicts with the readability measures which gave ERRORS an estimated "reading age" of 17+ years whereas TIME was given an estimate of 15/16 years which agrees more with the SMOG[13] estimate for PROJECTILES of 16 years.

13 Fry gives an estimate of 12 years see 5.6.1

5.6.7 Patterns in results

(i) Looking at the results in terms of the facility and discrimination of each item and identifying the type of error which pupils' wrong answers seemed to indicate, a clearer picture of how the errors were distributed may be obtained.

Fig 5.9 Facility/Discrimination PROJECTILES Items



(S=semantic error, P=physics error, G=grammatical error)

Fig. 5.9 displays each item in terms of its facility and discrimination and also shows the type of **error** that pupils made when responding to the item (as noted in Table 5.9), where relevant[14]. Although no particular pattern emerges from the distribution of S and P errors, errors which seem to result from a misunderstanding of the grammar of the sentence or phrase (G errors) are located in the upper right quadrant of the graph, which shows they have high facility and high discrimination. This suggests that even with "easier" items, some lower scoring pupils are misunderstanding the grammar.

(ii) The type of error which a pupil makes must have some relationship to the passage, but is perhaps more strongly related to the pupil, in particular, the strategy the pupil is using to answer the cloze question. That is, when an error is made by a pupil, the error cannot be seen solely as a property of the item in the way that "lexical / grammatical" words were defined in ERRORS and TIME. Hence it makes sense to look at the types of errors made in relation to the pupil.

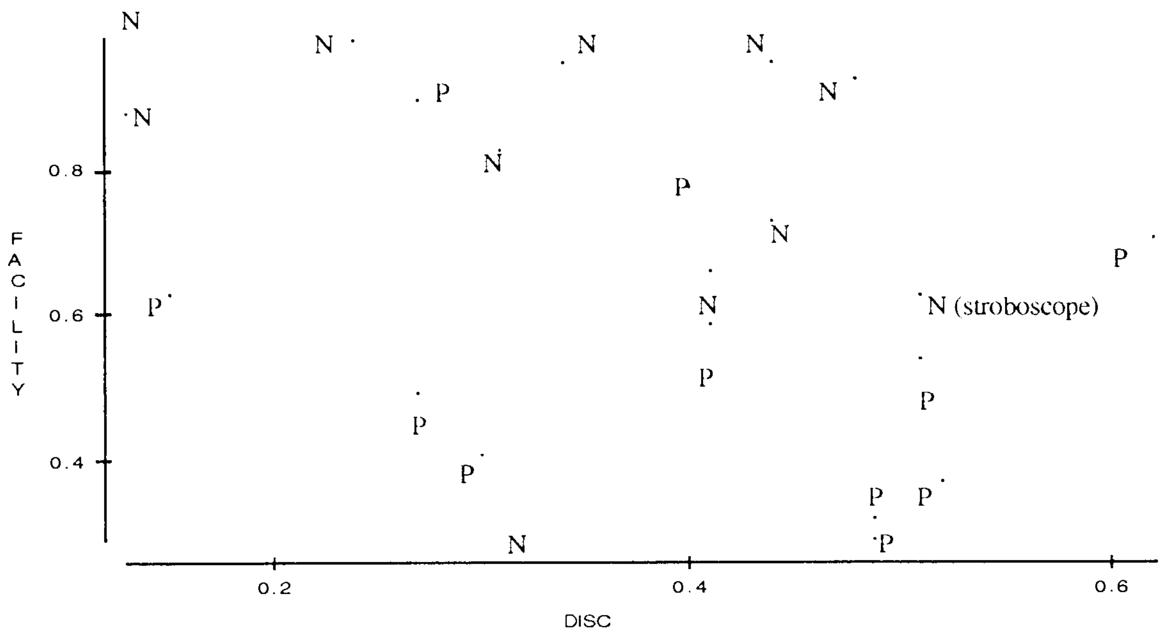
(iii) One further idea is to split the items into two groups, physics and non-physics as defined in 5.6.3 (and shown in table 5.9). Making the assumption that these categories are "properties of the word" in a similar way to how lexical and grammatical items were

---

[14] Some items had no incorrect answers i.e. the item was either answered correctly by all pupils or left blank.

defined, the points can be displayed in terms of facility and discrimination indices as in Fig 5.10.

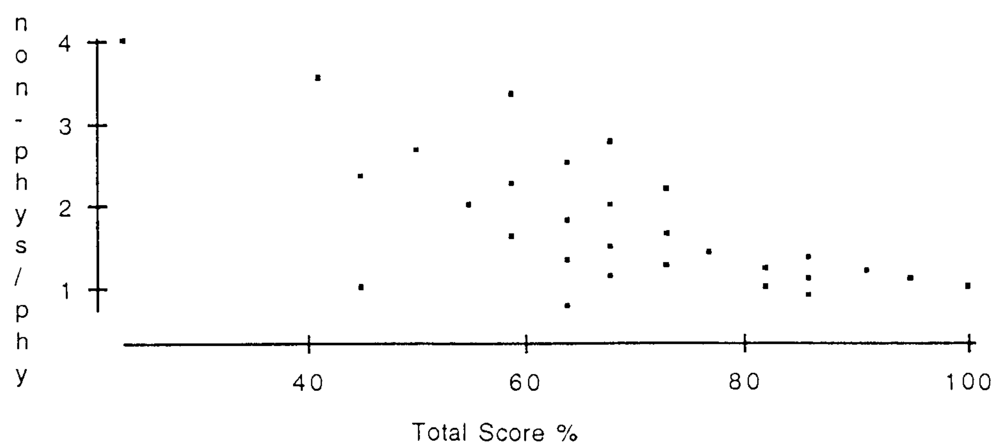
Fig 5.10 Facility and discrimination of physics (P) and non-physics (N) items.



Of the six items with the highest discrimination, all but one are physics items. The non-physics item is "stroboscope", which according to the defining criteria (see section 5.6.3), is deemed to be a non-physics item. The results show that "stroboscope" is still perceived as a physics item. Ten of the eleven non-physics items have facilities greater than 0.6. The graph shows a general tendency for **physics items to be less easy and more discriminating** than non-physics items.

(iv) In order to look at the relative contribution of physics and non-physics items to total scores, we can plot each pupil's total against the **ratio** of correct non-physics to physics items.

Fig 5.11 Ratio of non-physics / physics items against Total score



There is a significant negative correlation of **- 0.7** ($p<0.01$) in this relationship suggesting that lower scoring students are more likely to answer non-physics items correctly and are mainly losing marks on physics items. This implies that their knowledge of physics is weaker than higher scoring students.

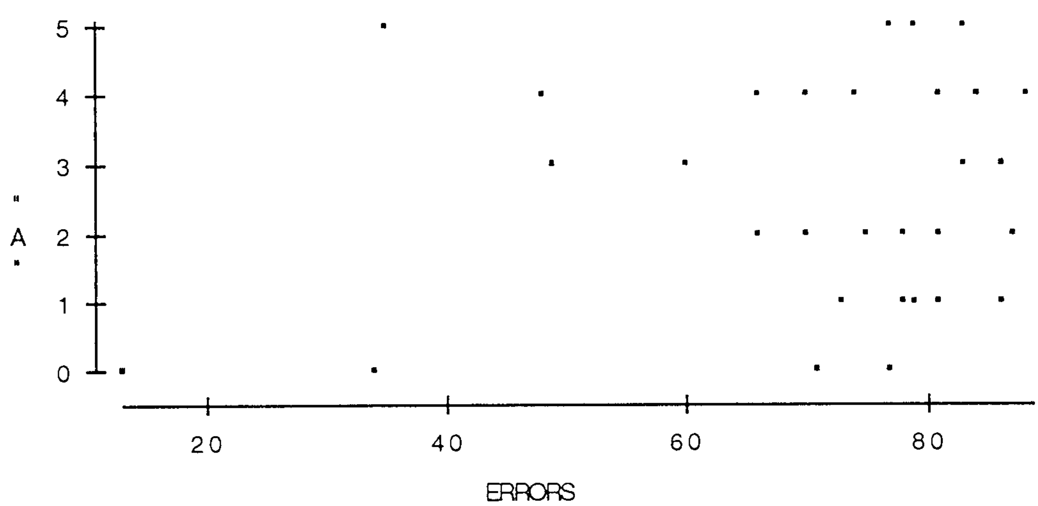
5.7 Comparing the cloze test results

As a first stage of reviewing the cloze tests, a comparison will be made of the students' results in these tests. In order to provide what could be considered to be "an independent indication of student ability", the A level grade is included in the analysis.

Figs 5.12, 5.13 and 5.14 show how physics pupils' scores for the three cloze tests correlate with their A level results[15] which are shown on the graph on a scale of 0 - 5.

(A grade = 5, B= 4, C = 3, D = 2, E=1 and 0 = fail)

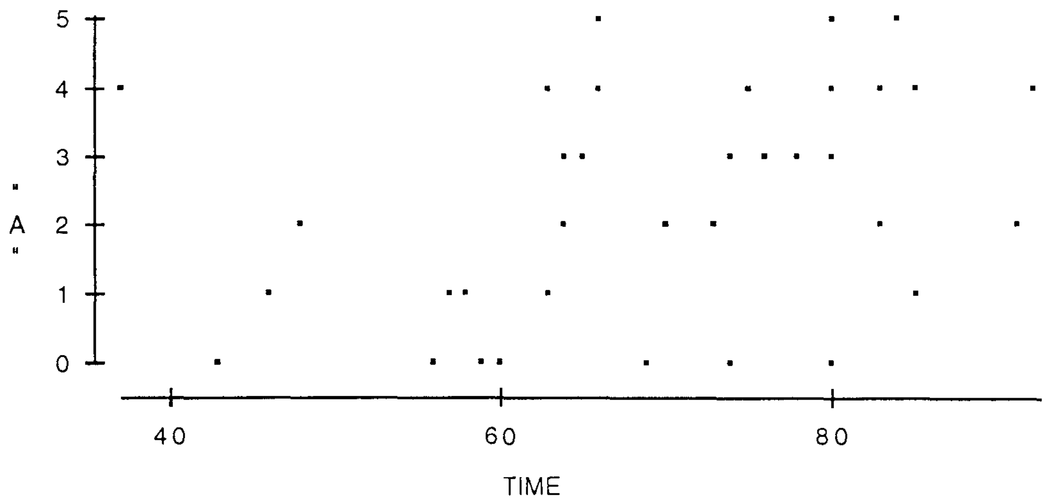
Fig 5.12 A Level results / ERRORS scores



The coefficient of correlation is 0.182 which is not statistically significant. Although most pupils score over 60%, several of the high scorers fail or obtain low grades at A level. One pupil (code:AMIN) who obtained an A at A level scores less than 40% which also reduces the possibility of a significant correlation between these scores.

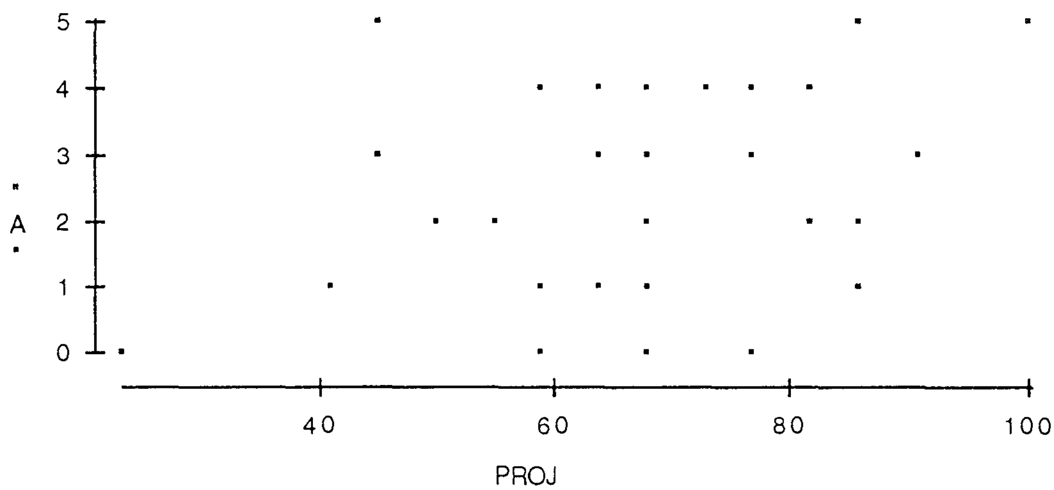
[15] Only in cases where the A level grade is known.

Fig 5.13 A Level results / TIME scores



A correlation coefficient of 0.347 which is statistically significant ($p < 0.05$) is found. Although there is a wide range of TIME scores from pupils who failed the A level exam, other results point to a clear relationship in scores of TIME and A Level. Interestingly, AMIN who was pointed out in the previous paragraph, obtained a lower score in this exercise than the two other pupils who did the exercise and obtained an A grade at A level. However, AMIN's score here is closer to 70%, which, bearing in mind that this exercise was given near to the end of the first year, may show that his performance in this type of test has improved during the course of the year.

Fig 5.14 A Level results / PROJECTILES scores



The correlation here is 0.359 which is statistically significant ($p<0.05$), despite AMIN's score of less than 50% in this exercise. PROJECTILES was given to pupils just after ERRORS so the comment made above about AMIN's progress during the course of the year, remains feasible.

As might be expected ERRORS scores are closely related to PROJECTILES scores as scattergraph Fig 5.15 shows. The coefficient of correlation is 0.614 which is statistically significant ($p<0.01$).

Fig 5.15 ERRORS / PROJECTILES

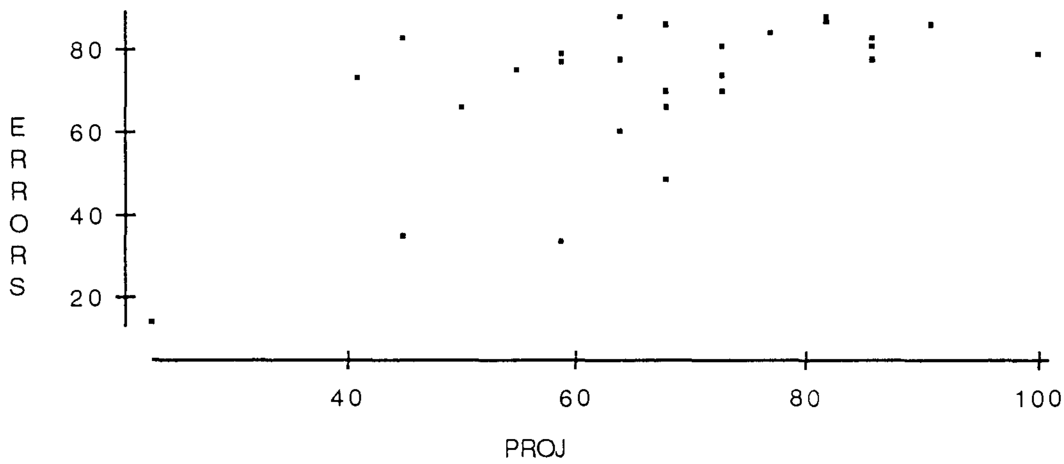


Fig 5.16 shows the scattergraph for the ERRORS and TIME results, which has a correlation coefficient of 0.304 (not significant). The low correlation is partly due to the three lowest scorers on TIME having relatively high scores on ERRORS because without these three points there would be a clear positive correlation. So, perhaps these three students do not make the same degree of improvement in their reading skills as some of the others in the physics group.

Fig 5.16 Scores on ERRORS / Scores on TIME

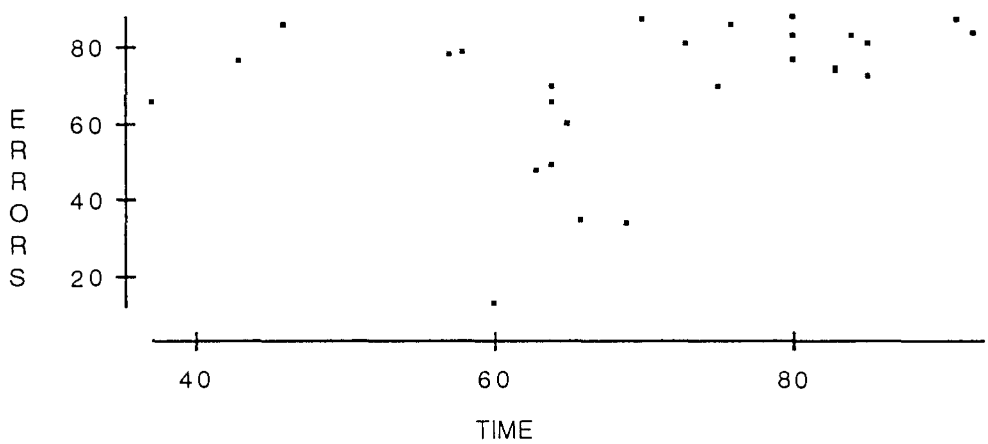
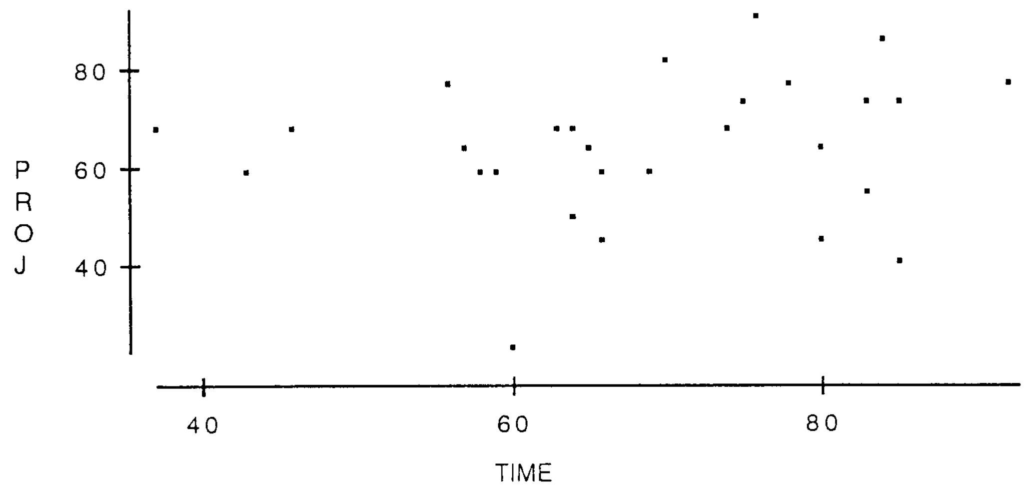


Fig 5.17 Scores on PROJECTILES / Scores on TIME



The scattergraph for PROJECTILES / TIME, Fig 5.17 shows very little correlation and the coefficient of correlation is 0.166. The three points at the far left are the scores of the same three pupils mentioned above who obtained a low score for TIME but a high score for ERRORS. Here again they obtain higher scores for PROJECTILES than TIME, but even the rest of the points show very little evidence of correlation.

5.8 Summary discussion of cloze results

Distinguishing facets of reading skills

As well as classifying items as grammatical or lexical and physics or non-physics, every item was assigned a group according to the possible strategy or skill which would be necessary to find the answer. It is impossible in a cloze test to completely control the proportion of each category of item. I believe these are important variables to consider when analyzing the results of cloze exercises for diagnostic or summative purposes. However, this assumption is really only valid if each category can be shown to involve a separate skill or if categories inter-relate in a predictable way. There is little hard evidence of this so far. What can be said however is that:

(i) when cloze items were selected specifically as "physics" or "non-physics" the "physics" items were the most discriminating;

(ii) grammatical items seem to have a higher discrimination than lexical items for the physics group.

Measuring reading skills

A summary of the three text difficulty assessments (Fry, Flesch and SMOG) together with the results of the cloze tests categorized into three levels is given in Table 5.11.

The Fry and Flesch results are fairly consistent but SMOG gives a higher reading age for PROJECTILES[16]. The cloze results indicate that the majority of pupils are reading the passages at the Independent level.

Table 5.11 Summary of Reading Assessment results

Cloze	Fry	Flesch	SMOG	Frustration	Instructional	Independent
ERRORS	17years	48%	17.5 yrs	9%	9%	82%
TIME	15 years	58%	16 years	9%	26%	65%
PROJECTILE	12 years	71%	16 years	2%	29%	68%

The cloze results suggest that ERRORS is "easiest" since the highest proportion of pupils can read this independently, even though Fry, Flesch and SMOG consistently agree that it is the most difficult exercise of the three. An alternative interpretation ~~explanation~~ is that 91% of pupils read the TIME and ERRORS passages at the Instructional level or better, whereas this value is 97% for PROJECTILES.

From the teacher's point of view the cloze exercise can identify pupils who are reading at the Frustration level, although it is not clear at this stage which text assessment most closely matches the cloze scores. As the results for Fry and Flesch are so consistent, using one or the other seems a reasonable suggestion, but it seems worthwhile to keep the SMOG test as well.

Choosing texts and tests

The results of the cloze tests show that most pupils cope well with passages which text assessments suggest are of the appropriate level of difficulty.

Using ERRORS results as a reference, firstly because it is the "regular deletions" type of cloze and secondly because it is taken from a standard pupil textbook, we can note the following:

(i) "Non-standard" passages such as TIME cause more difficulty because the presentation / style may be unfamiliar to physics pupils. Results may improve with practice on passages from a variety of sources.

(ii) The task set is important. Deliberately choosing certain words or types of word (physics / non-physics) seems to affect pupil performance.

(iii) Even the "regular deletions" method of cloze can generate different proportions of types of word eg. lexical and grammatical or physics and non-physics. This should be considered when comparing pupil performance in cloze tests.

---

16 Reasons for this discrepancy are discussed in 5.6.1

(iv) Results can be analyzed by sorting items into "skill groups" according to the supposed skills needed to find the missing word. There may be potential here for finding the specific problem areas of pupils who are reading at the Frustration level.

Physics achievement

The external indicator of physics competence used so far is the final A level score. Two of the cloze tests PROJECTILES and TIME show significant correlation with this.

For ERRORS and TIME, items which were deemed to require physics knowledge did not have particularly good discrimination[17] with the physics group. However, for PROJECTILES, there was a very clear indication that physics items did have a high discrimination and furthermore evidence that lower scorers in this exercise were gaining their marks predominantly with non-physics answers. A cloze test such as PROJECTILES with selected omissions is thus a fair indicator of physics knowledge.

The correlation of TIME with A level score cannot be attributed to the discrimination of the physics items so directly. It is possible that another factor links this cloze exercise with achievement in this subject and this possibility will be investigated in Chapter 8.

Comparison with non-physics students

For ERRORS, the physics group had higher facility overall which was reflected in the higher proportion of pupils who read at Instructional level or better (91% physics, 74% english). As far as discrimination is concerned, only the discrimination of the grammatical strategies was significantly higher in the physics group which suggests that higher scoring pupils in the physics group are better at solving problems of grammar, but not necessarily at identifying reading or physics related items.

For TIME, the proportion of the physics group who are reading at the Independent level has decreased but this proportion for the english group has increased greatly. However, looking at the groups in terms of pupils who read at Instructional level or better, the proportion of physics pupils has remained at 91% whereas the proportion of english pupils has risen by 11% to 85%. Whereas the facility of items overall was not much different for both groups, the facility of grammatical items was significantly better for the english group. The discrimination of lexical items and reading strategies was also significantly better for the english group. Bearing in mind that the english group will have spent a good deal of time during the year reading and analyzing texts of various kinds the improvement in performance, and particularly the fact that high scorers correctly answer items involving reading strategies, is easily explained.

---

[17] Discrimination of physics items was substantially better for TIME than ERRORS

As for the physics group, it would be unfair to jump to the conclusion that there has been a stagnation in their reading skills over the course of the year. Although pupils who read this passage at Frustration level would be a cause for concern to their teacher, the passage on which TIME is based is very different from ERRORS. To investigate the possible progress of the pupils in reading comprehension, a passage more like ERRORS would have to be used.

CHAPTER 6: READING ALOUD

6.1 Introduction

By listening to pupils read, reading teachers try to both encourage and assess children's reading. Attempts have been made to systematize the assessment aspect for both diagnostic and summative purposes and here attention has been focused, particularly at the beginner reader level, on the mistakes, mispronunciation and hesitations that a child makes in a specially selected passage.

A technique known as miscue analysis[1] has developed, which although widely used with young readers, has not been investigated with older children except in cases of reading difficulties. Indeed, it is held that after the age of eleven or so children's reading is affected by factors which miscue analysis does not take into account. However, by listening to, or better still, recording, a student reading a passage it is possible to measure a number of variables apart from hesitations, which might have relevance to other exercises and possibly add another dimension to the study of the student's language.

One of these variables is time taken to read a given passage, as there are suggestions that a slow rate of reading is correlated with difficulties in comprehension (Watson, 1992 #49). To investigate this claim there must be some way of testing comprehension; asking the student questions about the passage is one possible way of looking at the reader's comprehension of the passage. Thus, in the exercise READING ALOUD I recorded the time taken for the student to read the passage, the number of hesitations made and the student's responses to five questions. In fact, two additional pieces of information were recorded, which will be discussed later.

6.2 Relevance to the teacher

Listening to an A level student read is a very unusual activity in a physics classroom. It is fair to say that the process of listening to individual students read is time consuming and it is possible that some students would find the idea bizarre or intimidating and resist participation. However, even given the time and student cooperation, can the results of the

---

1See 4.2iv for discussion of Miscue Analysis exercise be interpreted in a way that is meaningful and helpful to the teacher?

The teacher would wish to know whether measuring the number of hesitations tells him/her anything significant about a student's reading skills and if there is anything to be gained from listening to the pupil read and answer questions individually rather than following the normal pattern for comprehension exercises.

Realistically, there would have to be very good evidence to suggest that there are distinct benefits of this procedure to convince many physics teachers to try this type of oral exercise. Besides this, the question of whether similar results could be achieved with the student's own teacher doing the listening cannot be answered by this investigation.

6.3 Choice of passage

A passage of suitable content was sought which would be relevant to a student studying physics at this level without being particularly syllabus bound. Popular science articles, written in a lively way and having contemporary subjects which might interest young adults, were considered. Two news magazines TIME and NEWSWEEK were widely available in Kenya and both regularly carried science and technology features. After looking at several contemporary editions (Spring 1991), a report of 676 words on the possible dangers of low-power electric currents was selected as the passage to be read aloud. Although the style of this article is very different from the material adapted from textbooks which has been used in other exercises an assessment of readability using the standard tests was made. The results are as follows:

FRY	
READING AGE: GRADE 13 = 13 + 5 years	= 18 YEARS
FLESCH	
READING EASE	= 45%
(Parameters 55% = fairly difficult; 40% = difficult)	
MCLAUGHLIN'S SMOG	
READING AGE	= 19 YEARS

The reading assessment shows that this passage is marginally more difficult than others that have been set, but still within an acceptable range given that the students involved are 16+ and have some up-to-date background knowledge of the subject of electric fields. A slightly more difficult test is appropriate given the type of exercise which aims to look primarily at variables in reading styles and where all answers to the questions posed can be recovered from what has been read.

6.4 Aims of the READING ALOUD exercise

In terms of the objectives of the study, the purpose of this oral exercise is to address four of the research questions as follows:

Question 1 Distinguishing facets of reading skills
What variety is there in oral reading in terms of time taken and hesitation? Are there certain words in a passage which cause difficulty? How does comprehension relate to reading speed and fluency?

Question 2 Measuring reading skills
Are measurements taken of aspects of oral reading such as time taken and hesitations useful as an index of "reading ability" at this stage? Do these measurements have any relationship to other areas of pupil performance?

Question 3 Choosing texts and tests
Regarding readability of texts, how do results of this oral exercise compare with other forms of readability assessment? Would it be useful to identify pupils who have particular difficulties with this exercise? Is there any evidence that oral exercises are a useful procedure for teachers to carry out?

Question 4 Physics achievement
What do the results tell us about a pupil's understanding of physics? How do the results compare with conventional tests of physics knowledge and understanding and other exercises in this study?

6.5 Administering the test

In each school a quiet room was found where individual students arrived at 15 minute intervals having been excused from a physics practical. After introductions the student was told that s/he would be asked to read a passage aloud and would then be asked some questions about the passage. The student was asked if they objected to the reading and questions being taped. During the introduction, before the recording device was switched on the students were questioned about their mother tongue and also whether they ever read science articles in magazines. Most students seemed relaxed and happy to participate. In one school (School Y) students were anxious about how their performance would be graded and these students were reassured that the results of the exercise would not affect their school assessment.

6.6 Data Recorded

The text that the students were asked to read aloud can be found in **Appendix 8** labelled: READING ALOUD: Mystery and Maybe Danger in the Air.

The following data were recorded for each student:

1. The time taken to read the passage

There is evidence that fluent readers read more quickly and that fast readers may show better comprehension than slow readers.

2. The number of hesitations / stumbles

It is often suggested that, with younger readers at least, the larger the number of hesitations the greater the reading difficulty.

3. The responses to five questions which test recall and comprehension

(Students did not refer to the passage when answering these questions.)

a) Can you explain briefly what the passage was about?

b) Is the passage mainly about high or low power electromagnetic fields?

c) Are these fields ionizing or non-ionizing?

d) Have these effects been known about for a long time, or are they recent discoveries

e) The passage mentions a study done in Colorado, can you explain what this was?

4. Whether the word "causal" was pronounced correctly

Mispronunciation of "causal" as "casual" was found to be such a common error that given the possible implications that changing the word has for the meaning of the passage, the connection between the pronunciation and the other variables were noted.

6.7 Results

The results grids can be found in the **Appendix 9** labelled READING ALOUD: RESULTS GRIDS. The grids show columns for: time to read the passage (minutes/seconds), number of hesitations, points awarded for questions 1 - 5, point awarded if "causal" was pronounced correctly and the student's mother tongue.

The questions were marked as follows:

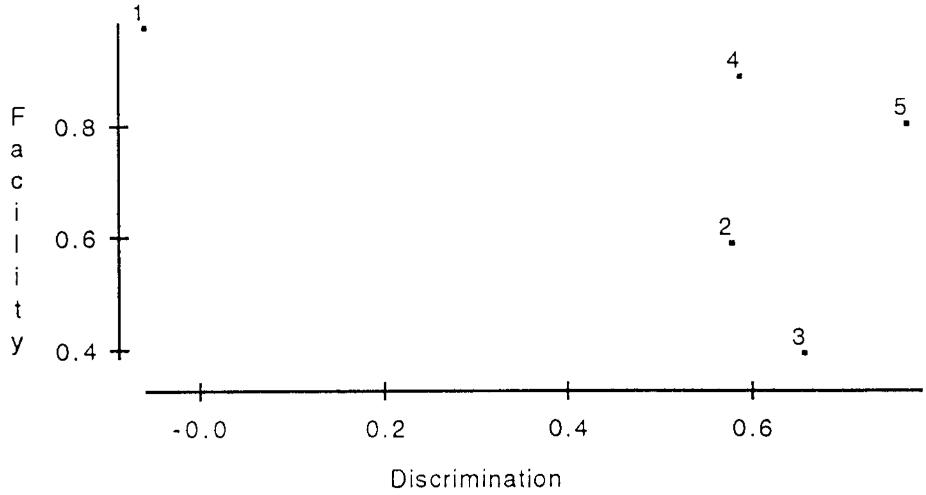
1) Some reference to main points such as: health risks / cancer due to low frequency electromagnetic fields (1 mark)
2) Low power fields (1 mark)
3) Non-ionizing (1 mark)
4) Dangers of low power fields only apparent relatively recently (1 mark)
5) Children living near powerlines found to have higher incidence of cancer (1 mark)

Forty six students were interviewed. One student struggled with the reading and requested that he was not recorded (although he insisted on finishing the exercise) and one set of results was incomplete due to a damaged tape. Thus a total of forty four pupils' work was recorded.

6.8 Reliability and performance

The facility and discrimination of the five questions, calculated in the same way as for the cloze tests (see section 5.4.5) are given in Fig 6.1

Fig 6.1 Facility and Discrimination of Questions 1-5



Apart from the first question which had a poor discrimination due to its extremely high facility, the other questions had much higher discriminations, but, possibly due to the very small number of questions here, the reliability of the test was not as high as the close tests, with Cronbach's alpha calculated to be 0.44. The results show a marked variation in the time needed to read the passage. The analysis which follows will attempt to show whether these variations are just random attributes of different reading styles and habits, or pointers to the student's language skills and understanding of the passage.

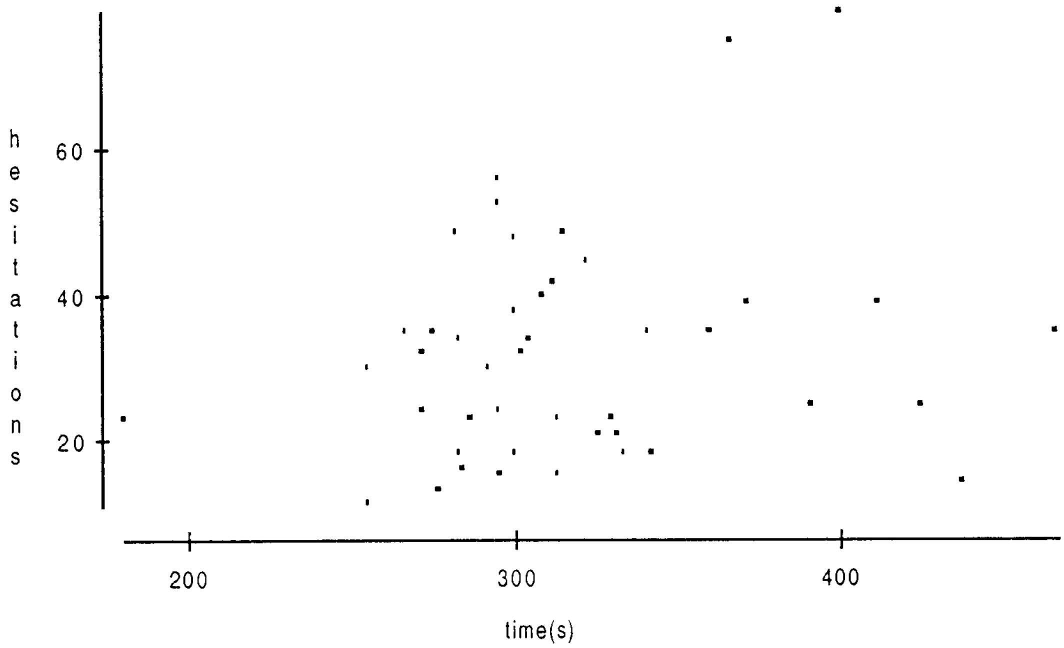
6.9 Patterns in results

6.9.1 Hesitation rate and time taken

Fig 6.2 shows the hesitations made and the time taken by each pupil. There is no obvious relationship between the time taken for a pupil to read the passage and the number of hesitations. This result implies that the **pupils who take longer to read the passage are not necessarily hesitating over individual words.**

Although for the group as a whole (n=44) frequency of hesitation and time taken do not seem to be linked, when the results for the slowest readers (time taken > 360 seconds) are looked at in more detail there appears to be a negative correlation between numbers of hesitations and time. For the slowest readers there could be a tendency to compensate for "lack of fluency" (more hesitations) by reading more slowly.

Fig 6.2 Number of hesitations made by pupils / time taken to read the passage.



Performing a cluster analysis on the points in Fig 6.2 will help to show how points can be grouped. This could be useful in explaining how students are performing relative to each other and how this relates to other aspects of this test.

Fig 6.3 Dendrogram showing the results of a cluster analysis on Fig 6.2

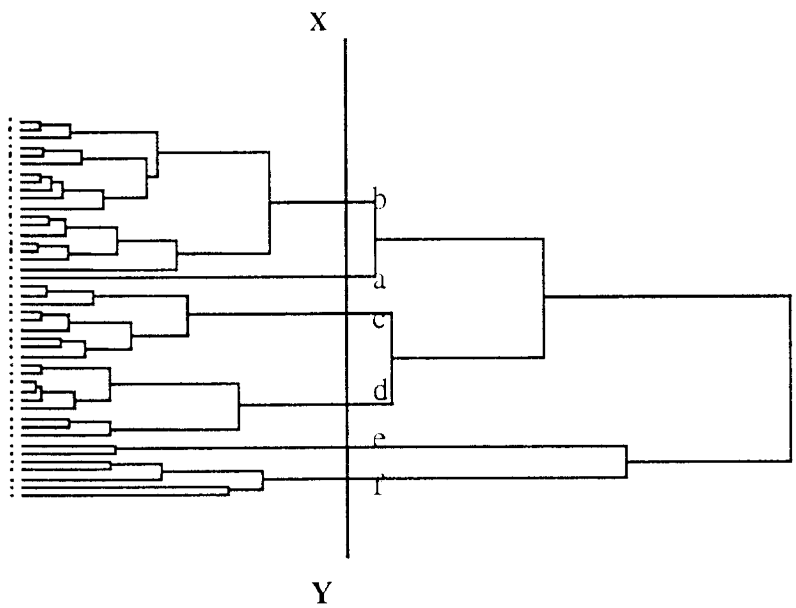
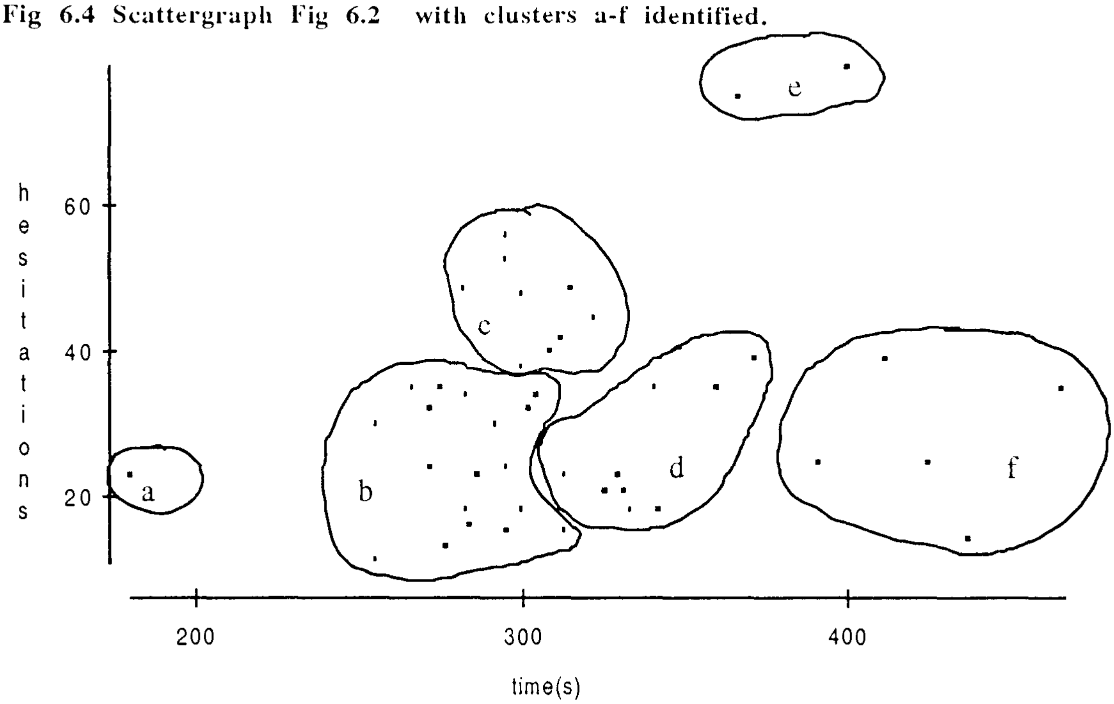


Fig 6.4 Scattergraph Fig 6.2 with clusters a-f identified.



The results of a cluster analysis (complete linkage) is shown in Fig 6.3. A vertical line, XY, is drawn though Fig 6.3 to show the level of grouping that will be considered. Six branches on the dendrogram, labelled a-f correspond to the groups with the same letter on the scattergraph Fig 6.4.

The characteristics of each cluster are as follows:

a - fast reader; low hesitation (< 5% total words read)

b - medium / fast reader ; low hesitation (< 5%)

c - medium speed reader; medium hesitation (6 - 9%)

d - medium / slow reader; low hesitation (< 5%)

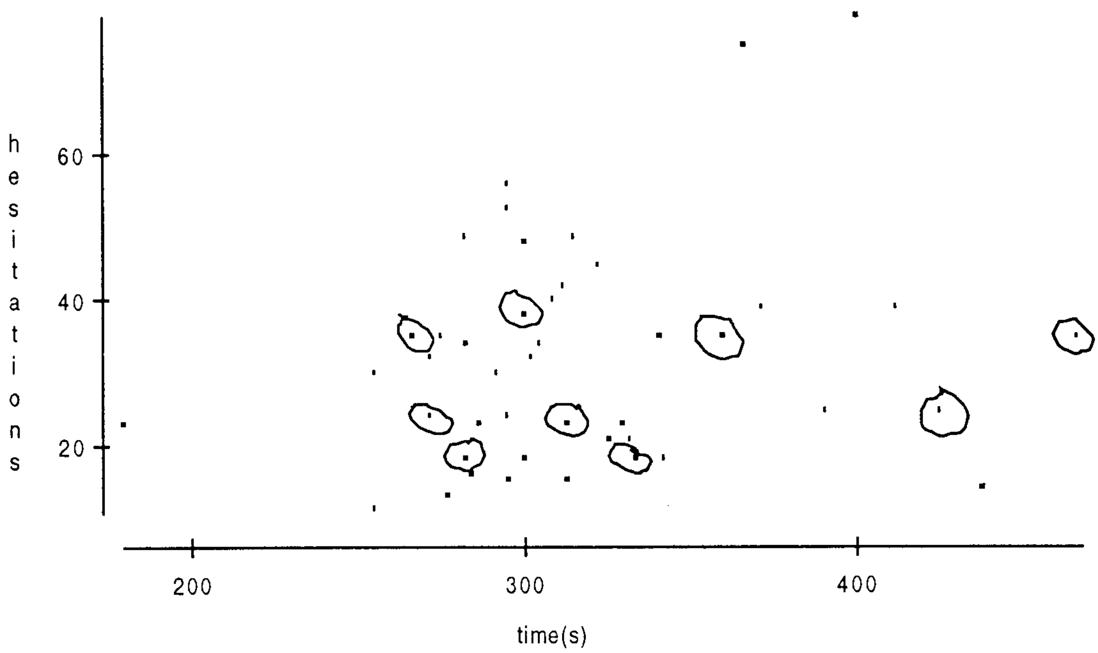
e - slow reader; high hesitation (> 9%)

f - slow reader; low hesitation (<5%)

The majority of points are found in clusters b, c and d where the range of time taken is from 255 - 372 seconds (41 % of total spread) and the hesitations from 11 - 56 (2% - 8% of total words read).

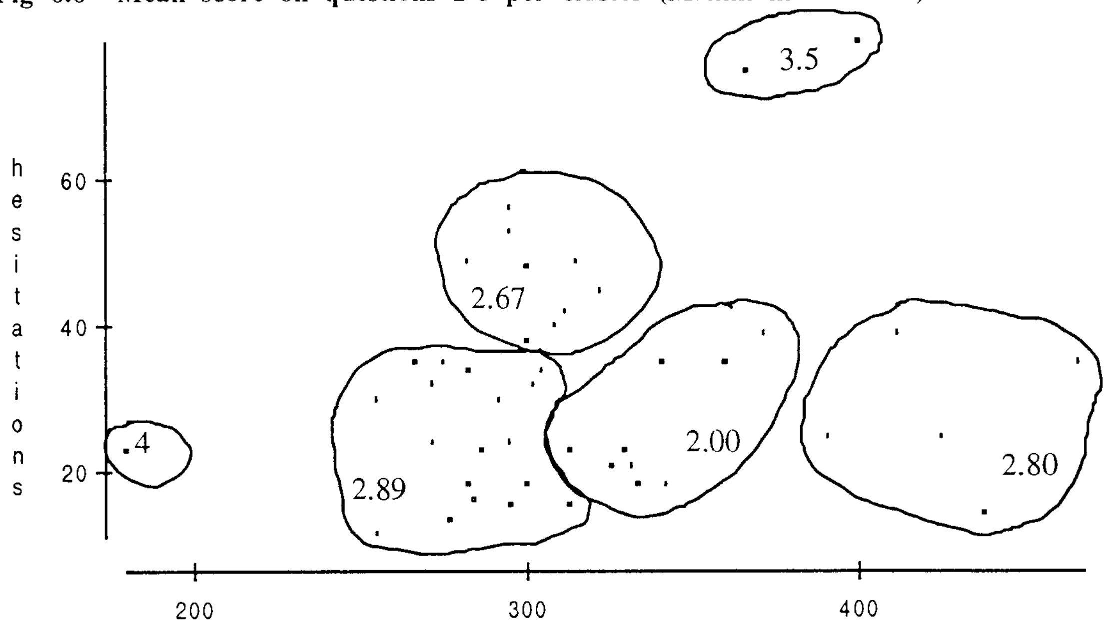
Fig 6.5 shows the hesitation/time scattergraph with the individuals who pronounced the word "causal" correctly. The nine pupils who did pronounce "causal" correctly are located in clusters b, d and f , that is, they seem to vary greatly in the amount of time taken to read the passage but hesitate over less than five percent of their words.

Fig 6.5 Hesitation/time graph showing correct pronunciation of causal (ringed)



Looking at how pupils perform in questions 2 - 5, Fig 6.6 shows the mean scores for these questions for clusters a-f.

Fig 6.6 Mean score on questions 2-5 per cluster (Maximum score =4)



This could indicate that pupils who are reading very slowly or hesitating frequently are trying to understand what they read, which leads to success in the short-term task of answering questions about the passage.

When A level grades are substituted for question score, the means shown in Fig 6.7 are found for clusters a - f.

Fig 6.7 Mean A level grade per cluster (Grade A=5,B=4,C=3, D=2, E=1, Fail=0)

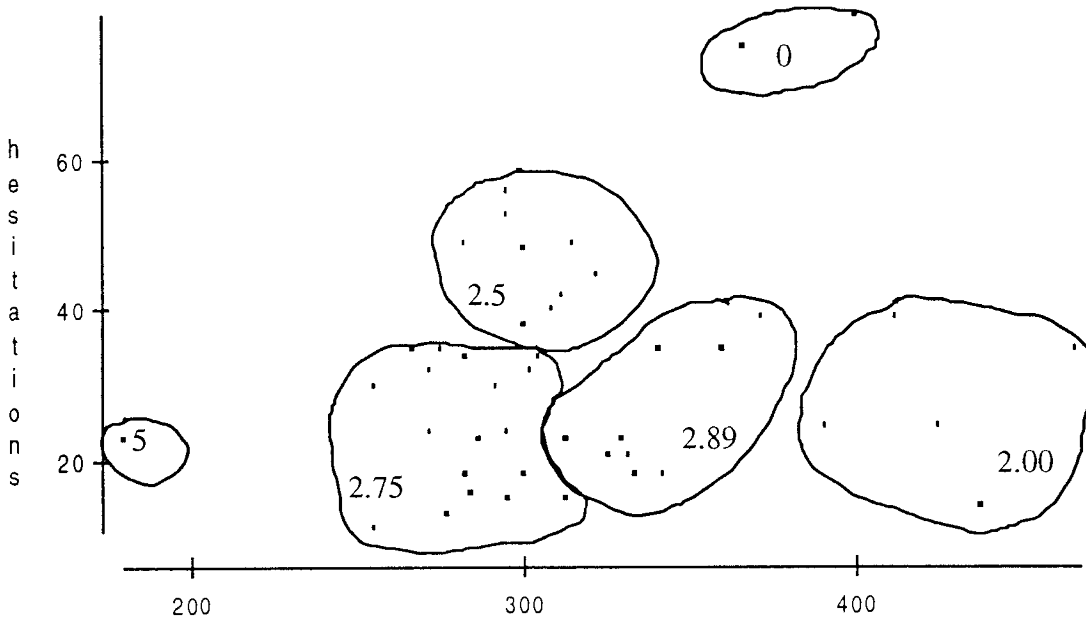


Fig 6.7 gives a more consistent picture of pupil performance than Fig 6.6, with clusters b,c and d closer together in terms of mean grade, but with a tendency to decrease in mean from left to right.

Comparing Fig 6.7 with Fig 6.6 it would seem that:

• the slow / hesitant readers do not do as well at A level as in the questions on the passage. These reading characteristics have limited or short-term benefits, but have no advantage for general progress in the subject.

• medium speed readers (clusters b,c and d) seem to be part of a homogeneous group in terms of mean "ability" as reflected in A level grades. The apparent advantage that moderate hesitations / fast readers had over moderate hesitations / slow readers in answering questions on the passage, is not maintained in A level grades.

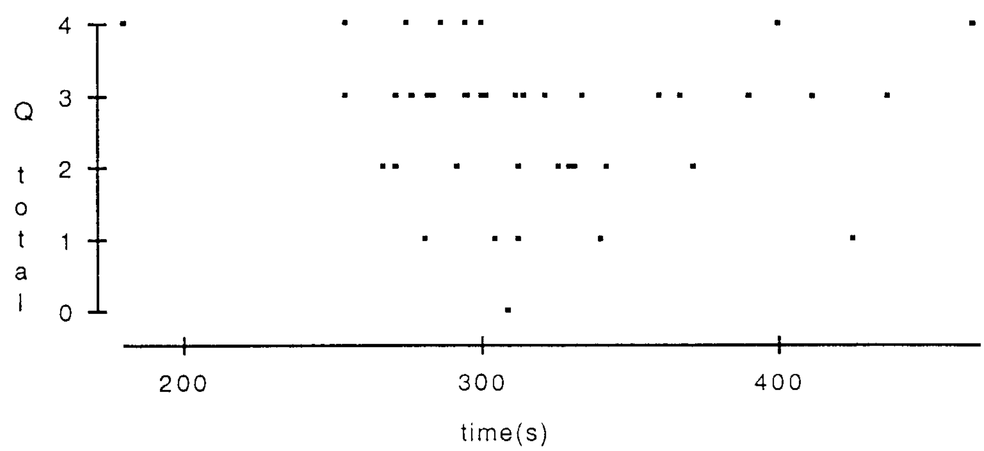
6.9.2 Reading rate and reading proficiency

Clearly, there is more to reading than acquiring speed or reducing hesitations. Miscue analysis (see 6.1) suggests that these relatively easily measured quantities relate to reading "proficiency" which includes the ability to comprehend the text. The next step therefore is to look more closely at a "measure of comprehension" and to see how this relates to reading and hesitation rate. This was the purpose of asking students questions about the passage and sections 6.8.2i and 6.8.2ii show how the variables time taken and hesitations made are related to question score. In fact, question 1 had such a poor discrimination it was removed from the analysis and the graph shows results for questions 2-5.

6.9.2i How question score relates to time taken

Fig 6.8 shows question score plotted against time taken to read the passage.

Fig 6.8 Graph to show total correct questions vs time taken



The scattergraph (Fig 6.8) shows an increase in the variability of time taken as score increases, but no particular correlation. However, if the nine slowest readers (time taken > 359 seconds[2]) are removed there is a correlation of -0.419[3] which is significant ($p<0.05$). This seems to suggest **faster readers generally have better comprehension than slower readers**. Although some pupils need to read slowly in order to understand the material and avoid hesitating, as argued in section 6.8.1

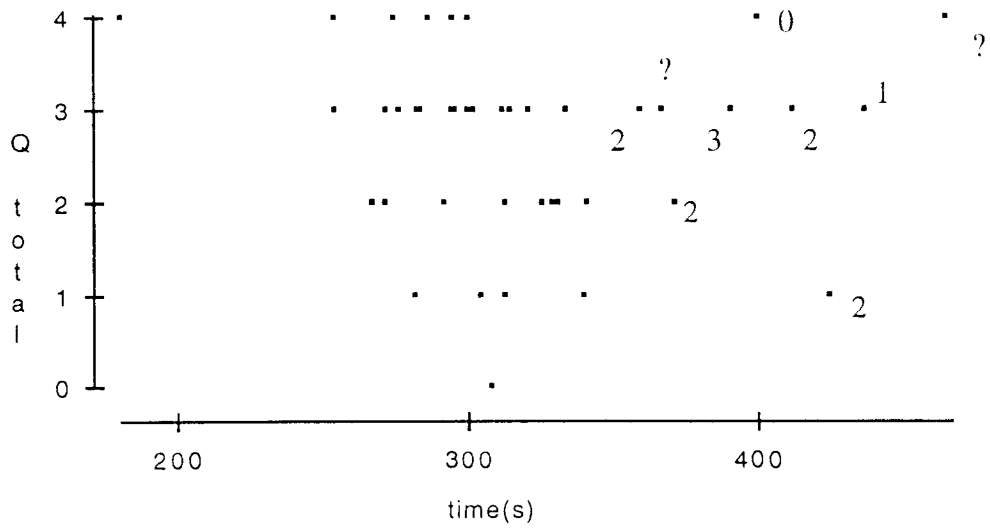
To inspect this group of nine of the slowest readers in more detail, it may be interesting to look at how they perform in some other test. Fig 6.9 shows the same scattergraph as Fig 6.8 but with the A level points of members of the slowest group shown.

---

[2] There is an 18 second gap between the ninth and tenth slowest readers which occurs at the 360 second level which is used as a line of demarcation between the "excessively slow readers" and the rest of the group. The case for regarding the "excessively slow readers" as a separate group is made in 6.8.1.

[3] To check the possibility that the fastest reader, who happens to score full marks in the question is not unduly affecting the result, this point was removed and the data re-tested. The correlation coefficient dropped to -0.367 but this was still significant (p,0.05).

Fig 6.9 Question score / time taken with A level grade points of slowest group



Among the slowest readers are pupils who scored low grades at A level as well as pupils whose results are not known because they did not complete the course at the same school (shown as ? on the graph). The mean A level points[4] of this group of the slowest readers (9 pupils) is found to be **1.714** whereas the mean of the remainder of the group whose results are known (28 pupils) is **2.818**. This difference is significant ($p<0.05$).

6.9.2ii How question score relates to hesitations made

Fig 6.10 shows the scattergraph of question score against hesitations made.

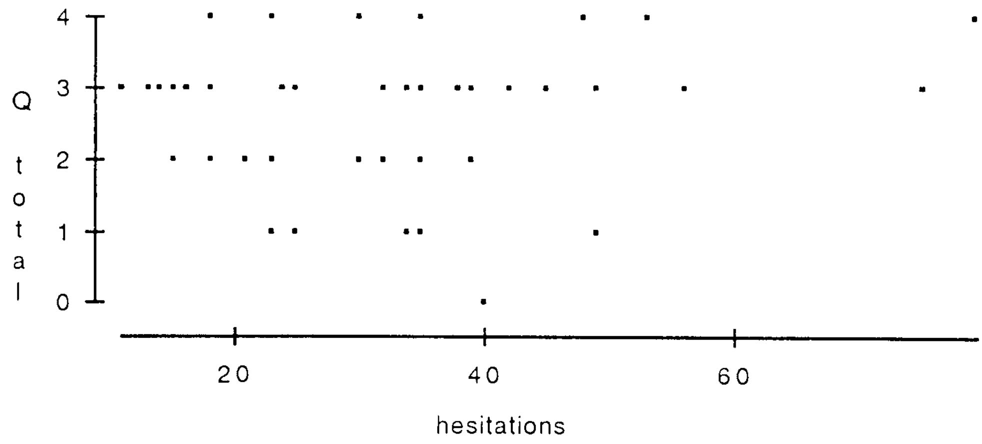
Like Fig 6.8, a "V" distribution of scores is shown which in this case means a greater variation in hesitations for higher question scores, a similar pattern to the previous graph of question score against time taken.

Nine pupils make 40 or more hesitations (>6% of total words), but even if a case could be made for removing these scores, the remainder do not have a discernible correlation.

---

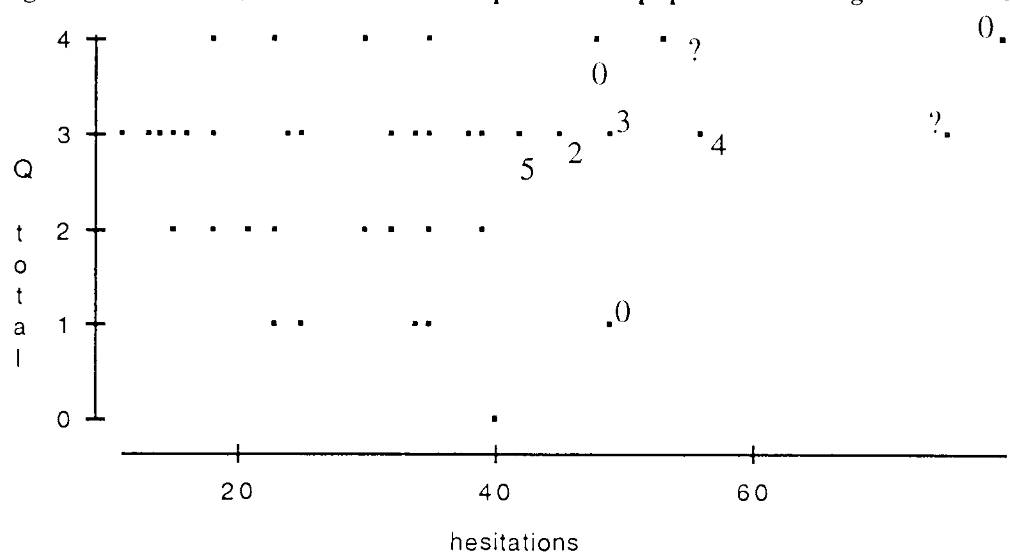
[4] 5 points for A grade, 4 points for B etc as shown in Fig 6.7

Fig 6.10 Graph to show total correct question vs number of hesitations



To investigate this group with high hesitation rates further, the A level score was inspected as in 6.8.2i. Fig 6.11 shows the same scattergraph as Fig 6.10 with the A level scores of the pupils with the highest hesitation rates.

Fig 6.11 As above, with the A level points of pupils with a high hesitation rate



Although this group contains some low scorers as well as pupils who did not complete the course, the scores are not significantly different from the rest of the pupils. So, we conclude that **pupils who make more hesitations are not in general likely to answer more questions wrongly** than other pupils. There is not any evidence to suggest that the pupils who hesitate most are less successful in the A level course.

The thesis proposed by miscue analysis that increasing hesitation points to decreasing reading proficiency is not supported by these results, if we assume that answering questions correctly reflects comprehension. One possibility is that the excessively slow readers who have a relatively low hesitation rate, referred to in 6.8.1 are masking a general trend in support of miscue theory. However, although when the hesitation scores of the three slowest readers are removed from the graph, the correlation coefficient does show an increase, though this does not become significant. So, hesitation rate does not appear to be as reliable an indicator of reading for these students as it has been shown to be for beginner readers.

6.9.3 Relationship to A level score

This section looks at the results of Reading Aloud in the context of the A level score of each pupil, where the latter is used as an indication of pupil's ability / attainment in physics. The purpose of doing this is to see how variables such as time taken reading, hesitations made and "comprehension" relate to pupil's eventual achievement in the subject, although it should be noted that the A level examination look place over a year after READING ALOUD.

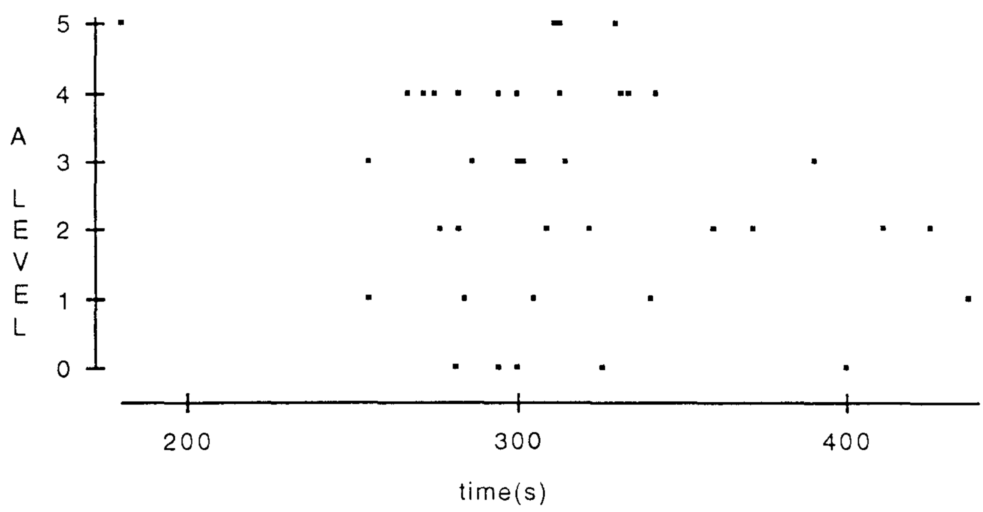
6.9.3i A level score and time taken

Fig 6.12 shows A level score plotted against time taken to read the passage.

There appears to be a slight negative relationship over the whole group, and the coefficient of correlation is - 0.346 which is found to be significant ($p<0.05$). Furthermore, there seems to be a "ceiling" on the A level score of the nine[5] slowest readers (those who took longer than 359 seconds to read the passage) at grade C or 3 A level points, which may indicate that "excessively" slow readers may be hampered in examinations by their reading rate.

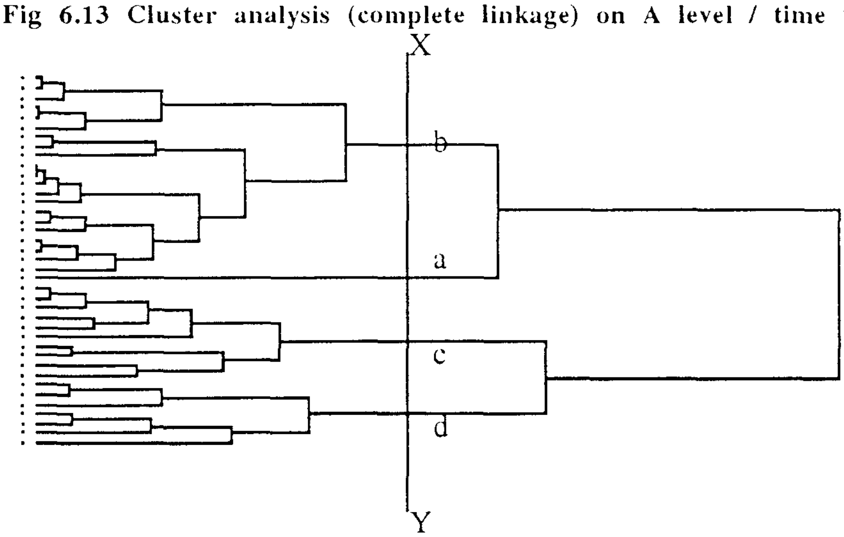
[5]Only seven of these pupils A level result is known.

Fig 6.12 A level score vs time taken to read passage



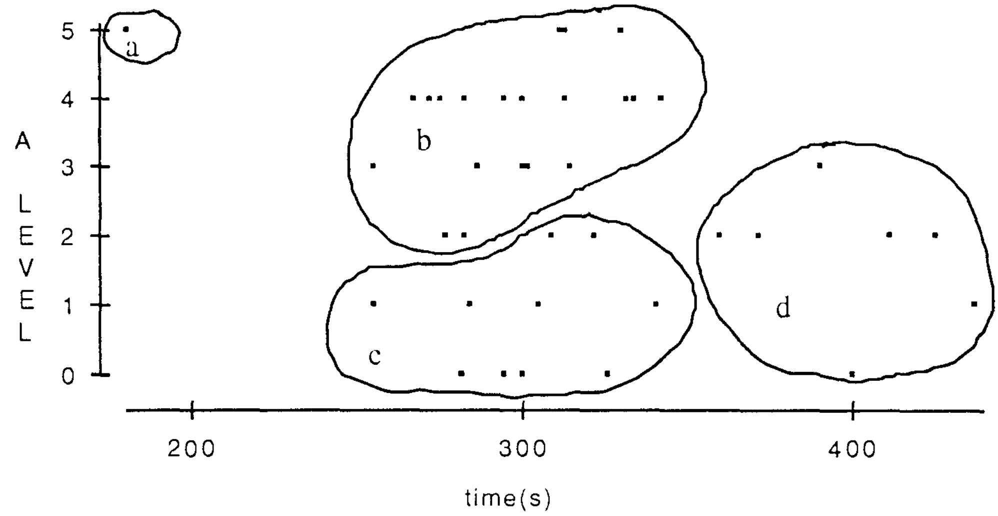
To inspect the distribution in greater detail, a cluster analysis (complete linkage) was carried out and the results are shown in Fig 6.13.

Fig 6.13 Cluster analysis (complete linkage) on A level / time taken data



On the dendrogram Fig 6.13 at the reference level XY, four clusters a, b, c and d are seen. These are identified on the scattergraph Fig 6.14

Fig 6.14 A level / time taken scores to show clusters



From this perspective the four clusters of pupils consist of:

a fast readers who score very well at A level (1 pupil, mean 5 points at A level)

b medium speed readers with medium / good A level results (20 pupils, mean 3.65 points)

c medium speed readers with low / medium A level results (10 pupils, mean 0.8 points)

d slow readers with low / medium A level results (7 pupils, mean 1.74 points)

The majority of the pupils whose results are in the scattergraph are "medium-speed" readers. The majority of these pupils have A level grade C or better. There is a difference between the A level scores of the medium speed group (b and c combined) and the slowest readers. This difference is statistically significant ($p<0.05$). However, there is also a significant difference ($p<0.05$) between clusters b and c the low scoring and high scoring medium speed readers. There is no significant difference between the scores of clusters c and d.

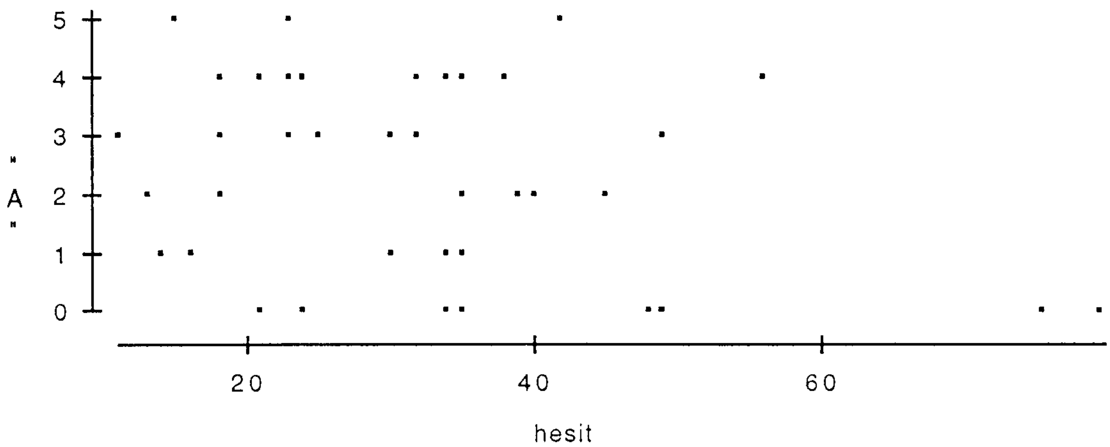
Another way of looking at the results which are suggested by the cluster analysis is to look at two major clusters the first consisting of clusters a and b and the second consisting of clusters c and d. These two clusters have means of 3.7 and 1.2 which are significantly different (0.01). Because of the overlap in the times taken by members of groups b, c and d it would be difficult to justify calling group b "faster readers" and c and d "slower readers".

Thus, all that can be said is that there appears to be a variety of medium speed readers, some doing rather well at A level and others faring not so well. Slower readers, however, tend to do less well at A level ~~and~~ consistent with the possibility is that their reading is one factor which may be hindering their progress.

6.9.3ii A level score and hesitations

Fig 6.15 shows a scattergraph of A level score plotted against hesitations.

Fig 6.15 A level scores vs hesitations



There is a correlation of -0.327 which is statistically significant at the 0.05 level, between A level results and hesitations, although the two points on the extreme right account disproportionately for this.

For most of the pupils there is not much evidence of a clear relationship between the number of hesitations and the A level grade which is eventually achieved.

6.10 Summary discussion of READING ALOUD results

Time taken to read the passage

This proved to be the most interesting variable. Having noted the great variation in reading time it was hoped to investigate the link between this and comprehension of the passage, measured by the score on the questions. Although a significant correlation was not found, a connection was detected between the final A level grade achieved and the speed of reading, in as far as pupils who are among the group of fast or moderately-fast readers, are more likely to achieve a significantly better grade at A level than pupils in the group of slowest readers. Time-limited reading exercises would have been a way of testing whether fast readers are consistently more successful in comprehending text in a given time. Since none of the exercises in this investigation were strictly time limited, the relationship between reading rate and performance cannot be compared within this study.

Number of hesitations

The majority of pupils hesitated over less than 5% of the words, which may endorse the suitability of the passage which the conventional reading assessments cited in 6.3 indicated. A simple relationship between number of hesitations and comprehension was not established. But, by looking at clusters of pupils with similar hesitation rates it was observed that the comprehension of the passage as reflected in the questions score, was slightly better for pupils with high hesitation rates. However, the A level grades for these pupils were lower. I suggested that pupils who had a high hesitation rate were searching for **meaning**, which had the short-term effect of raising their question score, but no advantage in overall progress in the subject as measured by A level results. This would seem to be consistent with the proposal that pupils who are struggling to make sense of what they read (and hence hesitating more) will be at a disadvantage when under examination conditions

An interesting relationship was noted between the number of hesitations made and the time taken to read the passage. The two variables appeared to be related for all but the slowest readers, who seemed to control or limit the number of hesitations they made, by reading much more slowly .

The responses to five questions

In fact, only questions 2 -5, which had reasonable discriminations were used. Facility and discrimination for the individual questions were good but perhaps there were simply not enough questions to adequately test the relationship of comprehension to time taken and hesitations made and that a larger battery of questions would have made a more powerful tool of investigation.

However, a statistically significant inverse relationship between questions correctly answered and time taken was found, provided the results from the six slowest readers were ignored. I suggested in section 6.8.1 that reading slowly may be an "alternative strategy". pupils who are aware that they need to read the passage extra carefully in order to be sure of answering the questions. This has the dual effect of depressing their hesitation rate and making it more likely that they answer questions correctly, but at the expense of making their reading time "excessively" long. The effect of limiting time in a similar exercise could have been easily investigated so that the "alternative strategy" hypothesis could have been tested.

Pronunciation of "causal"

This was widely mispronounced "casual" but there seems to be no particular advantage to students who did pronounce the word correctly. A question based on the causal/ casual link could have been useful, but the wrong pronunciation did not point to a lack of attention to the reading as was suspected. There were a number of cases of fairly random mispronunciations of other words, but it seems that in this exercise pupils were searching for generalities in meaning and almost had to overlook minor points in order to grasp the essential material. There is some evidence that pupils who make fewer hesitations are more likely to pronounce causal correctly, but the speed of reading is, apparently, not important.

Relationship with A level results

No correlation between A level results and the score on questions was found, but a statistically significant correlation was found for A level versus time taken and A level versus hesitations.

Scattergraphs show that the scores from a few individuals seem to produce these correlations. However, there is evidence based on analyzing clusters of pupils that faster and moderate-speed readers perform better, as a group, than slow readers.

Of course, there are undoubtedly many variables which affect pupils' final A level grade, but it makes sense to suppose that an efficient reader who can read both quickly and meaningfully would have a distinct advantage in a time-limited examination such as A level. The pupils in this study who were able to answer questions successfully and make fewer hesitations only by reading very slowly were unable to use this technique in the A level examination. The results may indicate that their reading may have been, at least, one disadvantage.

CHAPTER 7: THE COMPREHENSION EXERCISES

7.0 Introduction

The four exercises in this chapter share the characteristics of what are generally known as comprehension exercises. They are based on the format of having the pupil read a passage of text and answer questions based on or related to it. As discussed in section 4.2.2, comprehension exercises are routinely used as tests of understanding of the content of text in many subject areas. Where physics A level examinations entail a reading exercise, this usually consists of several paragraphs of text followed by a series of questions which test the pupil's interpretation of the passage. Frequently, the passage chosen contains a large amount of quantitative data which require mathematical skills to interpret, in which case the exercise is usually called a "data analysis".

Although data handling is not the focus of this study, two of the exercises chosen in this section involve the pupil in some numerical manipulation. Two other exercises involve using diagrams to represent information. Broadening the scope of comprehension exercises enables alternative forms of "active reading" activities to be scrutinized, as suggested in Chapter 4.

7.0.1 Purpose of the chapter

There is no doubt that comprehension exercises in the traditional mode of requiring written answers to questions centred around a text, are a rational and widely accepted form of text-based exercise. This chapter will look at the results obtained from four exercises which require written answers involving information recall, explanations and drawing conclusions from the text, as well as other forms of non-written[1] answers. Each exercise which comprises a passage and set of questions can be found in the Appendices, as can the tables of results for each exercise. Specific references to the appendices are given in the text.

Each exercise is described, discussed and analysed individually in the sections which follow. There will also be some comparison of results in this chapter

The analyses will attempt to establish from the results answers to the following questions which arise from three of the Research Questions (see Chapter 3 section 7):

---

[1] "Written" in the sense of continuous prose.

Question 1 Distinguishing facets of reading skills

What kinds of skills are needed to give different types of written answer and how does this compare with non-written answers? Is there evidence that some skills are indivisible or independent of others? If not, is there any pattern to show how they might be related? Can pupils' strengths and weaknesses be identified which could help improve future performance?

Question 3 Choosing texts and tests

Are different types of comprehension exercises suitable for various forms of text?

Are there trends or tendencies in the way pupils answer certain types of question which could be useful for a teacher to know, for example, are there advantages / disadvantages of using some forms of questioning?

Question 4 Physics Achievement

Are the exercises valid in assessing understanding of the physics content of the text? How do the results of these exercises relate to other forms of testing?

7.1 TYPES OF FORCES

7.1.1 Details of the exercise

This exercise, which can be found in **Appendix 10**, consists of a passage of approximately 650 words chosen from an A level student text which gives a qualitative introduction to the topic of forces and the nature of friction. A reading assessment carried out in the same way as for the previous exercises, shows that A level students [2] should find the passage fairly easy. Although the Fry and Flesch give similar results, the Smog method gives a higher reading age. However, this is partly due to the repetition of words with three syllables or more such as electromagnetic and gravitational, which do not necessarily increase the difficulty of the passage.

FRY READING AGE:	GRADE 9 or 14 years
FLESCH READING EASE:	64% (55% = fairly difficult; 65% = standard)
SMOG:	17 years

The paragraphs were numbered (1 - 9) for ease of reference and to facilitate comprehension.

There are three types of activity involved in this exercise:
Underlining: choosing the single most important phrase/sentence in each paragraph;
Drawing diagrams: representing the sense of each of four paragraphs;
Explaining: giving an explanation of a phrase in the final paragraph.

7.1.2 Relevance to the teacher

This exercise uses underlining and drawing to explore a text in addition to the more usual method of asking for written explanations. This could have two attractions for a teacher, firstly, posing interesting questions on fairly short, "straightforward" paragraphs and gaining meaningful replies is not always as simple as it sounds. By asking a pupil to underline the most important sentence in a paragraph the element of "prompting" where the question provides grammatical[3] or contextual clues, can be avoided. Secondly, comparing responses to the different types of question may be a more efficient diagnostic tool for the teacher, and this section looks at how results could be interpreted.

---

[2] Relative difficulty of the passage approximately between PROJECTILES and TIME.
[3] In "Giky martables" in *Language Teaching and Learning*, page 86 Clive Carré shows how students can "scoop answers out of a text by depending on context and not necessarily on understanding" (Carré, 1989 #36).

7.1.3 Mark scheme

QUESTIONS 1-4

"Underline one sentence or phrase which is the most important."

More than one sentence is selected	**zero marks**
A phrase or sentence selected (Question 1 only)	**one mark**
Phrase or sentence significant to the paragraph	**two marks**

QUESTION 5-8

"Sketch and label a diagram to illustrate the paragraph."

Q5

2 rough surfaces which touch in several places **one mark**

Arrows drawn at points of contact to indicate force of road on stone or possibly vice versa. **one mark**

Arrows drawn normal to the surface and labelled normal contact force. **one mark**

Q6

A diagram to show that the sum of the individual contact forces is a single vertical upward pointing force called the resultant contact force **two mark**

Q7

Normal contact forces skewed from vertical, against direction of travel **two marks**

or Horizontal arrow called friction with vertical (up) arrow called normal contact force

Q8

Either diagram of surface to show how individual contact forces add up to give a non vertical resultant **two marks**

or Diagram showing normal (vertical) contact force and horizontal friction/ air resistance forces added to give tilted force.

Q 9

"Students are asked to read para 9 and explain the phrase 'if there was no friction there would be no nails, no nuts and bolts, no screws etc'."

No attempt to discuss a situation where there was no friction	**zero**
Some attempt to say what would happen with no friction	**one mark**
Fuller account of the consequences of no friction	**two marks**
An analysis / illustration of one example of the absence of friction	**three marks**

TOTAL **20**

7.1.4 Discussion of mark scheme

Q1

Only one sentence was accepted for two points "In science etc". This captured best the sense of the first paragraph. Other sentences or phrases in the paragraph which were essentially examples of what this sentence stated were really not so important. For this question only, one point was awarded as long as the student had underlined not more than a sentence, since this is an important part of the instructions which the student has demonstrated an ability to follow.

Q2

As this paragraph was so short, a sentence in length, two marks were only given for "outside the nucleus..." including the names of the two forces. Students who underlined the whole sentence were given no marks since no discrimination has been shown. Clearly, this question is an anomaly since underlining the whole paragraph would have been true to the rubric of "underlining the important sentence". This situation could have been avoided by either expanding the paragraph to several sentences or stating in the directions that a phrase (perhaps of a given word length) was required.

Q3

This paragraph discusses electromagnetic forces and several sentences seem to say important things about these forces. However, the most all-embracing is "All forces of contact are electromagnetic forces". The first and second sentences elaborate on this. The sentence beginning "Whenever the atoms.." seems to be just a precursor to the subsequent statement. Thus, only "All forces of contact ..." was awarded two marks.

Q4

There are just three sentences in this paragraph and it was felt that each had its merits however, the first sentence was deemed to be the most significant, since the subsequent sentences are really illustrations of the first statement and two marks given for this only.

Q5

To obtain the first mark students had to label the rough surfaces "stone" & "ground" etc. For the second mark points of contact had to be made clear and some evidence of forces of contact at these points was necessary. If the force arrows were shown perpendicular to that particular plane of the rough surface the extra mark was given

Q6

The resultant contact force had to be shown as a surface force and not just vaguely floating for two marks. In cases where the arrow was labelled but not perfectly placed 1 mark was given.

Q7

Ideally this should have the same diagram as for Q5 with the contact forces sloping against the direction of motion, however evidence of forces opposed to the direction of motion called air resistance and/or friction in addition to the vertical contact force was sufficient. Friction arrows did not have to lie on the surface to obtain the mark.

Q8

A triangle of forces addition was sufficient for 2 points. Only one mark was awarded if the resultant was drawn incorrectly.

Q9

For three marks the student had to show that s/he had thought about the consequences of having only perpendicular contact forces in the world either by explaining at least one situation in detail or by giving new examples of things that would not be possible and why. Less detail but clear explanations was given 2 points. Brief descriptions about nails sliding out etc were given 1 point. Anything less given zero.

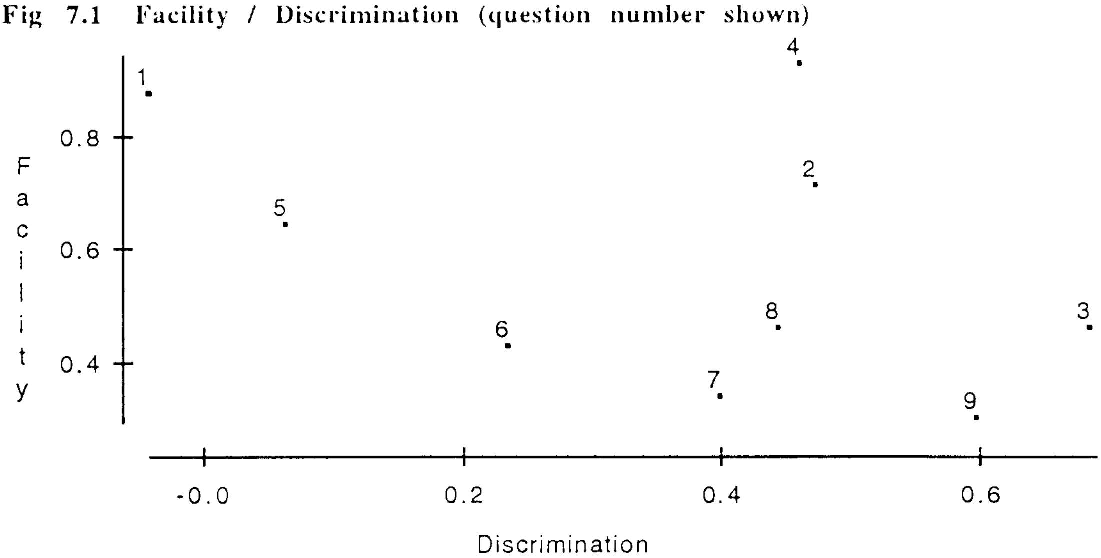
7.1.5 The results grid

The essential part of the students' response is given in the grid and the mark awarded for each question as well as the total score. The four pages of results together with the collated results which show the scores only, can be found in **Appendix 11** labelled TYPES OF FORCES Results Grids.

7.1.6 Patterns in results

The facility and discrimination of each question are shown in Fig 7.1.

Fig 7.1 Facility / Discrimination (question number shown)



Somewhat surprising at first glance is the variation in discrimination of questions of the same type. Questions one to four involve underlining, yet the discriminations of Q1 and Q3 are at the extremes of the range of discriminations. A similar difference in discrimination can be seen between Q5 and Q8 which are both diagram drawing questions. Both Q1 and Q5 seem to encourage guessing which may reduce the reliability and validity of this test particularly as there are relatively few items. The scores will be assessed from different viewpoints in the following four sub-sections.

7.1.7 Scores in different tasks

One picture of the students' response to the three different types of question is provided by Fig 7.1 (previous page) which shows a slight degree of clustering between the scores of three of the diagram drawing questions (6,7,8), but rather less for the underlining questions (2,3). Although, as a group, questions 1-4 have a facility that is statistically significantly higher ($p<0.05$) than questions 5-8, there is little other evidence from the plot that the difference in the responses can be attributed directly to the tasks which the questions demands.

To investigate relationships between types of questions correlations between the responses were calculated and Table 7.1 shows the correlation between the scores for each question .

Table 7.1 Correlation between Questions 1 - 9

Pearson Product-Moment Correlation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	1.000							
Q2	-0.311	1.000						
Q3	-0.106	0.272	1.000					
Q4	0.176	-0.204	0.282	1.000				
Q5	0.199	-0.051	-0.249	-0.168	1.000			
Q6	-0.330	0.230	0.208	-0.464	0.108	1.000		
Q7	-0.486	0.149	0.395	0.111	-0.354	0.200	1.000	
Q8	0.249	0.273	-0.007	0.095	0.107	0.136	-0.043	1.000
Q9	-0.214	0.188	0.350	0.509	-0.234	-0.089	0.263	-0.012

Plotting scores from the four underlining questions (1-4) against the four diagram - drawing questions (5-8) shows no particular relationship which means that students who score well in these three underlining questions do not necessarily score so well in the three diagram drawing questions and vice versa.

Scores from question 9 which requires an explanation for an answer, have a correlation coefficient of 0.509 ($p<0.01$) with one of the underlining questions (Q4), but there is no correlation with any of the diagram drawing questions. This could point to a similarity in the tasks of underlining and explaining which is not present between diagram drawing and explaining.

7.1.8 How the questions are categorized

Each paragraph in the passage is numbered and related to the question of the same number. As stated above, altogether three types of task are asked for in this exercise, namely underlining, diagram drawing and explaining. Questions which seem to require careful reading of the text and no specialist knowledge of the subject, I have designated as *Language-based* , whereas those that seem to require a specialized knowledge of physics, I have called *Physics-based* .

7.1.8i Language-based questions

Question 1

"Underline one sentence or phrase which you feel is the most important in this paragraph".

Paragraph one has 121 words with the key sentence embedded in the middle, the idea that precise definitions of words are important in science is explicitly stated. Underlining the most appropriate sentence should follow simply from the reading and hence can be considered a "language-based question".

Question 5

"Sketch and label a diagram which shows what the written information means. Use arrows to indicate forces".

Paragraph five is a short paragraph which describes a fairly simple image. Two features that will gain a point each from the mark scheme are stated clearly. It should be possible to draw 2 jagged lines which touch in a few places and thus gain two out of three marks, without using specialist science knowledge.

Referring again to Fig 7.1 it is interesting to note that questions 1 and 5, the two language-based questions, have the two lowest discrimination indices (both less than 0.1) This suggests that comparing language-based questions even when different tasks are involved, does not distinguish between pupils as well as physics-based questions.

7.1.8ii Physics-based questions

Most of the exercises in this section relate to *forces* to some extent and hence I called them subject-based.

Questions 2,3 and 4

"Underline one sentence or phrase which you feel is the most important in this paragraph".

Paragraph two is a single sentence where the essential meaning appears to be very clear, but although the facility is fairly high the discrimination is only moderately good. Gaining the marks, however, relies on distinguishing the appropriate phrase from the sentence, which could be considered to be a language skill.

Paragraph three looks more difficult. It is a densely worded paragraph of over 150 words and the key sentence is a statement which is probably a surprise to most students at this level. Nevertheless, it seems highly dependent on a good knowledge of electromagnetic forces. The relatively low facility (0.45) and the high discrimination (0.7) reflect the demands the question makes on specialist skills.

Paragraph four has only three sentences and seems much easier to understand than the previous paragraph, with the first sentence picking out the theme of the paragraph. Again, the ability to distinguish a general statement from examples is important, and because of the specialist content of the statements may be dependent more on familiarity with the subject than reading skills. A high facility is shown for question four (0.9), but a moderate discrimination (0.45).

Question 6 and 7

"Sketch and label a diagram which shows what the written information means. Use arrows to indicate forces".

Paragraph six is a single sentence but the diagram needs some experience of the stylized representations of objects and forces. The student has to recognise that the statement refers to "the stone resting on the road" from the first sentence of the previous paragraph, and the whole stone rather than the surfaces which the previous question dealt with. This inference is only possible from having experience with this type of representation. Having said that, it is also a fairly straightforward example, and Fig7.1 shows that although the facility is moderate (0.45) the discrimination is low (0.25) indicating that some lower scoring students are able to gain some points here.

Paragraph seven and paragraph eight carry the theme of "forces on the stone" forward with similar skills being required as in paragraph six but increasing complexity. This is matched by the increase in discrimination of questions 6,7,8 (0.25, 0.4, 0.45 respectively) as shown in Fig 7.1.

Question 9

"Explain what the author means in paragraph 9 by, "if there was no friction there would be no nails, no nuts and bolts, no screws etc."

Paragraph nine seems to supply all the information needed to answer the question but phrases such as "component of a contact force" assume background knowledge. The question gives no clues as to how to answer the question so confidence in giving written explanations would be useful too. This question has the lowest facility of all, but despite this the discrimination is fairly good.

7.1.9 Looking at types of errors made

Where marks have not been scored for a question, it may be useful to establish, for diagnostic purposes, the type of error being made. Here a comparison is made between student responses to an underlining question (Q3) and a diagram question (Q7). The objective was to compare two questions with a similar facility and discrimination. Fig 7.1 shows Q3 and Q8 satisfy this criterion. However, Q8 is linked to and dependent on the context of Q7. Since Q7 has only a slightly lower facility and discrimination and is relatively independent of previous context the responses to Q7 are examined.

Question 3

"Underline one sentence or phrase which you feel is the most important in this paragraph".

Table 7.1 shows the errors made by 10 low scores (total score<10) and 10 high scorers (total score 12+) An attempt is made to grade the responses into a hierarchy, where "no response" is classified as the lowest level of skill and so on.

Table 7.2 Errors made in Question 3

Response	Low scorers	High scorers	Comment
Blank	2	-	Paragraph too long/difficult
2 sentences underlined	2		Misunderstood instructions
Whenever the atoms of one object ...	3	-	Does not link with e.m.forces
Since all atoms have charged particles ..	1	3	Does not link with contact forces
..but is used in rather a special way involving	1		An example only
In the vast majority of mechanics problems ...	1	1	No mention of contact forces
Electromagnetic forces exist between moving or stationary charges.		1	No mention of contact forces

Of the ten students who scored less than 10 marks in the exercise all failed to score in this question, which contributes to the high discrimination mentioned in 7.1.5iii. Four of the low scoring students have demonstrated a **low level of skill** by either not underlining anything in this paragraph or underlining more than one sentence.

It is assumed that the paragraph is linking electromagnetic forces with contact forces and the key sentence contains an important statement concerning these two elements. Most of the alternative statements shown in table 7.1 fail to mention one of these elements. Some of the sentences pick out important statements about one of the element, but others such as "Whenever the atoms of one object..." do not. It is notable that this particularly empty statement was chosen by three of the low scorers.

As expected, fewer higher scorers than lower scorers fail to answer the question correctly (half as many), but more interestingly, the higher scorers tend not to make the kind of "low level" errors that lower scorers do.

Question 7

"Sketch and label a diagram which shows what the written information means. Use arrows to indicate forces".

Eight of the low scoring and three of the high scoring students gained no marks for this question, these results being summarized in Table 7.3.

Table 7.3 Errors made in Question 7

Response	Low scorers	High scorers	Comment
(i) Blank	3		Question too difficult
(ii) Diagram showing arrows only	1		Misunderstands instructions
(iii) Diagram showing a stone on a slope	2		Misunderstands paragraph, infers sliding means down a slope.
(iv) Diagram showing stone on a flat surface with inappropriate, unlabelled arrows.	1	1	Direction and nature of forces involved unclear.
(v) Diagram showing stone on a flat surface with unlabelled arrows pointing right and left.	1	2	Direction of forces responsible for movement known.

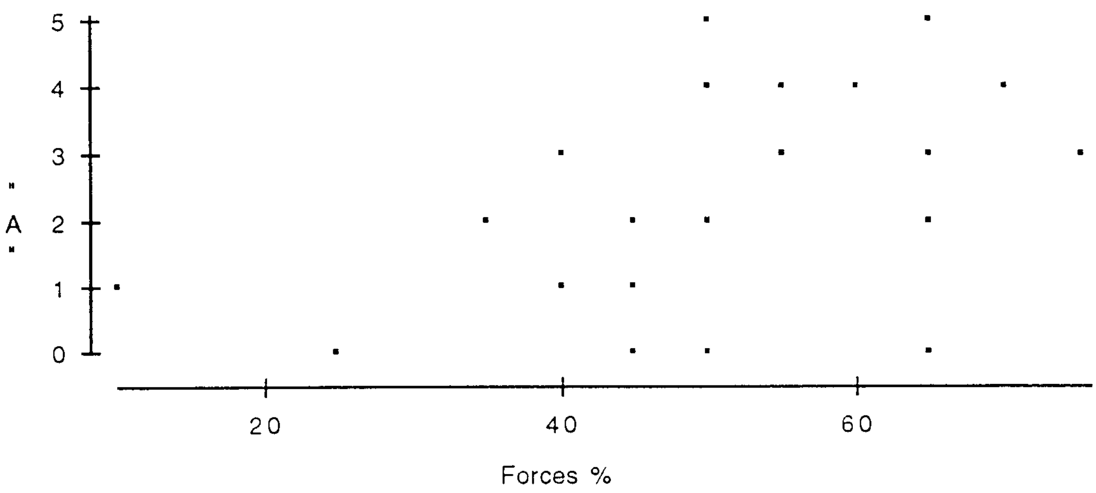
Responses (i), (ii) and (iii) in Table 7.3 suggest a low level of skill where the student cannot answer the question or misunderstands the question and the situation described in the paragraph; (iv) suggests that the student has some idea about the situation depicted, but is unclear about the direction of the forces involved; (v) some knowledge of the forces involved is shown.

Again, the responses show that high scoring students make responses which show a higher level of skill than low scoring students.

7.1.10 Relationship with other results

Fig 7.2 plots the FORCES score against the A level grade point of each student.

Fig 7.2 FORCES scores / A level points



A **correlation of 0.406** is found, which is statistically significant ($p<0.05$). However, there are no correlations with the results of any of the cloze tests or the Reading Aloud exercise.

7.1.11 Summary of FORCES exercise

Of the three types of task asked for in this exercise underlining seems to be easier than others but responses to questions of the same type do not correlate so there is not much evidence of a distinct skill of "underlining" or "diagram drawing". The correlation between scores on Q4 with those of Q9, the explaining question, may indicate some consistency between the underlining task and explaining task.

Questions which rely on careful reading of the text only, have the lowest discrimination of all. The increasing discrimination of question 6, 7 and 8 matches the increasing complexity of the physics in the three questions.

Low scorers seem to be make disproportionately more errors indicating lower levels of skills than high scorers. Low skill levels includes not answering questions, misunderstanding or failing to follow the questions' instructions or giving completely inappropriate answers.

The significant correlation between FORCES scores and A level grades, but not with the cloze or READING ALOUD exercises might indicate that the skills involved in this test are relevant to A level but not other language-based exercises.

7.2 INTERNAL RESISTANCE

7.2.1 Details of the exercise

This exercise, which can be found in **Appendix 12**, is more typical of the kind given to a physics class at this level than the last exercise, in that problem solving/arithmetic are involved. The calculation aspect should be a device for getting at the underlying principles, which, in this case are: conservation laws, definition of p.d. and ohmic and non-ohmic circuits. Of course, "getting the right answer" is important in questions involving calculations, as is "showing all your working" as students are constantly exhorted to do. However, a correct calculation does not necessarily mean understanding of the underlying principles although this tends to be what many teachers assume. This exercise asks numerical and non-numerical questions related to the passage, but also draws on information not given in the passage. It is important to distinguish these elements for the purpose of analysis and to compare the responses to questions which cover essentially the same material, but which ask the question in different ways.

7.2.2 Selection of the passage

The passage was taken from one of the standard physics texts given to A level students.A passage of 550 words was found and the readability assessed by the Fry, Flesch and SMOG methods used with other exercises:

FRY READING AGE:	GRADE 12 = 12 + 5 years =17years
FLESCH READING EASE	47% (Parameters 55% = fairly difficult; 40% = difficult)
SMOG:	18 years

The problems with measuring readability in this exercise are dealing with the formulae and word equations. A word equation is regarded as a collection of individual words whereas an equation using symbols is regarded as one word, this has the effect of increasing the syllable count which will contribute to the relatively high reading age. The three methods, however, give similar results.

In choosing this particular passage a number of well-known text books were compared, but there was little variety in the way authors approach the topic of internal resistance of a cell. However, this passage begins with a reference to an observation which almost all students should have made either from their own experiments or through demonstration, possibly even in the O level course. The student is then led into thinking about the consequences of this observation in terms of the definition of the quantities involved and their mathematical and dimensional relationship. The end point is the arrival at a formula which students are expected to be able to use to solve numerical problems. In fact, the formula itself is very simple and should not cause difficulty at this level, however, the fact that the "lost volts" cannot be measured directly, needs to be carefully explained, and relies on a firm grasp of the fact that current flow is constant throughout the circuit. The term potential (usually p.d. at this stage) does seem to cause panic among some students and can lead to students experiencing unnecessary difficulty with this straightforward topic. This passage sticks to referring to energy supplied or changed per coulomb in addition to setting out the salient points of the argument clearly.

7.2.3 Relevance to the teacher

There are several reasons why this exercise is relevant:

Firstly, since the topic is straightforward with only a few important concepts to understand, setting this exercise would be a simple way of identifying at the beginning of the topic of electricity, students who are having difficulty with the key concepts.

Secondly, as the passage is found in a popular set book, it may be a suitable way of introducing students to reading from texts.

Thirdly, the questions can be adapted to suit the concerns the teacher has for his/her particular class. Since the "comprehension exercise" is a generally accepted tool for assessment and to some extent, learning, exercises of this type have a training aspect which the teacher may wish to exploit as a learning device.

7.2.4 Mark scheme

Questions 1, 2 and 3

"The effect of internal resistance can be seen when a bus or car starts with the lights on. Suppose the starter motor requires a current of 100A from a battery of e.m.f. 12 V and internal resistance 0.04 Ohms to start the engine".

"Q1. How many volts are lost?"

Correct answer with unit (i.e. 4 volts)	1 mark
Some evidence of "working" i.e. substituting into Ohm's law	1 mark

"Q2 What is the terminal p.d. of the battery with the starter motor working?"

Correct answer with unit (8 volts)	1 mark
Subtracting answer from Q1 from 12 volts (emf)	1 mark

"Q3 Why do the lights dim if they are designed to operate on a 12V supply?"

Lights will be dimmer because they are operating on 8 volts pd	1 mark
although the emf of the battery is still 12 volts	1 mark

Question 4

"The phrase "energy supplied per coulomb" occurs several times in the text. Explain what you understand by this phrase."

Definition of pd 1 mark

Question 5

"The symbol V is called "useful volts". Is this perfectly true, explain."

No 1 mark

Reason 1 mark

Question 6

"There is another word in the passage used to describe lost volts, what is it?"

Wasted pd (internal pd allowed) 1 mark

Question 7

"What is a "low-voltage supply", where and why are you likely to use one?"

A good example such as a lab.power pack (not car battery) 1 mark

Question 8

"To measure e.m.f. precisely an instrument is required which draws _______ current."

Zero 1 mark

Question 9

"It is suggested that internal resistance is not constant. Name one factor which might affect the internal resistance of a cell."

Temperature / current 2 marks

Total **14 marks**

7.2.5 Discussion of mark scheme

"Q1. How many volts are lost?"

The student has to use Ohm's law for v=Ir, which is stated in the passage, v is called "lost volts", so the answer can be derived solely from the passage, but almost certainly students will have met this idea elsewhere. There seemed to be little problem with the "working" but a few students failed to calculate the correct answer and some neglected to give a unit which was also penalised by one mark.

"Q2 What is the terminal p.d. of the battery with the starter motor working?"

This seemed to cause more problems than the first question which, in most cases, was due to students failing to see the relationship between e.m.f. and terminal voltage when current flows. In the formulae, V is called "useful volts" and also "p.d. across R". However, the fact that the p.d. across R is the terminal p.d. is established in the first paragraph. So, this seems to be the crucial point that has been missed by some students.

"Q3 Why do the lights dim if they are designed to operate on a 12V supply?"

The important thing here is to realise that it is not that the starter motor is in use that is causing the lights to dim, but the fact that the large current drawn is making the p.d. "lost" inside the battery significant. This question is therefore very important in assessing understanding and has links with the previous question.

"Q4 The phrase "energy supplied per coulomb" occurs several times in the text. Explain what you understand by this phrase."

Change in energy per unit charge is the definition of p.d. — this is actually stated in the passage and the student will have come across this definition elsewhere.

"Q5 The symbol V is called "useful volts". Is this perfectly true, explain."

The answer is really given in parentheses in paragraph 1, but it is something that would have been discussed before.

"Q6 There is another word in the passage used to describe lost volts, what is it?"

Again, this uses the fact that changes in energy per unit charge is the definition of p.d. whose unit is the volt; as mentioned in paragraph 2. Internal p.d./volts was allowed since it is a logical extension of the idea of internal resistance; p.d. across r was also given the mark.

"Q7 What is a "low-voltage supply", where and why are you likely to use one?"

This question tries to make links with students' own experiences, by asking for an example of a low voltage supply; the answer anticipated was the lab. "power pack" which usually gives a maximum output of 24V. Very few students gave that answer. The students who were given a mark tended to give general explanations such as a "low voltage supply is used when a mains supply would be dangerous", which seemed to rely more on common sense than actual experience of a physics laboratory.

"Q8 To measure e.m.f. precisely an instrument is required which draws __________ current."

The answer zero (or "no") can be inferred from the final paragraph of the passage.

"Q9 It is suggested that internal resistance is not constant. Name one factor which might affect the internal resistance of a cell."

Here students are asked to recall a factor which can affect resistance. They have certainly looked at how some resistors are affected by temperature and this is the most obvious response. In this case it is not the ambient temperature which will be significant but the temperature changes caused by the current. Since the question asks for one factor a point was given for each; only one student established the connection between current and temperature and was given two marks.

7.2.6 Exploring the questions

As mentioned in 7.2.1, the questions in this exercise differ in how far they depend upon the text and the precise skills required to answer each question correctly. Table 7.2 compares each question with respect to four criteria: the physics content of the answer, whether or not the text provides the answer, which other questions, if any, link with this question and the sorts of skills that answering the question requires. By grouping questions it is hoped to further compare individual responses to look for possible relationships in skills in different tasks or understanding of various concepts.

Five groups of questions can be distinguished from Table 7.2., these are:
Q1&2, Q2&3, Q7&9,Q1 &6 and Q1,2 &6.

Q1,2 These questions involve calculations.

Q1 is a straightforward question involving a very simple substitution and calculation; students will have met this type of question many times in their O and A level courses.

Q2 is similar to Q1, but to answer this correctly the student has to see that "terminal voltage" and "useful volts" refer to the same quantity. As far as the passage is concerned this information can be gleaned from two paragraphs and so giving the correct response probably indicates that the student is able to integrate information, which is a "high order"[4] reading skill.

Q2,3 are really looking at the same thing but Q2 involves a calculation whereas Q3 requires an explanation.Q3 is probably the most searching question on the content, and a good answer should encapsulate all the key points that are being made in the passage.

---

[4]Levels of reading skill, see Bullock definition Chapter 2.

Table 7.4 Comparison of questions

Q	Content of answer	Does text provide answer?	Link with other questions?	Skills involved
1	lost volts, v,v=Ir calculation	√√√		recognize v, substitute, calculate, give unit
2	terminal p.d.,useful volts V rearrange E=V+v	√√	Q1	recognize terminal p.d. = V rearrange,substitute,calculate
3	emf,V,different because of p.d. drop across r, *when current flows*	√√√	Q2	distinguish emf/V explain difference due to current flow through cell
4	dW/dQ definition of p.d.	√√√		recognize definition of p.d.
5	work done overcoming resistance of wires "wasted"	√√		distinguish "input" from "output"
6	lost volts, "wasted"W/Q p.d. across r/internal p.d.	√√√	Q1	recall alternative name
7	low voltage supply what it is and where used	no		connect with laboratory experience
8	internal resistance only becomes significant when current flows	√√	Q1, Q2	recognize significance of current in emf measurement
9	temperature affects resistors,current affects temperature more than than ambient temperature	no		recall behaviour of resistors

(√√√ = question/answer use same words; answer obvious with minimum scanning
√√ = answer involves more than one paragraph, some scanning /word substitution)

Q7 and Q9 both ask for information not supplied in the passage. Admittedly the answers are not interdependent, but looking at the responses comparatively might give some idea of which students are able to relate to "background information" most easily.

Q1 & 6 relate to "lost volts" although in different ways, one requiring a calculation and the other a suitable alternative word from the passage

Q1,2 & 8 are concerned with the current flowing through the battery.

7.2.7 Exploring the results

Students' responses to each question are shown in the grid given in **Appendix 13.** Initially, questions are compared by the facility and discrimination of the responses which are shown in the scattergraph Fig 7.3. and their correlations shown in Table 7.5.

Fig 7.3 Facility / Discrimination of INTERNAL RESISTANCE questions

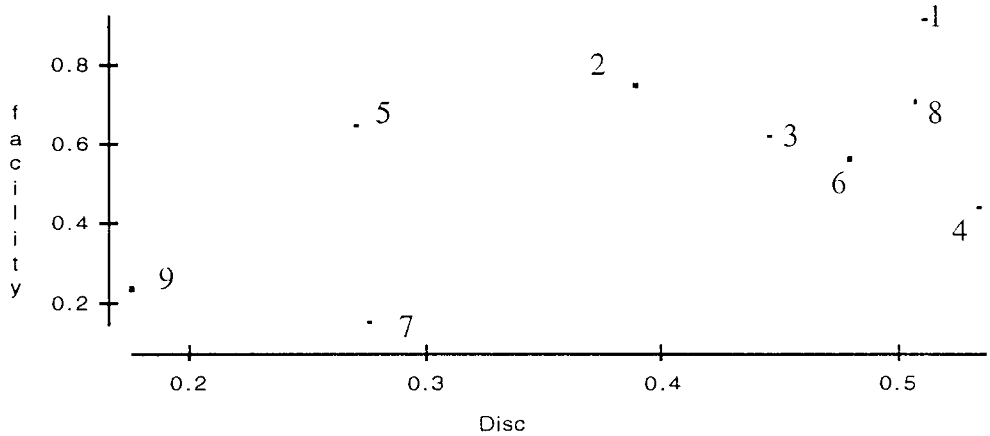


Table 7.5 Correlation of responses to INTERNAL RESISTANCE questions

Pearson Product-Moment Correlation

34 total cases
of which 3 are missing in at least one variable.
Pairwise deletion of missing cases.

	1	2	3	4	5	7	6	8
1	1.000							
2	0.285	1.000						
3	0.242	0.047	1.000					
4	0.115	0.054	0.302	1.000				
5	-0.103	-0.064	-0.223	0.159	1.000			
7	0.192	-0.342	0.219	0.483	0.044	1.000		
6	0.255	0.161	-0.064	0.012	0.121	-0.012	1.000	
8	0.417	0.113	0.041	0.253	-0.116	0.259	0.110	1.000
9	0.000	-0.034	0.000	-0.280	-0.108	-0.247	0.285	0.000

The facility of most questions is high with reasonable discrimination, but the two questions with the lowest facility have poor discrimination. These are **Q7 & Q9**, neither of which have answers given in the text. It seems that their low facility leads to the low discrimination. There is a small negative correlation (-0.247) between responses on the two questions, which is not significant. The conclusion from this is that although the tasks were similar, the two questions rely on specific background knowledge that is not linked in any way.

The two questions involving calculations **Q1 and Q2** have descending orders of facility and discrimination. There is a small but non-significant correlation (0.285) between Q1 and Q2 which seems surprising. However, Q1 asks *"how may volts are* *lost?"* whereas Q2 asks *"what is the terminal p.d. of the battery with the starter motor working?"*. There may be a more direct connection between Q1 to the formula "V=IR" than "terminal p.d." to the relevant formula. Furthermore, "terminal p.d." is only stated once in the passage in the last paragraph, but there are at least four ways in which "terminal p.d." is referred to in the passage, "p.d. across R", "V", "useful volts" and "energy CHANGED per coulomb by external circuit".

Q2 & Q3 have broadly similar facility and discrimination indices, but question 3 which asks for an explanation of why the car lights dim when the starter motor is turned on is found to be more slightly more difficult with slightly better discrimination than question 2 which requires a calculation of the terminal voltage when the starter motor is switched on. There is a negligible correlation (0.047) between the responses to these two questions. Calculating the correct terminal voltage does not lead the student directly to what may seem, from the teacher's point of view, the obvious conclusion regarding the dimming of the lights

Q1 is easier and more discriminating than Q6. Although both questions are concerned with "lost volts" the correlation coefficient is only 0.255, so it may be that the two tasks (calculating in one case, and finding an alternative word from the passage, in the other) are not necessarily easy or difficult for the same students

Q1,2 & 8 all three questions which involve internal resistance are fairly easy, although Q1 & Q8 have higher discriminations than Q2. Q1 & Q8 have a correlation coefficient of **0.417 which is significant at 0.05 level**. Again, it seems that overlapping of ideas rather than similarity of task is responsible for this relationship.

An unexpected correlation which was statistically significant ($p<0.05$) was found between Q4 and Q7. Q4 has the highest discrimination of all the questions, whereas Q7 has one of the lowest. They are both fairly difficult questions according to Fig 7.3, and they are both concerned in some way with "voltage". Q4 is about the definition of p.d. which is a difficult concept at this stage as it defines the relationship between two highly abstract quantities and Q7 requires recall of a "low voltage" supply. The tasks the questions set seem to be very different, yet the correlation of responses points to a connection between the questions which must be based on the overlapping of ideas.

7.2.8 Relationship with other results

There is no significant correlation between the results of this exercise and other exercises, including the previous comprehension exercise FORCES. Although there appears to be some degree of positive correlation between the scores, only 16 students produced results to both tests. However, as Fig 7.4 shows there appears to be a correlation with the scores of this exercise and the final A level grade points which is calculated to be **0.563**. This is statistically significant ($p<0.01$).

Fig 7.4 Scores of Internal Resistance / A level

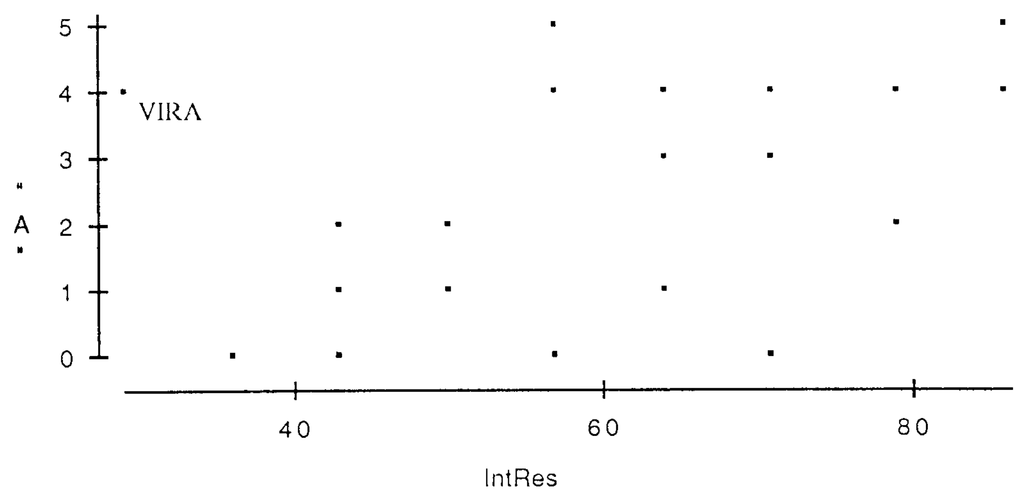


Fig 7.4 indicates one particularly anomalous result, with the lowest scoring pupil VIRA gaining four points at A level (grade B). This pupil failed to score more than one mark out of a possible four for the first two questions which were the calculations, only one other pupil did this and he also failed the A level (shown 0 in Fig 7.4). This seems to account for VIRA's displacement so far to the left of Fig 7.4 . It seems unlikely that VIRA had difficulty with such simple calculations, but this cannot be checked satisfactorily in this study. Certainly, given his results on the cloze exercises (ERRORS 88%, TIME 80%, PROJECTILES 64%) his reading competence is good, and no clear explanation of this result can be offered at this stage.

7.2.9 Summary

The results of this exercise suggest that questions which are broadly covering the same material correlate better than questions that involve similar tasks on slightly differing topics. However, the connection between the material has to be very obvious in order for a statistically significant correlation to be seen.

Correlations between responses seem to be very sensitive to the wording of the question. When there are two questions on more or less the same theme and one question uses terminology which is less familiar or more complex than the other, there is less likelihood of correlation between the questions.

The correlation of the results of this exercise with A level results yet not with the other exercises examined so far in this study suggests that this "traditional-style" comprehension test has more in common with the skills required at A level than those used in language-related exercises. But, as 7.2.8 points out there are interesting variations in the pattern of student answers that will be addressed in a later chapter.

7.3 DAMPED OSCILLATIONS

7.3.1 Introduction to the exercise

The questions in this exercise are related to the material in the passage and less dependent on knowledge not directly related to the topic discussed. The passage, which is an extract of an A level textbook, contains very little mathematics and is concerned with the energy losses from oscillating springs and developing this to look at suspension and shock absorbing systems.

7.3.2 Relevance to the teacher

The topic of damping is quite short, usually following the much more complex introduction to s.h.m. which faces the student with often unfamiliar mathematics. The study of damping can be a good opportunity of reviewing key concepts such as the relationship between energy and amplitude of oscillation, how and why frequency is affected by friction and to extend the discussion to suspension systems, shock absorption and what it means to have a "comfortable ride". The questions attempt to look at the interpretation of phrases in the passage to assess understanding of basic concepts, and also look at the student's ability to apply knowledge by considering non-oscillating systems such as skiers and hydrofoils. It is sometimes convenient for the teacher to give an extract or page reference to the text as a reading exercise and to follow up or supplement with questions which interrogate progressive levels of reading and understanding. To this end this exercise looks in some detail at different types of interrogation of the text where background knowledge is re-awakened rather than relied upon entirely to answer questions.

7.3.3 Selection of the passage and readability

The passage is quoted directly from *Physics* by Robert Hutchings (Hutchings, 1990 #50), p151 - 153, although minor changes have been made to remove references to other pages and also to change the phrase "Bend zee knees" to "Bend the knees" (page 2 paragraph 2). Hutchings uses "Bend zee knees" as a pun based on German speakers' pronunciation of the "dh" [5] sound. However, as many students involved in the study spoke English as their second language, I thought it best to eliminate this possible source of confusion.

---

[5] Pronunciation of "the" in Chambers 20th Century English Dictionary is "*dhe*". .

The passage was extracted as continuous prose; the writing and four diagrams from the text were photocopied and pasted onto an A4 format (See DAMPED OSCILLATIONS) in **Appendix 14**)[6]. The appearance of the passage was like an extract from a textbook, and the photocopying was clear and legible. The questions on page three were typed and spaces left for students to fill in answers.

The passage was chosen because it was thought to be interesting, have clear relevant diagrams and be fairly easy to read. The latter opinion is supported by the following:

FRY READING AGE:	= 14 years
FLESCH READING EASE:	= 62 (65 = standard 55=fairly difficult)
SMOG	= 16 years

The passage has a similar level of difficulty to TYPES OF FORCE and should be easier than INTERNAL RESISTANCE.

7.3.4 The students and the test conditions

The exercise was given to the physics groups of all four schools and a total of 43 student responses were collected. The exercise was given for a homework so it is not known how far the answers were discussed amongst the students.

[6]Although p 3 of the exercise is in the original format p1 and p2 have been typed out again since the originals were lost.

7.3.5 Mark scheme

Question	Responses	Mark
2a Explain: "the total mechanical energy of the oscillating system".	some explanation of "total mechanical energy" relation to "oscillating system"	1 1
2b Explain: "the amplitude is reduced in a large number of oscillations".	definition of amplitude interpretation in terms of "light damping" or over a long time	1 1
2c Explain: "the damping is slightly under critical damping"	description of critical damping implications of "slightly less..."	1 1
2d Explain: "damped by a shock absorber".	prevented from normal oscillation by a damping device called a shock absorber	1 1
2e Explain: "active suspension".	senses unevenness in vehicle's path adjusts hydraulics to give correct height	1 1
3 The passage says: "Not only does friction have an effect on the amplitude, but it also has the effect of reducing the frequency slightly." Why should this be so?	loss of k.e. leads to loss in velocity hence T and f	2
4 Describe briefly, in your own words, a car's suspension system.	springs and shock absorbers connected between wheels/body further description of how damping gives comfortable ride	2 1
5 How do the thighs and calves of a good skier act like a damped spring?	legs do not oscillate like springs, but can change length using muscles to maintain c.o.g. of upper body in the same plane	2 1
TOTAL		**18**

7.3.6 Discussion of the questions

Question 2 a- 2e

"Find the following phrases and explain in your own words as fully as you can, what they mean"

Questions which refer back to phrases in the text and ask for clarification are thought to encourage reflective reading. It would be sensible to select phrases which cover the key ideas or information of the passage. One would normally expect these to be more or less evenly spread throughout the passage, if not, the content of the passage would seem out of balance and imply to the student that sections of the passage are irrelevant. The instructions given to the student are: "explain in your own words as fully as you can, what the phrases mean". Before writing an answer a student will have to make several decisions, based on questions such as:

- which are the key words of "content and/or process" ?
- do I explain the key words "individually" i.e. is a definition needed?
- do I explain the words in the context of the passage?
- which clues are available from the rest of the passage to guide my response?

Identifying the key words is as much a matter of recognizing grammatical clues as of understanding the words themselves. For example, if in 2b the phrase quoted was "x is reduced in a y" it is obvious that the identity of x and y are required for the phrase to have meaning. However, if an explanation of x and y are expected but a student considers one too straightforward to define, no credit can be given even though this might mean that the word is well "understood" by the student. "Overlooking the obvious" is a tendency which teachers try to coach pupils to overcome, especially at exam time, but it may cause a problem in the analysis if students are failing to mention words they find too easy.

It is not specified in the question whether to explain words individually or in their context in the passage, so it is reasonable to expect students to do either or both, but the criteria for the quality of the definition must include to some extent how the word fits in with the sense of the phrase.

Question 3

"The passage says, "Not only does friction have an effect on the amplitude but it also has the effect of reducing the frequency slightly." Why should this be so?"

This question is related to 2a in that friction results in a loss of mechanical energy of the oscillating system. The student has to make the connections between kinetic energy and velocity and reduced velocity and longer period / lower frequency, both of which would have been met at GCSE and certainly in the introductory mechanics in the A level course, but there are not many prompts in the passage to help the student remember these relationships.

Question 4

"Describe briefly, in your own words, a car's suspension system."

That the car's suspension system consisting of springs and shock absorbers connected between the wheels and the body of the car, is given clearly in the passage. The question however does not merely ask for a list but a description, so, although it could be argued that "springs" are self-evident and require no explanation, it is by no means clear what a "shock absorber" actually is. Although damping is referred to in terms of increased friction, how damping occurs is not made explicit. To answer the question correctly the mode of action of a shock absorber must be mentioned, this may well come from some previous knowledge if the inference in the passage is not taken up.

Question 5

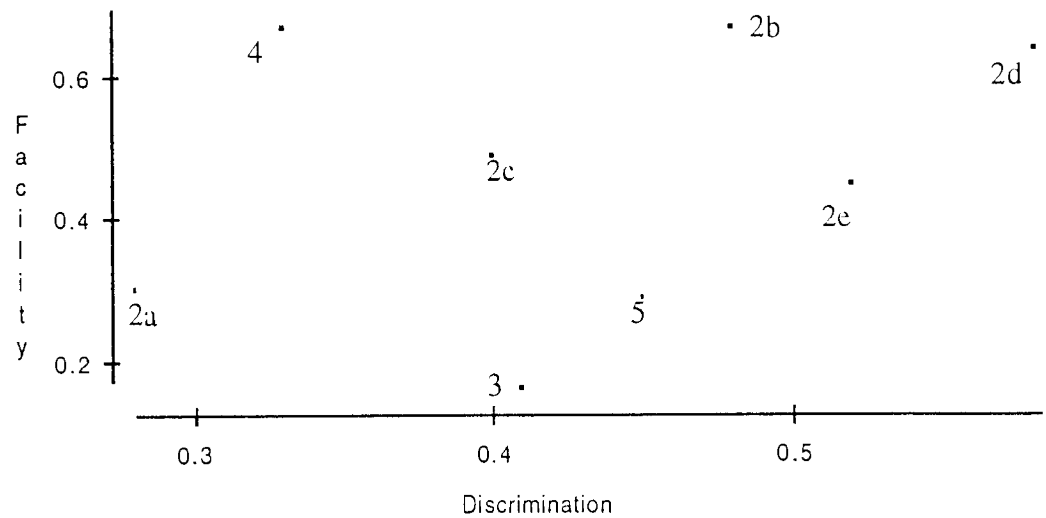
"How do the thighs and calves of a good skier act like a damped spring?"

To answer the question the student has to make clear how the skier's legs can change length. Shock absorbers must be described so that it is clear that they provide springs with resistance to their motion and preferably, how they do so. There is a connection here with the last point in the previous question and it seems unlikely that a pupil who did not gain that point would be able to score full marks with this question. It is possible that some pupils interpret "absorb shock" in what might be termed a naive way, and that reading the description of a skier riding over bumps will challenge that belief. It would be interesting to note the actual wording of student responses for this question in order to investigate this possibility more fully.

7.3.7 Exploring the results

The results grids for this exercise are found in **Appendix 15**. A scatterplot of the facility and discrimination of the responses is shown in Fig 7.5.

Fig 7.5 Facility / Discrimination of DAMPED OSCILLATIONS questions



The responses have lower facility than those from the previous exercise INTERNAL RESISTANCE, but the discrimination of the items is moderate to good.Those questions with low facility are 2a, 3 and 5. As noted in 7.3.6 questions 2a and 3 are related in that they both deal with the energy of the system, while question 5 asks for a comparison between a skier's legs and a damped spring.

It is puzzling that the facility of 2a was low. I had thought that this question would be fairly easy, since the term "total mechanical energy" would be familiar to the pupils. Whereas, I expected 3 to be difficult as the pupil would firstly have to recognise that friction resulted in a loss of "total mechanical energy to the system" and secondly to make the connection between loss of energy and reduction in frequency. Similarly, the legs and thighs of a skier do not have an obvious connection with a damped spring except at a sophisticated level of abstraction.

To inspect the **relationship between responses**, correlations were calculated and are shown in Table 7.5, where the three correlations greater than 0.320 (shown in bold) are significant ($p<0.05$).

Table 7.5 Correlation of responses to DAMPED OSCILLATION

	2a	2b	2c	2d	2e	3	4
2a	1.000						
2b	**0.329**	1.000					
2c	0.049	0.107	1.000				
2d	-0.104	0.091	**0.453**	1.000			
2e	0.031	**0.497**	-0.035	0.156	1.000		
3	0.093	-0.035	-0.076	0.125	0.003	1.000	
4	-0.067	-0.061	0.034	0.149	0.061	0.093	1.000
5	0.086	0.091	-0.028	0.004	0.041	0.257	-0.170

Questions 2a - 2e all require explanations of phrases from the passage, although from Fig 7.5 the responses appear to have little in common, except that the discrimination of 2b, 2d & 2e are not very different. In fact, the responses of the following correlate significantly at 0.95 confidence: **2a with 2b** (0.329), **2b with 2e** (0.497) and **2c with 2d** (0.453).

As mentioned in the previous paragraph 2a concerns energy and this could be a cause of its difficulty. To answer the question satisfactorily student needs some familiarity with the meaning of "energy".

To answer question 2b which correlates with 2a, the student must understand "amplitude" and "oscillation". These two words have relatively simple definitions and are observable quantities. Furthermore, the passage refers to a diagram "Fig 10.18" given on the first page which shows a graphical representation of gradually decreasing amplitude, which should leave the student little scope for error. It is plain that 2b is the simpler of the two questions and students who can answer 2a successfully are also likely to cope with 2b, which helps to explain the correlation.The low correlation between most of the questions may point to the test having a low reliability and this will be discussed further later.

7.3.8 Further item analysis

The results of the exercise so far are disappointing. Although the facility and discrimination are both fairly good, there is no immediately visible pattern to the results. This section will scrutinize the assumptions which I have made in setting and marking the questions and compare the predicted to the actual response. Table 7.6 shows whether the question was thought to be a physics-based question or reading-based question, the predicted and actual facility and discrimination classified into 3 groups low, medium and high, as well as the correlation of the responses to scores on firstly, ERRORS and secondly A level grade. The point of finding the 2 correlations was to use ERRORS scores as an indication of each pupil's "reading skills" and A level scores as an indication of physics competence.

Table 7.6 Item Analysis of Damped Oscillations

Q	Reading /Physics	Predicted fac /disc	Actual fac /disc	Correlation to ERRORS	Correlation to A level	Scope of question & Comment
2a	P	medium fac. low disc	low fac low disc	0.060	0.418	Energy. Pupils good at physics can access this information best.
2b	P	high fac low disc	high fac med disc	0.318	0.012	Amplitude. Seems to favour "good readers".
2c	P	med fac high disc	medi fac med disc	0.212	-0.253	Damping. Wording of phrase may be confusing.
2d	P	med fac high disc	low fac high disc	0.325	0.020	Shock absorber. Good readers more likely to answer well.
2e	R	med fac high disc	med fac high disc	0.565	-0.051	Active suspensions. Favours good readers
3	P	low fac high disc	low fac low disc	0.034	0.062	Friction/frequency. Good students cannot access their physics knowledge & reading skills do not help.
4	R	med fac low disc	low fac low disc	0.254	-0.170	Car suspension. Good reading seems to help slightly.
5	P	med fac high disc	med fac med disc	0.201	0.097	Legs/damped springs. Reading seems more important than physics.

In general, correlation of responses to questions with ERRORS is greater than with A level which might suggest that the exercise is slightly more dependent on aspects of reading skills which are not particularly measured by A level. Question 2e in particular, which asks about "active suspensions" has a statistically significant correlation ($p<0.01$). This is also one of the few questions where results match the prediction which was based on the fact that the relevant information is retrievable from the passage.

The one question that correlates statistically significantly ($p<0.05$) with the A level score is question 2a. It was expected that a question about "total mechanical energy" would be fairly straightforward in terms of physics content and the correlation shows that pupils who scored highest at A level also tended to get this answer right. The fact that the discrimination is low for this question means that able pupils, those who go on to do well at A level, are not doing particularly well overall in this exercise.

A possible clue as to why this is the case is suggested by the response to question 3. This question asks for an explanation of why friction decreases the frequency of oscillation, which requires physics knowledge not given explicitly in the text. Yet, pupils who have more competence in physics are not getting this answer correct.

This could be because the relationship between frequency and friction is difficult to explain, or, because the language is fairly complex: "Not only does friction have an effect on the amplitude but it also has the effect of reducing the frequency slightly". It might be fair to ask whether pupils actually understand the question, or whether some "able" pupils are being confused by the language as seems to be the case in 2c: "the damping is slightly under critical damping".

7.3.9 Relation with other exercises

Table 7.7 shows the correlation of the scores of DAMPED OSCILLATIONS with other exercises and the A Level results. Entries in bold are significant at a probability level of 0.05 or less.

Table 7.7 Correlation of DAMPED OSCILLATIONS with other exercises

Exercise	Correlation coefficient
INTERNAL RESISTANCE	-0.085
FORCES	**-0.470**
PROJECTILES	**0.541**
TIME	0.017
ERRORS	**0.467**
A LEVEL	-0.085

There are statistically significant positive correlations with the results of PROJECTILES ($p<0.01$) and ERRORS ($p<0.05$), both of which are cloze exercises, but not the third cloze exercise TIME.

There is little correlation with INTERNAL RESISTANCE (-0.085) one of the previous two comprehension exercises. The other comprehension exercise FORCES has a significant negative correlation with DAMPED OSCILLATIONS of -0.470. This seems rather puzzling, but as Fig 7.6 shows one point on the far left of the scattergraph is unduly influencing the apparent correlation. Removing this point reduces the coefficient of correlation to -0.383 which is not significant.

There is also no discernible correlation with the A level scores as Fig 7.7 shows. Two pupils who obtained A grades at A level, both score between 40% and 60%. There is a particularly wide variation in the scores of pupils who obtain grades E, D and C at Advanced level. The lack of correlation between individual questions and A level score was pointed out in the previous section.

Fig 7.6 Scattergraph of DAMPED OSCILLATION and FORCES

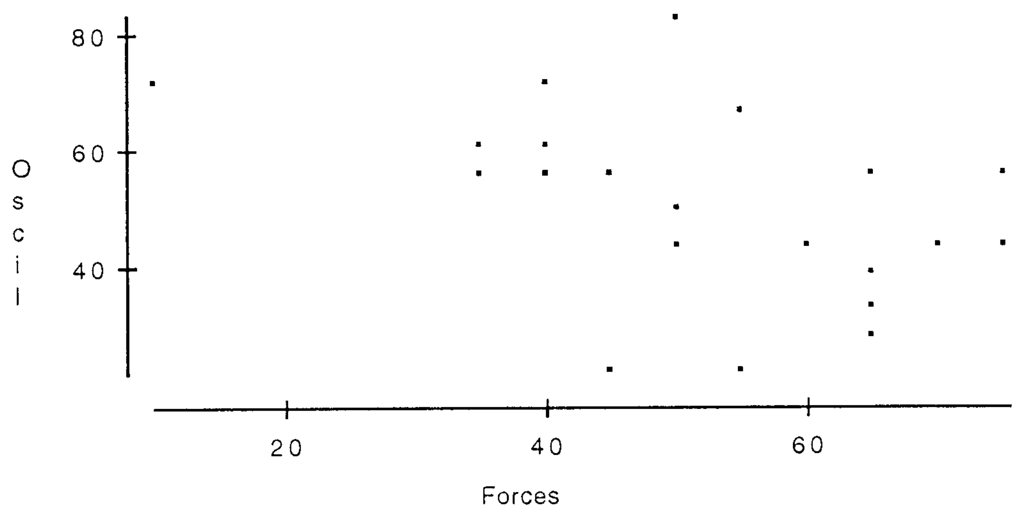
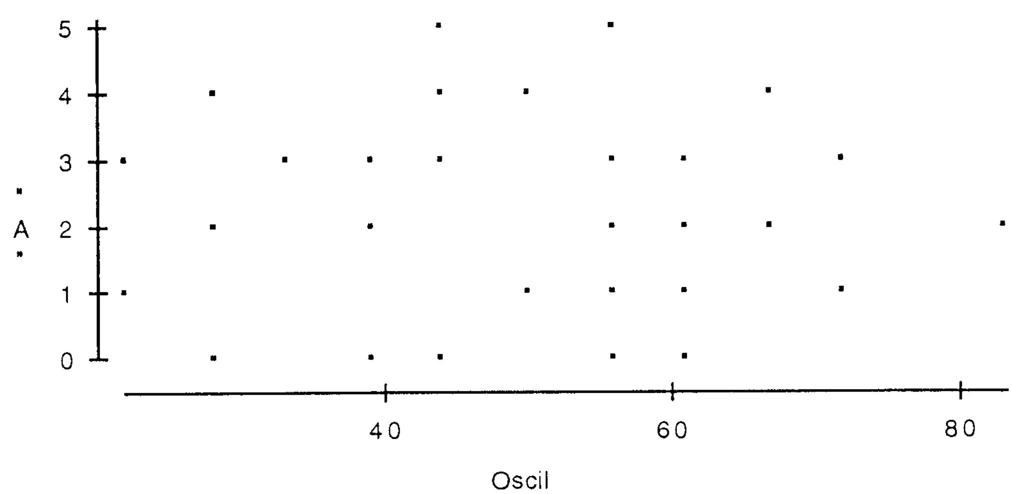


Fig 7.7 Scattergraph of DAMPED OSCILLATION and A Level scores



7.3.10 Discussion of exercise

This exercise asked for explanations of phrases used and descriptions of some of the ideas covered in the passage. Thirteen of the eighteen marks in the mark scheme were awarded for points which were thought to be physics related, yet, there is little evidence that pupils used their physics knowledge effectively. On the contrary, using ERRORS results as an indication of "reading" and A level result as an indication of "physics" skills, it would seem that pupils who come out best at reading, had a slight advantage in this exercise. Something seems to be thwarting pupils, who are presumed to have a good understanding of physics, from demonstrating their skills. Possible explanation are that the presentation or the language used in the passage is confusing, despite the relatively modest reading level score found from Fry etc, or, that the questions are ambiguous and pupils are not at all sure what is required of them.

7.3.10i Reliability

Clearly, this exercise is not as successful as intended, but is there consistency at least in the way the pupils have answered the questions, in other words, how reliable has the exercise been?

We know that comprehension exercises are unlikely to have as high a reliability as cloze exercises. The reasons for this are because the marking of comprehension questions is usually less objective than cloze exercises and because the tasks involved are more diverse. Still, the DAMPED OSCILLATIONS exercise, unlike some of the other comprehension exercises, has really only one *type* of question (questions which ask for explanations), so the *internal consistency* and hence the reliability coefficient should be high compared to the other comprehension exercises.

The reliability coefficient of DAMPED OSCILLATIONS was estimated by a "split-half" method corrected using the Spearman Brown prophesy (Crocker, 1986 #9), where the correlation between the total scores on alternate questions was calculated. The coefficient of reliability was found to be 0.42. For the sake of comparison , the reliability of all four of the other comprehension exercises was calculated using the same method, and the results are shown in Table 7.8.

Table 7.8 Reliability of comprehension Exercises

Exercise	**Reliability Index**
DAMPED OSCILLATIONS	0.42
INTERNAL RESISTANCE	0.46
FORCES	0.51
HEAT RADIATION	0.56

DAMPED OSCILLATIONS does seem to have the lowest reliability of the comprehension exercises, despite the fact that the questions are by comparison with the other exercises of this group much more homogeneous. FORCES, for example has three different types of question: underlining, diagram drawing and explaining, yet it's reliability is greater than DAMPED OSCILLATIONS.

7.3.10ii Assessment of passage

Having looked again at the questions given in the exercise (section 7.3.8) and the reliability of the responses above, it remains for the passage itself to be re-examined.

I gave the DAMPED OSCILLATIONS passage and the other three comprehension passages to four physics teachers together with a questionnaire like the one shown below (one for each exercise). The questionnaire asked the teachers to estimate the physics and language difficulty in terms of what they would expect from a first year A level physics group.

DAMPED OSCILLATIONS

1. Please grade the passage on the following criteria by circling a number on the scale:

		Easy				Difficult
a)	Physics difficulty:	1	2	3	4	5
		Easy				Difficult
b)	Language difficulty:	1	2	3	4	5
c)	How clearly the physics is presented:	Unclear				Very Clear
		1	2	3	4	5
2.	Would this be a suitable passage for first year A level pupils?	Too Easy				Too Difficult
		1	2	3	4	5
3.	Would you use this passage with your group?					YES / NO

Teachers' responses to the questions are shown in Table 7.9. The responses from each teacher are shown and the "means" are described in brackets.

Table 7.9 Results of teachers' questionnaire on comprehension passages

Question	DAMPED OSCILLATIONS	FORCES	INTERNAL RESISTANCE	HEAT
1a Physics difficulty	3, 3, 3, 2 (moderate)	2, 2, 2,3 (easy)	4, 3, 3,4 (fairly difficult)	4, 4,3,3 (fairly diff)
1bLanguage difficulty	2, 2, 2,3 (fairly easy)	4, 2, 4,2 (moderate)	3, 3, 5,4 (fairly difficult)	4, 3,3,4 (fairly diff)
1c Physics clarity	4, 4, 4,2 (clear)	3, 4, 2,3 (moderate)	4, 3, 1,2 (unclear)	2, 2, 3,1 (unclear)
1d Suitability	2, 3, 3,3 (moderate)	2, 3, -, 3 (moderate)	3,3, 3,4 (moderate)	4,4,3,4 (difficult)
2 Would you use this passage?	yes, yes, yes,yes	no,yes, no, yes	yes, yes,no,yes	yes,no,yes, no

The reactions of teachers questioned on the DAMPED OSCILLATIONS passage are remarkably consistent and suggest that:

- the physics seems only moderately difficult,
- the language fairly easy to understand, and
- it is suitable for a first year A level physics group.

Looking at the responses to question 2, it seems that DAMPED OSCILLATIONS was more likely to be chosen by these three teachers as a passage to use with their pupils than any of the others. So the difficulty does not seem to be with the DAMPED OSCILLATIONS passage, although one teacher remarked that DAMPED OSCILLATIONS was perhaps more suitable as background reading. I think this is a good point. As a teacher, one wants pupils to be aware of the *applications* of physics principles even if detailed analysis is not appropriate. However, the problem of how to adequately test that pupils have read the passage "well enough", still remains.

This points to the conclusion that perhaps it was my questions which caused the difficulty. The relatively poor reliability and the lack of clear correlations with other exercises lies more with the:

- *wording* of the questions of DAMPED OSCILLATIONS whereby pupils were not exactly sure what was required of them (see 7.3.8),
- *depth* of analysis that was requested, which was simply too difficult for the stage of the A level course the pupils were at,

or, as I am inclined to think, a combination of both.

7.4 HEAT RADIATION

7.4.1 Details of the exercise

This exercise was done by School Y only since they did not participate in INTERNAL RESISTANCE having not covered the "electricity" part of the syllabus at the same time as the other schools.. The passage consists of several pages of text on infra-red radiation of the kind that a teacher might give as a reading assignment, either direct from a book or in the form of notes (see HEAT RADIATION in **Appendix 16**) The exercise is designed to be "interactive" in as far as students are asked to add various things to the text, such as completing diagrams and adding explanations. It should be noted that these "embedded questions" are not made conspicuous by number, for example, and it is possible to miss them unless the text is being read fairly carefully.

7.4.2 Selection of the passage

The subject of electromagnetic (e.m.) radiation has a strong descriptive component as well as being open to a wide variety of practical applications and a mathematical element. The latter is chiefly to do with Stefan's law and an appreciation of the order of magnitude of the frequency and wavelength of the radiations. This passage touches on each of these aspects and forms a comprehensive picture of infrared (i.r.) radiation. The text, which was adapted from *Advanced Physics* (Gibbs, 1988 #52), was re-typed using a BBC computer processor with a daisy-wheel printer. The font used has a similar appearance to "courier" in that it gives wider spaced characters than "times" of the same size font. The diagrams were re-drawn freehand. The lack of dtp and laser printing when the exercise was constructed meant that the appearance of the text is more like teacher-produced notes than extracts from a well designed textbook.

Short extracts of the original text were used almost verbatim so that the language remained intact, and adjustments were made only to incorporate the "interactive questions" mentioned above and edit out references to other topics or pages. The passage had the advantages of a rational structure which was neatly sub-divided by headings and augmented with clear, simple diagrams. The readability assessment is as follows:

FRY READING AGE:	= 17 years
FLESCH READING EASE:	= 47 (40 = difficult 55=fairly difficult)
SMOG	= 19 years

My initial impression of the readability of the passage was considerably different to that revealed by the indices measured, in that I perceived the passage to be easier to read than those used in other exercises, whereas the results above point to it being more difficult than many others. Possible reasons for this will be discussed later in the chapter, nevertheless the reading age reflected by the FRY and FLESCH methods suggest that the passage should be compatible with the age range of the pupils taking the test (16 - 17 year olds). Again, it may be that repetition of words such as energy, radiation and infrared increase the syllable count without necessarily increasing the complexity of the writing.

7.4.3 The pupils and the test conditions

Results from this exercise are only available from one school group - School Y. This school had followed a different scheme of work to other schools omitting "electricity" from the lower sixth syllabus and substituting "waves" instead. This meant that School Y did not participate in the exercise Internal Resistance above. The exercise was given to students as a homework so they were not supervised, and it is not known whether or not students discussed the questions or their responses.

7.4.4 Relevance to the teacher

This is the longest passage so far in the study and covers a range of relevant information. As mentioned above, this sort of passage can be extracted from a student text and manipulated without too much difficulty to provide a realistic introduction to the task of using texts directly with pupils. The questions asked cover five skill areas which are of particular interest at this level: reading (R), inferring (I), accessing previous knowledge (K), diagram drawing (D) and mathematics (M). These areas are discussed further in 7.4.5, and help to make such an exercise "comprehensive" as well as a "comprehension" task.

7.4.5 Exploring the questions

The four questions found in the text ~~are~~ were intended to be fairly simple. Their purpose is to involve the readers in the text and suggest that by answering these questions they are understanding the material being read.

The first question is found half way down the first page, where there is a fairly conspicuous space for the response. *"Sketch and label a diagram of the ether thermoscope"*, requires diagram **drawing and labelling (D)** based on the description given in the previous paragraph. The diagram involves joining two bulbs by a tube showing that there is a liquid (ether) and gas (air and ether vapour) within the bulb and tube. There is no mention of calibration or how the instrument actually measures i.r. radiation except that the ether is pushed along the tube.

The second question, is found at the bottom of the second page and there is not an obvious space in which to write a response, so careless reading might mean that the question is missed. *"Use Prevost's theory to explain what happens now."* It refers to the previous sentences which describe how a body's temperature equilibrates with it's surroundings. An answer can be found by **inferring (I)** information read in the passage. Even if a student had not met the theory before it is not difficult to gather that at the same temperature bodies radiate and absorb energy at the same rate. An alternative response such as "at the same temperature the bodies stop radiating", contradicts the emphatic statement given at the beginning of the paragraph, and would not be tenable.

The third question is found at the top of the third page: *"Red visible light has a wavelength of approximately _________nm."* This information could be **inferred (I)** from the data given in the paragraph on the range of wavelengths of infrared light or simply by **remembering (K)** the wavelength of red light.

The fourth question embedded in the passage is found at the top of the fourth page. *"If the body has a surface area (A), then the TOTAL POWER EMITTED IS."* This requires **rearranging an equation (M)** from power per unit area to give the total power emitted by a black body. It is slightly confusing since both equations are labelled TOTAL POWER, and the same symbol E is used. The student has to recognise that by multiplying the first equation by the surface area A the total power emitted *by the whole body*, is being found. The multiplication step is a logical consequence, but it is possible that haste and/or confusion could cause a student to divide by A, however, reading down two paragraphs should be enough to confirm the answer.

For questions 1 -9 at the end of the passage Table 7.10 summarises what is required in the answer together with the skills involved in trying to answer the questions. For ease of classification these skills have been separated into five categories: **reading (R),** where information can be obtained fairly directly from the passage, **inferring (I)** where information can be deduced from the material in the passage. This is obviously related to "reading", but involves an additional logical process such as described in the third question in this paragraph. **Remembering previous knowledge (K), drawing a diagram from a description (D)** and **mathematical processing (M)** which in this exercise is restricted to simple algebra . To find the category in each case the simple question was asked: what is the most important skill the student needs to answer this question correctly? Where previous knowledge could be used to answer a question, eg. the wavelength of red light, these questions were only designated "K" if no indication of the answer was given in the text.

Table 7.10 Summary of skills relating to questions 1 - 9

Q	Scope of Answer	Relation to passage	Skills Involved
1	i.r. radiation invisible	p1 para1	R
	red light radiated too	p3 para1, p1 para 1	I
2	use of detecting i.r. in named example	p1 para1	I
3	list 4 examples	p1 - 2	R
	blackened to improve absorption of i.r.	p1 para 5& 6	R
4	photons of energy carriers	p1 para 6	K
5	3 examples of v hot bodies	p2 para 3	I
6	black absorbs from sun / emits less since it is cooler than sun	p2 para5	I
7	thermal conductivity	NONE	K
8	glass transparent to other wavelengths	p 3 para 2	I
	absorbed / re-emitted i.r. not transmitted	p 3 para 2	I
9a	forms of heat loss	p3 para 3	I
9b	same as fourth question in text	p4 (ii)	M
9c	diagram	NONE	D
	calculation	q9b & 9c	M

7.4.6 Mark scheme

(Questions I -IV in text)

I	Diagram of an instrument with two bulbs, one blackened, joined by a tube	1
	Labels: glass tube, blackened bulb, air/ether mixture (at least two labels)	1
II	Explanation based on radiation emitted and received at same rate	2
III	Wavelength of red light 700 nm +/- 5%	1
IV	$E = \sigma T^4 A$ ($E = \sigma T^4 / A$ given 1 mark)	2
1	No	1
	Body is not hot enough to produce visible red light as well as invisible i.r.	1
2	Description of one of the uses of i.r. radiation and how it works	2
3	List of all 4 detectors	1

	Explanation of blackening	1
4	Mention of photons or energy quanta	2
5	Three examples (1 mark each)	3
6	Reason must include absorber / reflector	2
	Explanation must mention non-equilibrium	2
7	Good / bad conductors of heat	2
	Body temperature	1
8	Other wavelengths transmit through glass, absorbed and re-radiated	1
	I.r. trapped inside hence warmer	1
9a	No atmospheric absorption and re-radiation	2
b	$E = \sigma T^4 A$	1
c	Diagram showing Sun, Earth, r and R correctly	3
d	$T^4 = 1400 \times 220^2 / \sigma$	2
	$T^4 = 1.2 \times 10^{15}$K or T = 5800K	1
	TOTAL	**36**

7.4.7 Discussion of mark scheme

The mark scheme was drawn up on a "pragmatic" model that a teacher might employ. Trying to define the exact criteria used is difficult as it is based on an amalgam of concerns: imitating the clinical objectivity which examination boards project, rewarding the response in terms of effort made and the "sophistication" of the technique used.

Looking at how the marks are distributed over the skill area gives the following breakdown:

Inferring	Reading	Mathematics	Drawing	Knowledge
16 (44%)	6 (17%)	6 (17%)	5 (14%)	3 (8%)

It is surprising, yet reassuring, to find that four of the five skill areas have approximately the same weighting in terms of marks, with Inferring making more than twice as large a contribution as the other categories. The assumption made is that inferring is a "higher order" skill than "reading" and as proposed elsewhere in this thesis, that comprehension (indeed, ultimately reading) is a process of making *inferences*. Investigating how students perform in each of these skill areas may prove interesting, not least, because this may reveal how effective reading in a particular subject area may be dependent on making inferences which are particularly appropriate to that subject.

7.4.8 Exploring the results

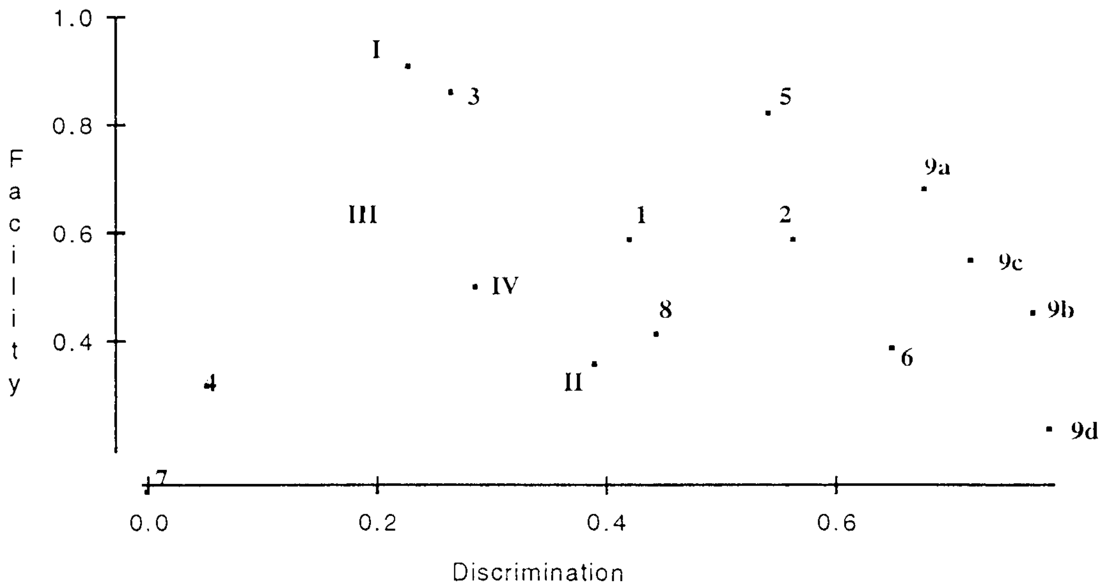
The grid showing the students' responses can be found in **Appendix 17**. Although there are only 11 sets of results[7] the spread of marks is good, ranging from 31% to 81%. The results will be investigated by firstly looking at the facility and discrimination of the responses and then by looking at relationships between responses.

7.4.8i Facility and Discrimination of Responses

The facility and discrimination of each question are shown in Fig 7.8.

The four questions embedded in the text (I - IV) have low discriminations compared with most of the questions at the end of the text although they have a wide range of facility. This may mean that they are not being treated as seriously as the questions at the end of the passage by the high scoring students.

Fig 7.8 Facility / Discrimination of Heat Radiation Questions



Of the rest of the questions 4 and 7 have the lowest discriminations (0.053 and -0.002 respectively) and facilities (0.32 and 0.12). Fig 7.9 shows how the skills[8] involved in each question are distributed. and makes it clear that questions 4 and 7 rely on information not supplied by the passage.

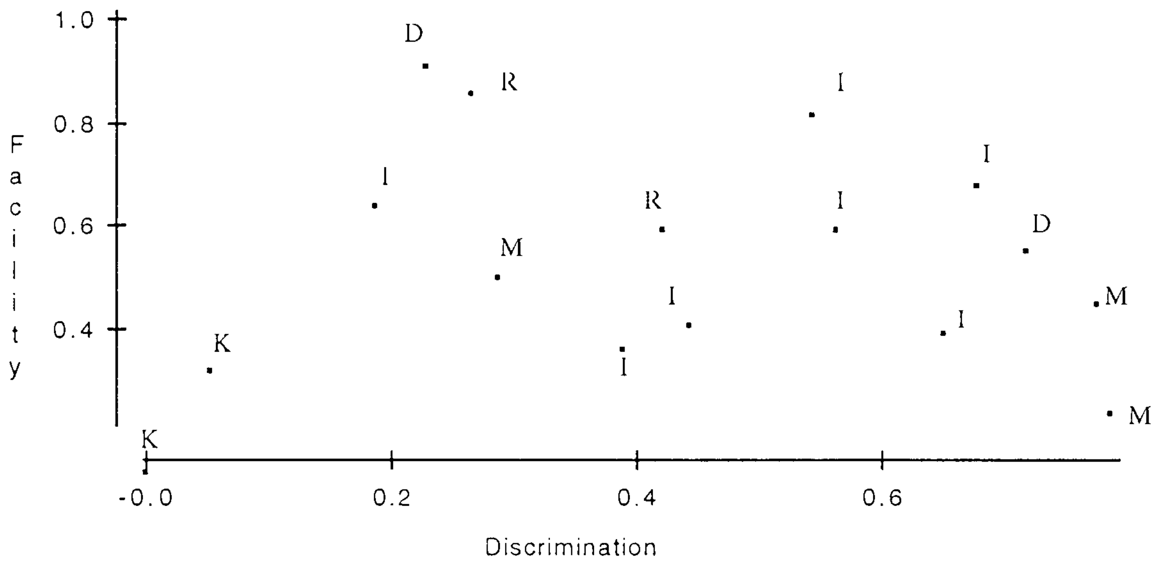
All four embedded questions (I - IV) have low discrimination, irrespective of the skills involved in answering them. Questions 3, 1 and 8 have descending facility and increasing

[7]Reasons given in 7.4.3.

[8]As discussed in 7.4.4

discrimination. Fig 7.9 shows that questions 3 and 1 are designated Reading questions. Question 3 requires all four detectors of i.r. radiation to be listed and an explanation of why surfaces of detectors need to be blackened for 2 marks, whereas question 1 asks if infrared radiation is visible and an explanation of "red-hot". Table 7.3 indicates that question 3 requires reading through several paragraphs over more than one page of text, while the answers to question 1 are stated more concisely in a couple of paragraphs at the beginning of the passage.

Fig 7.9 Distribution of skills for each question in Fig 7.6



The three questions which require some mathematics have facilities of 0.5 or less and apart from question IV[9], have the highest discrimination of all.

Answers involving Inference have a wide distribution of facility and discrimination, although Fig 7.11 shows that apart from questions I and III which differ from the others in that they are embedded in the passage, these responses tend to have higher discrimination.

7.4.8ii Relationship between responses

Correlations between responses are calculated in Table 7.7 in order to investigate if questions which are thought to use similar skills are answered correctly by the same pupils.

Correlation shown in bold type are statistically significant ($p<0.05$).

---

[9] An "embedded" question.

Table 7.11 Correlations between responses to HEAT RADIATION

	I	II	III	IV	1	2	3	4
I.	1.000							
II	0.239	1.000						
III	0.418	0.179	1.000					
IV	0.000	0.512	0.000	1.000				
1	-0.361	0.072	-0.072	0.000	1.000			
2	0.449	0.515	0.392	0.148	-0.208	1.000		
3	-0.140	0.334	0.585	-0.200	0.524	0.273	1.000	
4	0.206	-0.105	-0.088	0.377	- **0.684**	0.192	- **0.616**	1.000
5	-0.194	-0.174	-0.251	-0.415	0.298	0.134	0.060	-0.019
6	0.316	0.079	0.575	0.335	0.224	**0.653**	0.280	0.071
7	- **0.805**	-0.134	-0.160	0.000	0.251	-0.293	0.250	0.066
8	0.276	-0.257	0.055	0.132	0.185	-0.191	-0.243	0.126
9A	0.149	0.134	0.111	-0.319	0.539	0.180	0.400	-0.427
9B	0.289	0.449	0.069	0.494	0.023	**0.677**	-0.188	0.339
9C	0.188	0.080	-0.257	-0.115	0.324	0.279	-0.013	-0.40
9D	-0.115	0.275	-0.023	0.164	**0.770**	0.370	0.429	-0.383

	5	6	7	8	9A	9B	9C	9D
5	1.000							
6	-0.060	1.000						
7	0.346	-0.254	1.000					
8	0.208	0.119	-0.192	1.000				
9A	**0.686**	0.091	-0.083	0.469	1.000			
9B	0.354	0.575	-0.232	0.177	0.280	1.000		
9C	**0.652**	0.100	-0.072	0.571	**0.712**	0.482	1.000	
9D	0.458	0.590	0.017	0.188	**0.643**	0.576	0.557	1.000

A summary of all responses that correlate well is given in Fig 7.10 As only eleven pupils participated in this exercise, and a very high correlation is required for statistical significance, I have included in the diagram responses which have a correlation greater than 0.50

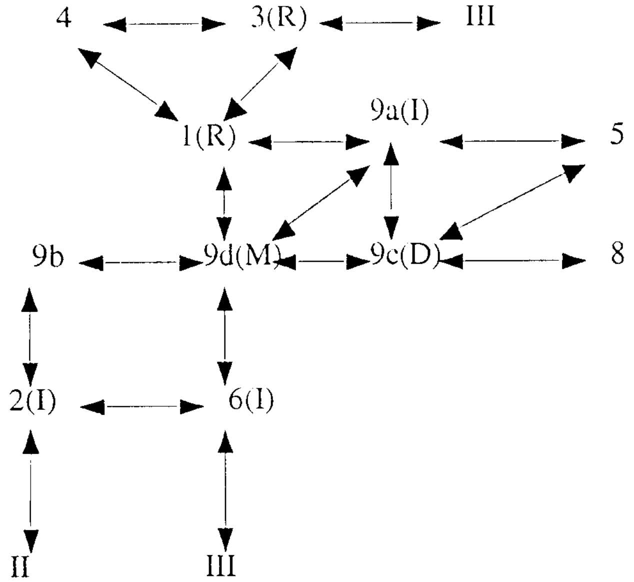
Fig.7.10 also shows that some items correlate well with several items. For example, 9d (a mathematical item) correlates with five other items. Whereas 1, 9a and 9c (which are reading, drawing and inferring items respectively) correlate with four other items each and 2, 3 and 6 (inferring, reading and referring) correlate with three other items each.

The correlation of 9d with 9a, 9b and 9c is not unexpected as they are parts of the same questions and hence interrelated.

Some items which correlate and are not particularly related in content, are of the same *type*. For example, 3 and 1 (both reading), 2 and 6 (both inferring) and 9a and 5 (both inferring).

Fig 7.10 Schematic diagram to show relationships between responses

(double-headed arrows indicate correlations > 0.50)



(M=mathematical, I=inferring, R=reading, D=drawing)

Rather than supporting a case for separate *factors* reading factor, drawing factor and so on, Fig.7.10 may suggest that students who score well in questions involving inferencing are also likely to have skills which help them with other types of question such as diagram drawing or algebra.

To look further at the interrelationship between items, I calculated the correlations between the "composite score" (found by adding up the marks for all the questions in one category[10])for each category. The results found for the individual questions are shown in Table 7.12:

Table 7.12 Correlations between composite scores

Pearson Product-Moment Correlation

	Q I-IV	Inferenc...	Maths	Diagram	Knowled...
Q I-IV	1.000				
Inferences	0.414	1.000			
Maths	0.568	0.643	1.000		
Diagram	0.229	0.707	0.324	1.000	
Knowledge	-0.082	-0.089	0.049	-0.173	1.000

There are statistically significant correlations between:

0.643 between Inferring / Mathematics items,

0.707 between Inferring / Diagram items

and a fairly high correlation between Maths and Q1 -IV.

---

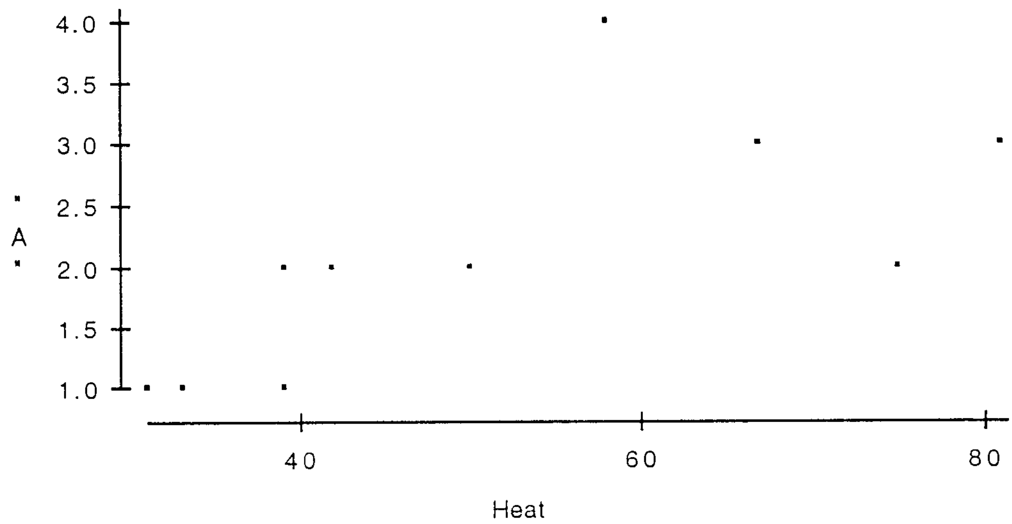
[10] See Table 7.4 column 2 for the questions in each category.

There was very little correlation between all the other combinations of categories, which again may support the putative importance of **inferring skills** in carrying out comprehension tasks of various kinds.

7.4.9 Relationship with other exercises

Good correlation was found with the scores of this exercise with the A level grades. Fig 7.11 shows the results for ten of the eleven pupils who completed this exercise and finished the A level course at the same school[11]. The coefficient of correlation was 0.685 which is statistically significant ($p<0.05$).

Fig 7.11 A level grades / Heat scores



For the other exercises, correlation coefficients were found as follows in Table 7.13

Only one score, that for the READING ALOUD questions did not have a fairly high correlation with HEAT RADIATION.

Table 7.13 Correlations between HEAT RADIATION and other exercises

EXERCISE	CORRELATION COEFFICIENT
DAMPED OSCILLATIONS	0.577
FORCES	0.468
READING ALOUD question score	0.650
READING ALOUD hesitations	-0.251
READING ALOUD time taken	-0.556
PROJECTILES	0.601
TIME	**0.779**
ERRORS	0.583
A LEVEL	**0.685**

[11] The score of the pupil who did not complete the course was 44%.

A correlation of 0.779 ($p<0.01$) was found with TIME. Correlation coefficients in excess of 0.5 were found with other exercises, notably other cloze exercises. Given the small number of pupils participating in this exercise these correlations are surprisingly high. The interesting point about the TIME exercise was that it was the last in the series, given to students at the end of the first year of the A level course (May/June), and HEAT was done just before, so they were chronologically close. This certainly hints that at the end of the first year, differentiation of marks (on this type of exercise at least) gives a good indication of potential ability and future performance in this subject.

7.4.10 Summary of HEAT RADIATION

Despite the small number of responses there have been some interesting results to this exercise. A question mark remains over the value of the "embedded questions" as the results suggest they are not being treated seriously by all pupils. There were no specific instructions given to answer questions within the text and it was not possible to obtain feed-back from the students about those questions. I have pointed out elsewhere[12] that pupils at this school seemed particularly concerned about marks and grading, and it is possible that they were more willing to answer "genuine" questions at the end than incidental questions in the passage.

As in other exercises, questions which rely on information not provided by the passage are consistently difficult and not worthwhile as discriminators.

There is not much evidence here to support the argument that there are separate categories of skills which are highly distinguishable, results from a larger number of pupils might have helped to clarify this position. However, there is a promising indication that looking at the *level* or *kind of inferencing* questions require may be a helpful way of looking at the results with the possibility that this could reveal the sort of "core inferencing skills" crucial to success in this subject.

---

[12] See Chapter 6 Section 4

7.5 Conclusions from chapter 7

Distinguishing facets of reading skills

A number of tasks have been given in these comprehension exercises among them: underlining important phrases, diagram drawing, explaining phrases, explaining relationships, solving numerical problems, making inferences based on information in the passage, making inferences from previous knowledge, answering questions embedded in the text. There is little evidence that each task alone demands a separate skill.

In two exercises each question was designated as either a "physics" question or a "non-physics" question depending on whether specific physics knowledge was required to answer the question. One exercise (FORCES) indicated that physics questions have better discrimination than non-physics questions, but the results from another exercise (DAMPED OSCILLATIONS) showed that this is not always the case and possibly that confusion can be caused by unfamiliar wording.

Two exercises showed that questions which required specific knowledge not mentioned in the passage had poor discrimination. The last exercise (HEAT) suggested that questions which require making inferences have good discrimination and correlate well with other questions, but embedded questions have very low discrimination, possibly because some pupils did not realise they had to be answered.

There is little to suggest that there are independent or indivisible specific skills involved, apart from the distinction between the responses to physics and non-physics questions, which might be thought of as "physics reading" and "non-physics reading" skills.

The best relationship was found between items that required inferring and other items such as those related to mathematics.

Looking at the errors pupils make has made it clear that there are degrees of "imperfection" and that by classifying the mistakes pupils make, it may be possible to offer more specific help to some pupils.

Choosing texts and tests

The table which follows 7.14 compares the reading level found by the Fry, Flesch and SMOG with the proportion of pupils who score 60%[13] or more in the each exercise.

---

[13] Scores of 60% and over were chosen as reference because this was the score used to differentiate Independent readers in the cloze tests. There is no theoretical or empirical basis for this figure in comprehension tests.

Table 7.14 Comparing reading level estimates with pupil performance

Exercise	FRY	FLESCH	SMOG	Pupils scoring over 60%
FORCES	14 years	64%	17 years	18/28 (64%)
INT.RESIST.	17 years	47%	18 years	16/34 (47%)
DAMPED OSC.	14 years	62%	16years	9/43 (21%)
HEAT	17 years	47%	19 years	5/11 (46%)

The Fry and Flesch estimates are fairly consistent, whereas SMOG gives higher estimates of reading age for each. The percentage of pupils scoring over 60% agrees well with Fry and SMOG values, except for the DAMPED OSCILLATION scores which are much lower than expected. There is no indication even from the SMOG result why this should be the case, and I suggested that the fault may lie in the questions which were asked. The questions tended to ask for explanations of applications of quite difficult concepts and this, in retrospect, was not appropriate for a passage that was more suitable as "background reading". Overall, teachers' opinions of the passages (see 7.3.10ii) tend to mirror the Fry and Flesch estimates.

There is evidence of the importance of how a question is worded; simplicity seems to elicit better discrimination in the responses. This means that direct questions such as "underline...", "find V if..." (i.e. numerical questions) have the advantage of their purpose being very clear.

As was pointed out above, "embedded" questions were answered poorly and it might have been worth emphasizing that these questions were meant to be answered.

Questions which rely on information not directly retrievable from the passage were also very poor discriminators and should perhaps be avoided in this type of exercise.

Question 4 Physics Achievement

Since three of the four exercises have a statistically significant correlation with the A level grade, it appears that the results of the exercises are relevant to pupil's competence in physics. Although INTERNAL RESISTANCE the exercise which is most like a traditional comprehension had the closest correlation with A level scores, the FORCES exercise which involved underlining and diagram drawing was not very far behind. The message seems to be that as long as the instructions are clear and the information is available or easily inferred a variety of questions can elicit the correct physics in the responses of able pupils.

CHAPTER 8: COLLATED RESULTS AND ANALYSES

8.0 Overview of chapter

This chapter attempts to review the data collected from the reading exercises and to investigate possible interrelationships between the sets of results. The analyses will be directed towards addressing three of the Research Questions in particular (see chapter 3. section 7), namely:

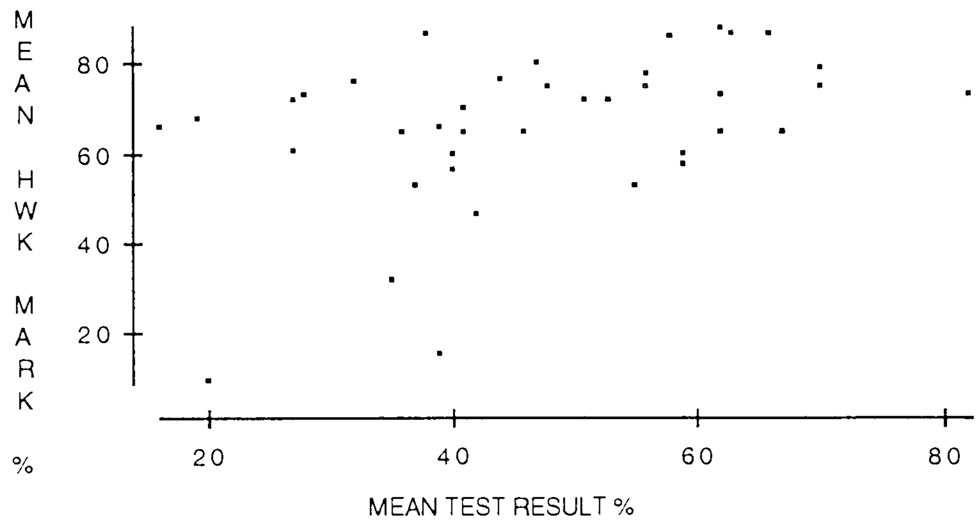
- differentiating facets of reading skills (q 1)
- measuring reading competence (q 2)
- relationship of results to pupils' competence in physics (q 4)

Before this, other means of assessing pupils' progress / achievement in physics, will be considered. These may be useful references when taken in conjunction with A level grade, to investigate pupils' performance in the subject overall.

8.1 Teachers' assessments of pupils

A mean percentage score of homework marks[1] over two terms in the first year was obtained for each pupil[2] from his/her teacher's mark book[3]. Scores in tests / examinations[4] given in the first year of A level study were also obtained. These results can be found in **Appendix 18.**

Fig 8.1 Mean homework mark vs mean class test score per pupil



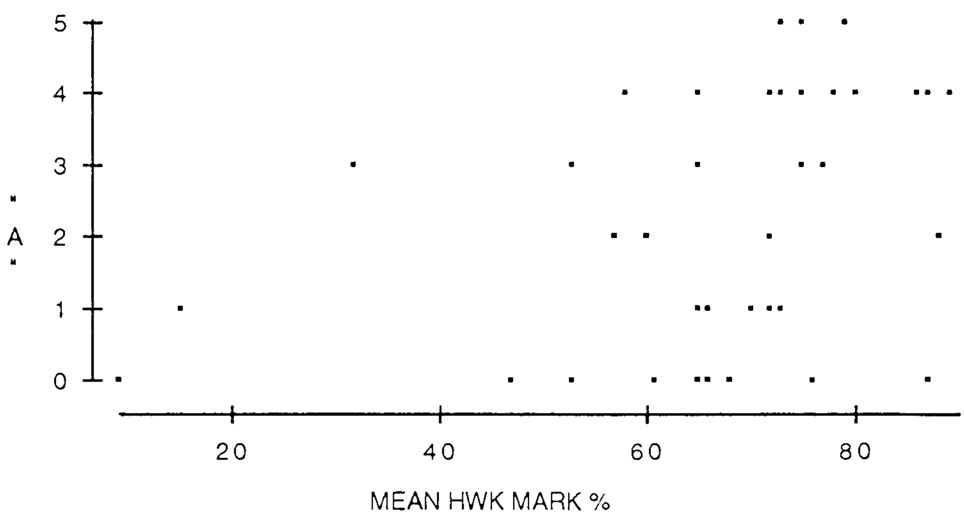
[1]This will be called "Homework" score
[2]Teacher's assessments were not obtainable for the 4 pupils in School Z.
[3] There was no control of the uniformity of the homework or tests that were set by individual teachers.
[4]This will be called "Test" score

It is proposed that these data be used as alternatives to A level grades as yardsticks of pupils' physics competence. Fig 8.1 (previous page) gives a plot of the two scores for each pupil.The plot shows that most pupils score higher in homework assignments than in tests although both were set and marked by the teacher. The narrow range of homework marks, (most pupils score between 50% - 85%), reflects the more generous marking a class teacher is allowed to use for homework assessments. However, the homework and test marks do correlate and a coefficient of 0.407 is found which is statistically significant at ($p<0.05$).

Bearing in mind that homework marking is not bound by strict objective criteria, and that a teacher may wish to encourage as well as assess pupils, it may be convenient to consider the homework score as an "effort" score, and the test result as an "achievement" score. Whether or not "effort" and "achievement' are separate traits and, more importantly as far as this study is concerned, whether these traits are apparent in the reading exercises, will be examined by factor analysis later in the chapter.

At this stage, the correlation of the teachers' marks with A level results will be inspected. Figs 8.2 and 8.3 illustrate how the A level grades correlate with homework scores and test scores respectively.

Fig 8.2 A level grade point vs mean homework mark per pupil



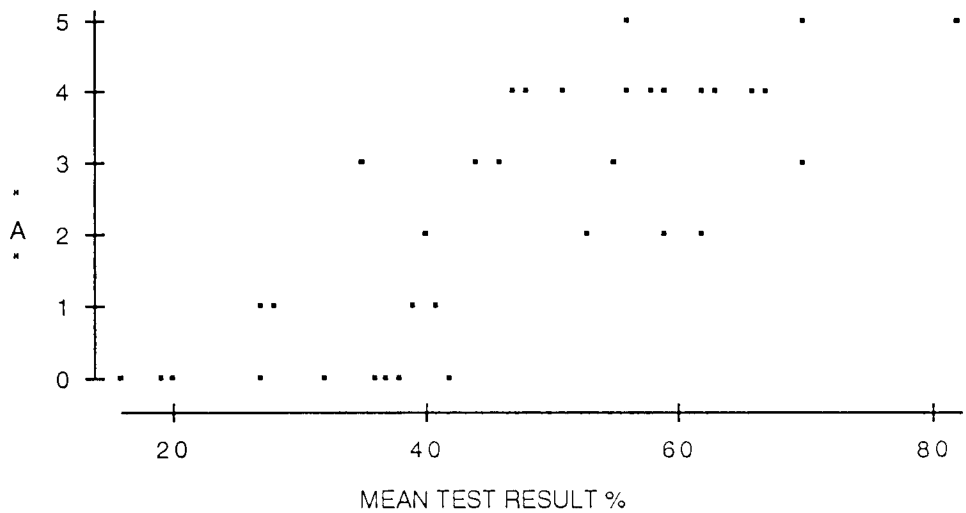
Despite the narrow range of homework scores of most pupils and the bunched up appearance of the plot, there is a correlation of 0.383 which is statistically significant ($p<0.05$).[5]

---

[5] Although if the scores of the two pupils with <20% homework score are ignored the correlation coefficient becomes 0.304 which is not significant.

Fig 8.3 gives a similar pattern except that points are displaced towards the left, particularly in the lower half of the graph. This illustrates the entirely normal phenomenon of diligent pupils turning in homework regularly and collecting respectable totals of homework marks, yet not necessarily being able to sustain such high marks in class test situations or, ultimately, in the A level examination.

Fig 8.3 A level grade point vs mean test mark per pupil



As might be expected, the correlation between A level score and Tests is very high, with a coefficient of correlation of **0.814** which is statistically significant ($p<0.01$).

Table 8.1 gives the correlation between the pupils' marks in the reading exercises with Test and Homework scores.

Table 8.1 Correlation between Reading Exercises/Homework, Test marks & A level

Reading Exercise	Mean Test Result	Mean Homework Score	A level
OSCILLATIONS	-0.105	0.049	-0.085
INTERNAL RESISTANCE	0.379	0.267	**0.563**
FORCES	0.335	0.290	**0.406**
Reading Aloud Questions	0.038	-0.020	0.013
Reading Aloud Hesitations	-0.202	0.067	**-0.327**
Reading Aloud Time taken	-0.123	-0.004	**-0.346**
PROJECTILES	**0.431**	**0.362**	**0.359**
TIME	0.319	0.165	**0.342**
ERRORS	0.258	0.181	0.182

Bold shows $p<0.05$

Overall, correlation with the exercises in this study as Table 8.1 shows, is also marginally better with the Tests than with the Homework scores. PROJECTILES had the closest correlation of the two, but the cloze tests generally correlated to about the same extent as the comprehension tests, apart from OSCILLATIONS. However, more of the correlations between exercises and A level score were significant than either the Test or Homework results, suggesting that these exercises have more in common with the A level examination than with the Homework and Test results.

8.2 Factor analysis

Factor analysis is directed towards the pattern of correlations among variables in a correlation matrix, with the aim of seeing if there are clusters among the correlations. The presence of more than one cluster may indicate an interrelating "factor" between members of each cluster. Factor analysis was carried out on data from this study to look at:

1. **physics versus non-physics items,**
   to test the hypothesis that there are "physics factors" and "non-physics factors" which distinguish how cloze or comprehension questions are answered;

2. **how the results of the exercises are related,**
   to seek factors which link exercises, with the possibility that these factors relate to the demands of the exercises, characteristics of the texts or skills needed by the students to answer the questions;

3. **how results relate to A level grades and Test / Homework scores,**
   to investigate the links between "conventional" testing and the reading exercises and to look at possible ways of interpreting these links.

8.2.1 Cloze exercises

The factor analysis was carried out on the correlation matrix shown in Table 8.2.for the three cloze exercises TIME, ERRORS and PROJECTILES where each item was designated as a physics item (P) or non-physics (NP).

Table 8.2 Correlation matrix for cloze exercises[6]

EXERCISE	TIME (P)	TIME(NP)	ERR (P)	ERR (NP)	PROJ (P)	PROJ (NP)
TIME (P)	1					
TIME (NP)	.75	1				
ERR (P)	.09	.27	1			
ERR (NP)	.26	.25	.87	1		
PROJ (P)	.06	.27	.45	.48	1	
PROJ (NP)	.04	.05	.5	.64	.58	1

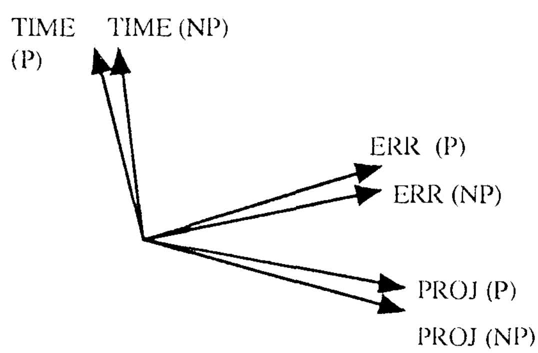
The factor procedure used was Principal Component Analysis and the transformation method was orthogonal / varimax. The results imply a two factor split as the factor loadings as Table 8.3 indicates, where bold type shows significant factor loadings.

Table 8.3 Factor Loadings Orthogonal Solution - Cloze

	Factor 1	**Factor 2**
TIME (P)	.03	**.93**
TIME (NP)	.16	**.92**
ERR (P)	**.85**	.13
ERR (NP)	**.89**	.21
PROJ (P)	**.73**	.09
PROJ (NP)	**.83**	-.07

The hypothesis that there is a "physics factor" and "non-physics factor" in cloze exercises is rejected as the physics and non-physics items of each test tend to travel together. The alternative suggested by the factor loadings is that there is a similar factor for ERRORS and PROJECTILES and a different factor for TIME. This relationship between factors is shown geometrically in Fig 8.4, with the angles between the vectors representing the vector loadings.

Fig 8.4 Vector representation of factor analysis of cloze exercises (not to scale)



[6]The matrix is based on results of the 20 Physics pupils who completed all three cloze tests.

The possible factors connecting ERRORS and PROJECTILES are:

- the exercises were chronologically close in administration (ERRORS first)
- passages used for ERRORS and PROJECTILES both taken from physics text books and the content is clearly relevant to the Physics A level syllabus

A plausible explanation is that both ERRORS and PROJECTILES reflect the standard of skills which pupils display on similar types of exercise at approximately the same time during the course.

8.2.2 Comprehension exercises

Only three of the comprehension exercise questions could be segregated into physics and non-physics items, these being, FORCES, HEAT and OSCILLATIONS. The correlation matrix for the results of these exercises for the 12 pupils who completed all three tests is shown in Table 8.4.

Table 8.4 Correlation matrix of comprehension physics and non-physics items.

	FORCES (P)	FORCES(NP)	HEAT (P)	HEAT (NP)	OSC(P)	OSC (NP)
FORCES (P)	1					
FORCES (NP)	.71	1				
HEAT (P)	.71	.58	1			
HEAT (NP)	.44	-.4	.5	1		
OSC (P)	.36	-.03	.76	.71	1	
OSC (NP)	-.03	-.46	-.26	.57	.09	1

The result of the analysis shows two factors as Table 8.5 indicates, but the split is not as clear as it was for the cloze exercise items. Although there appear to be separate factors for FORCES and HEAT physics and non-physics items this was not true for HEAT, so the factors cannot really be thought of as "physics' and "non-physics" factors.

Table 8.5 Orthogonal solution for physics / non-physics items.

	FACTOR 1	FACTOR 2
FORCES (P)	**.74**	.45
FORCES (NP)	.29	**.89**
HEAT (P)	**.86**	.42
HEAT (NP)	**.83**	-.5
OSCILLATIONS (P)	**.85**	-.16
OSCILLATIONS (NP)	.2	**-.8**

Repeating the analysis for FORCES and OSCILLATIONS physics / non-physics results only, increased the number of pupil results available for analysis from 12 to 26 since the HEAT exercise was only undertaken by School Y, but still no evidence of separate physics and non-physics factors was found.

8.2.3 Exercise results and A level

The process described in 8.2.1 was repeated for the correlation matrix containing results from all exercises apart from HEAT, as well as the A level grades. Table 8.6 shows the results found for the 13 pupils who completed all the exercises and whose A level results are known.

Table 8.6 Correlation matrix for all exercises plus A level

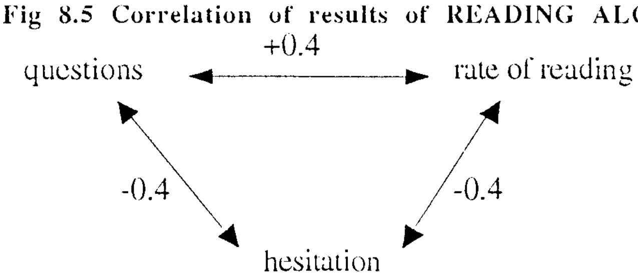
	A	ERR	TIME	PROJ	hesi*	quest*	FORCE	1 / t*	INTRES	OSCIL
A	1									
ERR	-.23	1								
TIME	**.23**	.35	1							
PROJ	**.38**	**.4**	.06	1						
hesi*	.09	.12	-.15	.12	1					
quest*	-.07	.39	.45	.2	**-.45**	1				
FORCE	**.37**	.07	-.01	.13	.03	.15	1			
1 / t*	**-.41**	.18	.09	-.33	**-.44**	**.41**	-.13	1		
INTRES	**.63**	-.39	.4	.01	**-.51**	.23	.27	-0.1	1	
OSCIL	.15	.33	-.17	**.53**	**.46**	-.17	**-.43**	-.27	-.29	1

*shows data relating to READING ALOUD (t - time taken to read the passage was poorly distributed so 1 / t or "rate of reading" values were substituted.

Bold show $p < 0.05$

One interesting point about the matrix is the relationship between rate of reading, number of hesitations and responses to questions on READING ALOUD. This is illustrated in Fig 8.5.

Fig 8.5 Correlation of results of READING ALOUD



The correlations could suggest a connection between rate of reading and the ability to answer questions on the text correctly and make fewer hesitations.

The results of the factor analysis are shown in Table 8.7

Table 8.7 Factor Loadings Orthogonal Solution - Exercises & A level

	Factor 1	Factor 2	Factor 3	Factor 4
A	-.05	**.84**	.35	.23
ERR	.47	-.55	**.59**	.14
TIME	**.67**	.25	.17	.03
PROJ	.15	.16	**.83**	.08
hesi*	**-.63**	-.23	.5	.13
quest*	**.86**	-.08	.06	.15
FORCE	.02	.17	.00	**.97**
1 / t*	**.56**	-.38	-.45	-.15
INTRES	.36	**.86**	-.21	.09
OSCIL	-.21	-.07	**.78**	-.49

Bold shows significant factor loadings and * shows data relating to READING ALOUD.

This solution suggests 4 factors which are:

Factor 1 A "READING ALOUD" factor related to TIME

Factor 2 An A level factor related to INTERNAL RESISTANCE

Factor 3 A cloze factor for PROJECTILES and OSCILLATIONS

Factor 4 A factor which is found in FORCES only.

However, since the number of pupils responses is small (13) and the sphericity test suggests that there is only a low level of structure, the analysis was repeated without INTERNAL RESISTANCE and OSCILLATIONS, to obtain a larger number of pupil responses. Table 8.8 gives the results obtained.

Table 8.8 Factor Loadings Orthogonal Solution - 5 Exercises & A level

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
A	.00	-.21	.45	**.73**
ERR	**.88**	.04	-.18	.03
TIME	.23	.34	-.18	**.79**
PROJ	**.69**	-.31	.25	.22
hesi*	.26	**-.77**	-.2	-.14
quest*	.5	**.67**	.32	.16
FORCE	-.01	.05	**.9**	.05
1 / t*	-.03	**.78**	-.28	-.08

Bold shows significant loadings and * shows data relating to READING ALOUD

This solution also points to four factors:

Factor 1 **Cloze ERROR and PROJECTILES**

Factor 2 **READING ALOUD**

Factor 3 **FORCE**

Factor 4 **A level and TIME (weakly related).**

The validity of the results is somewhat dubious as even with fewer variables the number of factors has remained at four. However, the READING ALOUD results cohere and could represent a stable READING ALOUD factor.

8.2.4 Test and Homework scores

To test the hypothesis that Homework and Test scores are related to different factors the results were compared simply with A level results and the following correlation matrix shown in Table 8.10 was found.

Table 8.9 Correlation matrix for A level, Homework and Test scores

	A Level	Homework	Test
A Level	1		
Homework	.23	1	
Test	.82	.34	1

The scores of 37 pupils are shown in the correlation matrix Table 8.10 and the results of the factor analysis are shown in Table 8.11.

Table 8.10 Orthogonal Transformation Solution A level, Homework & Test scores

	Factor 1	Factor 2
A Level	**.96**	.08
Homework	.15	**.99**
Test	**.93**	.21

The results show a division between Test and Homework scores with Test scores aligned with A level results and with Homework scores as a separate factor. This lends some credence to the possibility that Homework and Test scores reflect different attributes which could be "effort" and "attainment", as suggested earlier in this chapter.

8.2.5 Exercise results and Test and Homework scores

Factor analysis of all the exercises as well as the Test / Homework scores proved not to be feasible as the number of pupils who completed all the reading exercises **and** whose

Test / Homework results are known, was comparatively small[7]. However, it was possible to test six of the reading exercises in addition to the Test / Homework scores.

Table 8.11 shows the correlation matrix obtained from the results of 14 pupils.

Table 8.11 Correlation matrix for Reading Aloud / Tests / Homework

	ERR	TIME	PROJ	t(s)	hesi	quest	FORC	INTR	Hwk	Tests
ERR	1									
TIME	.27	1								
PROJ	.36	.1	1							
1/t*	.07	0	-.33	1						
hesi*	.23	-.11	.35	.51	1					
quest*	.37	.44	.18	-.51	-.21	1				
FORC	-.05	-.16	.06	.23	.4	-.47	1			
INTR	.32	.45	.28	-.17	-.41	.21	.28	1		
Hwk	.14	.31	.53	.36	.22	-.18	.44	.43	1	
Tests	.6	.43	.67	.19	.3	.06	.42	.57	.75	1

*Items refer to READING ALOUD exercise

One solution of this matrix is given in Table 8.12. Three factors are indicated:

Factor 1 An INTERNAL RESISTANCE factor

Factor 2 An ERRORS factor

Factor 3 A time taken[8] factor

Table 8.12 Factor Loadings Orthogonal Solution - 6 Exercises/Homework/Tests

	Factor 1	Factor 2	Factor 3
ERRORS	.2	**.85**	-.08
TIME	**.65**	.05	.01
PROJECTILES	**.41**	**.54**	**.44**
1/t	-.14	.14	**-.89**
hesitations	-.2	**.48**	**.7**
questions	.06	**.46**	-.4
FORCES	**.31**	.06	.1
INTERNAL RESISTANCE	**.83**	.12	-.42
Homework score	**.78**	.09	**.38**
Test score	**.75**	**.56**	.2

[7] Of the 46 pupils whose A level results are known less than 10 have a complete record of Reading Exercises and Homework / Test Scores.

[8] From READING ALOUD

Factor 1 is linked to both Homework and Test scores as well as TIME and more weakly to PROJECTILES and FORCES. All these reading exercises are known to correlate well with A level grades, so this could be called a "Physics A level" factor.

Factor 2 links ERRORS with Test score. If, as I suggested earlier in the chapter, Test score is an "ability" Indicator, ERRORS and to some extent PROJECTILES are good indicators of ability, and to a lesser degree the hesitation rate and questions answered in READING ALOUD.

Factor 3 links time taken to hesitations rate in READING ALOUD, which seems reasonable. Puzzlingly, this factor also links PROJECTILES with Homework, albeit rather weakly. If Homework score is regarded as an "effort" Indicator, this factor may suggest that slower readers with higher hesitation rates have a slight tendency to be more diligent about homework, but that this factor alone does not influence performance with many of the reading exercises.

One interesting result emerged when two comprehension exercises, OSCILLATIONS and FORCES were sorted into physics and non-physics items and compared with Homework and Test scores.

Using the results from the 20 pupils whose records were complete for Homework / Test, OSCILLATIONS and FORCES the correlation matrix shown in Table 8.13 was found.

Table 8.13 Correlation matrix using FORCES and OSCILLATIONS exercises sorted into physics and non-physics items

	HWK	Test	OSC (phy)	OSC (non-p)	FOR (phy)	FOR (non-p)
Homework	1					
Test	.51	1				
OSC (phy)	.26	.28	1			
OSC (non-p)	-.01	-.07	.41	1		
FORC(phy)	.31	.35	-.35	-.56	1	
FORC(non-p)	-.02	.04	.39	.39	.36	1

From this factor analysis the following 3 Factors are derived as shown in Table 8.14:

Factor 1 OSCILLATION non-physics Factor

Factor 2 Homework / Test Factor

Factor 3 FORCES non-physics Factor

Table 8.14 Factor Loadings Orthogonal Solution FORCES and OSCILLATIONS

	Factor 1	Factor 2	Factor 3
Homework	.13	**.86**	-.16
Test	-.15	**.83**	.18
OSC (phy)	**.65**	**.48**	.16
OSC (non-p)	**.88**	.03	-.05
FORCES(phy)	-.78	.37	-.02
FORCES (non-p)	.01	0	**.98**

Factor 1 relates OSCILLATIONS physics and non-physics items. This is a similar Factor to that obtained in 8.2.1 for the cloze exercises. What is strange is that FORCES physics is apparently linked to the "opposite" of this Factor.

Factor 2 involves Homework and Test Score and mildly relates to OSCILLATIONS physics and FORCES physics. This is the only suggestion so far in the analysis of the reading exercises of a Physics Factor.

Factor 3 appears to be a FORCES non-physics Factor which is not related to anything else. This may support the physics / non-physics split of the items in FORCES.

The results of OSCILLATIONS are not easily squared with the other comprehension exercises. In 7.3.9 I noted that pupils did not seem to be using their physics knowledge effectively in OSCILLATIONS.

The suggestion from Factor 1 here, is that OSCILLATIONS physics and non-physics items travel together in a way which is *opposed* to the physics items of FORCES. Yet, the physics items of both FORCES and OSCILLATIONS have a Factor in common with Tests and Homework scores.

So, although the evidence is conflicting due to the ambiguity of the OSCILLATIONS results, there is a hint that in the comprehension reading exercises physics and non-physics items are separate traits, with the physics items aligned to Test and Homework scores which can be regarded as conventional methods of physics assessment.

A further test to try to clarify whether there are separate factors for FORCES which could be called "physics factors " and "non-physics factors" was carried out and Table 8.15 shows the correlation matrix used. This analysis examines pupils' Homework and Test scores with their responses to FORCES physics and non-physics items .

Table 8.15 Matrix for FORCES physics, non-physics, Homework & Test scores

	Homework	Test	FORCES (P)	FORCES (NP)
Homework	1			
Test	.51	1		
FORCES (P)	.31	.35	1	
FORCES (NP)	-.02	.04	-.36	1

The matrix uses scores from 25 pupils and Table 8.16 shows the results of the factor analysis.

Table 8.16 Orthogonal solution of FORCES physics, non-physics Homework & Tests

	Factor 1	Factor 2
Homework	**.84**	-.06
Test	**.86**	-.02
FORCES (P)	**.47**	-.7
FORCES (NP)	.14	**.91**

FORCES physics items do seem to be aligned, albeit weakly, with the Homework and Test scores, whereas FORCES non-physics items are more closely linked with a separate factor.

8.3 Summary

Here, the evidence gathered in this chapter is related to the three Research Questions specified in 8.0.

Differentiating facets of reading skills

- Physics items cannot be related to a separate factor from non-physics items for cloze exercises.
- In reading exercises which are not of the cloze type there may be a separate factor for physics and non-physics items, but not in any simple way, and dependent on the content of the text.

These results could point to intrinsic differences between cloze and comprehension questions. The validity of distinguishing "physics" and "non-physics" question in cloze exercises may also be brought into question. The results, as reflected by cloze exercise results, seem consistent with the notion of reading not being readily divisible into *subject dependent and subject independent* skills or activities.

Measuring reading competence

- All cloze exercises are not necessarily measuring the same thing since they are not all aligned with the same factor.

It is not clear from the results whether the different factors might be related to the physics content of the passage, how close in time the exercises were administered or the style of the passage.

- In the READING ALOUD exercise the same factor links rate of reading, hesitations and questions answered correctly.

This suggests a "reading efficiency" factor, which points to a situation where fast readers comprehend material better than slower readers

Relationship of results to pupil's competence in physics

- Test scores and A level grades are aligned to the same factor whereas Homework scores have a separate factor.

These results may give some credence to the "achievement" versus "effort" labels for Test and Homework scores, which I suggested at the beginning of the chapter. However, when Homework and Test scores were tested with a cross-section of the reading exercises they tended to travel together indicating that both "effort" and "achievement" are required to perform well on the reading exercises in general. However, when only cloze and READING ALOUD exercises were investigated, there was a suggestion that although one cloze result (ERRORS) was connected with the Test factor, the time taken to read the oral exercise was aligned with the Homework factor. This may hint that slower reading is associated with pupils who put in greater effort.

CHAPTER 9: CONCLUSIONS

9.1 Introduction

This chapter contains four main sections, their purposes being to:

1. Evaluate results and analyses with reference to the research questions;
2. Review and critique the methodology used;
3. Suggest how the findings could be relevant to teachers of physics;
4. Discuss the implications of the results for future research in this area.

9.2 Overview

The research questions were proposed using a framework which is depicted in Fig 9.1. This shows the assumed relationships between texts and tasks which are provided by the teacher as well as the responses and other information gathered about pupil performance. Analyses made are shown by the letters a - e in Fig 9.1 and include: (a) text analysis (b) task analysis (c) item analysis of responses (d) intercorrelation and factor analysis of items and (e) intercorrelation and factor analysis between responses and other results such as A level grade, Homework scores and Test scores.

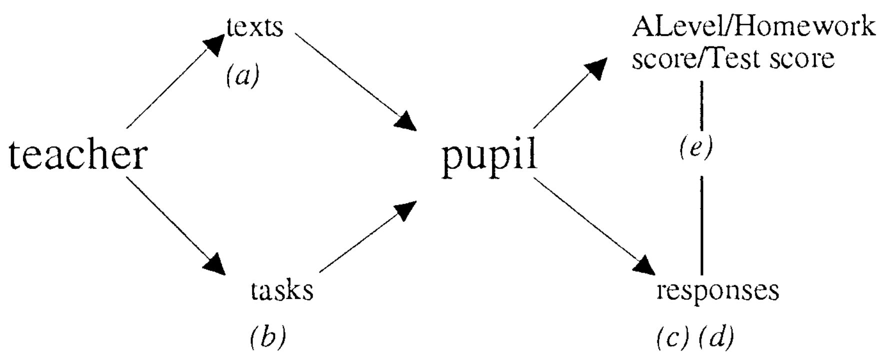


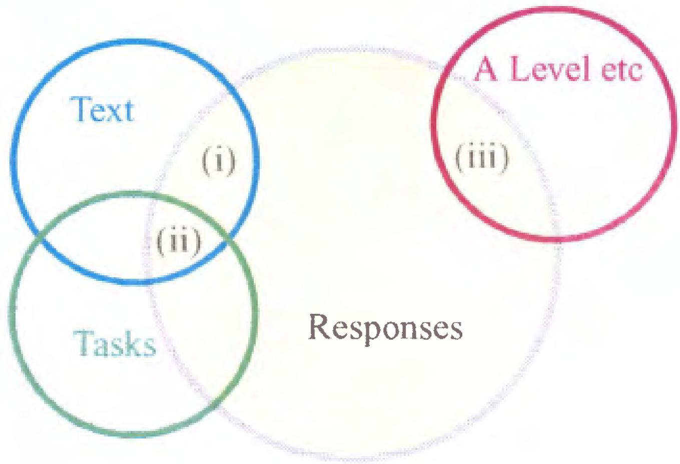
Fig 9.1 Schematic diagram of research framework

The value of the analyses, however, lies not in the sets of data *per se*, but in the interrelationships between them, since the purpose of the study is to investigate the processes or skills involved in pupils reading physics-related material.

Fig 9.2 represents how the areas overlap, with the research questions located mainly in three segments which are noted as **(i)**, **(ii)** and **(iii)** in Fig 9.2., these being:

(i) Text – Responses Interface,
(ii) Text – Task – Responses Interface,
(iii) Responses – A Level Interface.

Fig 9.2 Model of analysis framework showing Interfaces (i), (ii) and (iii).



The research questions are addressed in terms of how they fit into the three categories (i), (ii) and (iii) shown in Fig 9.2.

9.3 Summary of Results

In this summary each of the interfaces will be considered in turn with respect to the Key Guiding Questions (Chapter 3) and, wherever necessary the questions which arise from them.

9.3.1 (i) The Text - Responses Interface

Measuring pupil's reading skills

Can reading exercises help to measure pupils' reading skills and how could this be useful to a physics teacher?

Cloze tests give one kind of measure of reading skill and the results generally proved to be highly reliable. Evidence from the three cloze tests given in this study show that the majority of pupils read the material selected at the Independent level (Table 5.11) with a small minority of pupils reading at the Frustration level. Identifying the pupils who are struggling to read, and indeed all the pupils who are not reading independently, could provide the teacher with insight into the potential strengths and weaknesses of his / her pupils. This could lead the teacher to plan for activities with weaker readers ~~change the planning and delivery of the curriculum~~ with perhaps alternative texts ~~for weaker readers~~, or, a series of cloze exercises given over a period of time as a formative activity.

Comparing english literature A level students with physics students

How do the results of reading exercises used with english A level students compare with those of physics students and are there any implications in the comparisons which are relevant to physics teachers?

There appear to be differences in competence in the strategies used by each group of pupils in responding to cloze "questions". The level of competence achieved by both groups in each reading strategy does not appear to be static and may change with time or possibly different types of text. There is a suggestion from the results that english literature students read "better" at the end of the first year of the A level course than they did at the beginning, if the proportion of pupils who read at the Instructional and Independent levels is used as a yardstick, whereas there is no noticeable improvement in the reading of the physics group, although to be fair, there is little room for improvement.

However, the evidence is not really clear-cut because the passage on which the last cloze exercise was based – a science article from a news magazine – was so different from the first passage which was taken from a standard A level physics text.

English Literature students will have undoubtedly read a greater quantity and variety of texts during the year than physics students. If the difference between the english and physics group at the end of the year is due to the experience of reading a large volume and range of material, and it is difficult to think of another plausible explanation, this could reinforce the case for encouraging more reading in the first year of the physics A level course. Deliberate use of non-standard texts such as magazine articles, would widen the scope of written material which physics students are exposed to. Some of these passages could be given as cloze exercises to allow formative assessments of pupil progress to be made.

9.3.2 (ii) The texts - tasks - responses interface

Distinguishing facets of a pupil's reading skills

What can be said about skills at the linguistic level ?

Discrimination of grammatical items has been found to be greater than discrimination of lexical items which suggests that lower scoring pupils are less competent in the area of grammatical structure than higher scoring pupils. The evidence is, however, not consistent enough in the cloze exercises to make a solid case for a "grammatical skill" or indeed speculation about any kind of causal relationship between grammar and reading scores.

However, I would suggest that since the proportion of grammatical items in a regular-deletion cloze test cannot be controlled, some attention should be paid to the grammatical / lexical item ratio when the results of cloze exercises are to be compared. Differences between the scores of a particular pupil in different cloze exercises which cannot be explained by other circumstances may have some affiliation with the proportion of grammatical items.

What can be said about semantic skills?

Is there evidence of a "physics-reading" skill?

Categorizing items as "physics" or "non-physics", where "physics" refers to items presumed to require background physics knowledge and "non-physics" items which are independent of physics background, was possible for some of the exercises.

For the cloze results, I found a definite trend towards physics items being more discriminating than non-physics items, however, there appear to be no separate **factors** for physics and non-physics items in cloze exercises.

The comprehension exercises confirm the finding that physics items have a better discrimination than non-physics items. In only one case (out of four) is there a suggestion that there are separate factors for physics and non-physics questions in comprehension exercises.

These conflicting results may be due to the differences between cloze and comprehension exercises. Cloze "questions" slot into continuous prose and it is possible that other clues will be available from the text to help pupils find the appropriate word. This means that the problem lies in the way that physics and non-physics items are defined which leaves open the possibility that "genuine physics" items (assuming such items can be found) may be affiliated with a separate factor as appears to be the case in the comprehension exercises.

Is there evidence of other types of skill for extracting meaning?

Items categorized as "Inferencing" where the pupil has to make a logical leap from information given in the passage in order to answer the question adequately, had high discriminations and correlated well with other groups of items such as those which required mathematical skills. Johnston (Johnston, 1984 #37) points out that inferencing is an integral part of reading comprehension. He distinguishes four levels of inferencing ranging from "resolution of lexical ambiguity and resolution of pronominal and nominal references" to "establishment of context for the sentence and establishment of a larger framework for interpretation". I have separated Johnston's *types of inferencing* into two categories. I have called the first group of "lower level" processes, **Reading**, and the second group of "higher level" processes **Inferencing** or Inferring. This is consistent with Johnston's thesis that the first two are "bottom-up" processes whereas the second two are "top-down" processes. I believe that separating the two processes helps to distinguish between items on the basis of the level of sophistication the reader requires to answer them. This could make it easier to identify the likely more discriminatory items, as far as reading comprehension is concerned, in any battery of text-based questions.

Measuring pupils' reading skills

Can reading exercises help to measure pupils' reading skills?

This question appears again here because of some results from the READING ALOUD exercise. Measuring the hesitation rate for pupils reading out a passage is an established and useful index of reading ability for beginner readers. However, a simple connection between low hesitancy and high comprehension was not established in this study. On the contrary, the comprehension of pupils, as reflected in question score, was slightly better for pupils with a high hesitation rate. Stumbling over individual words may be a consequence which arises when some not-so-proficient readers attempt to extract meaning from the passage,

More interestingly, the time taken to read the passage did not have as simple a relationship with the number of hesitations, as might be expected. The two variables appeared to be related for all but the slowest readers, who seemed to control or limit the number of hesitations they made, by reading much more slowly. This appears to be a deliberate strategy which has the short term benefit of increasing comprehension while depressing the hesitation rate. However, this low rate of reading may be affecting the performance of these pupils in tests which are time limited, such as the A level examination.

Results show that faster readers do better at A level than slower readers and that pupils with low rates of hesitation obtain better A level grades than pupils with high hesitation rates. This is particularly interesting because the answers to the questions on the content of the passage did not relate significantly to A level results and recalling that very often the score of right answers to questions would be the criterion by which success on a test would be judged.

It has to be said that this finding could be due to the limited number of questions asked about the passage, but, the fact remains, that two **objective and quantitative** estimates of reading ability, namely, reading rate and hesitation rate, have been shown by this study to have predictive value for physics A level examination results.

Choosing texts and tasks for specific purposes

Could any of the results help a teacher to decide which passages might be suitable and the kinds of activities which should be usefully given?

Difficulty of passage

Of the three reading difficulty assessments which were carried out for each exercise, SMOG gave results which consistently showed a higher reading age than Fry or Flesch which were more or less equivalent. The SMOG estimate is based on the number of words of three syllables or more in ten sentences and we know that the occurrence of polysyllabic words is high in scientific writing in general and these passages in particular. I felt that because the same polysyllabic words tend to be repeated in a given passage the overall difficulty of a piece would not be increased in proportion to the number of these words, although other writers do not agree with this view (Harrison, 1982 #35). The cloze results tended to show that pupils generally found the passages much easier to understand than SMOG would have predicted. Of Fry and Flesch, **Fry** results are possibly easier to interpret since the results are given in terms of reading-age in years, whereas Flesch gives a percentage score which is related to a continuum of ease / difficulty.

Although SMOG consistently "exaggerates" difficulty, Flesch and Fry tend also to overestimate the difficulty of the passages. Since all three indices are based on syllable count to some extent this indicates that **readers manage familiar polysyllabic words more easily than predicted.** Jerry Wellington's assumption (discussed in 1.3) that science texts are more difficult than "crude" reading estimates are capable of assessing, is not supported by these results.

Of course, cloze exercises are also used to determine reading difficulty, but I have found that cloze results tend to reflect the *type* of passage used rather than objective reading difficulty, particularly if one looks at the number of pupils reading at the Independent level (over 60% correct responses). However, the number of pupils reading at the Instructional level or better (over 40% correct responses) appears to remain fairly constant despite the differences in reading difficulty predicted by Fry[1] or the type of passage chosen.

Type of passage

The evidence from this study suggests that material from magazine articles is more difficult for physics students than A level text book passages of a similar "reading age". It could well be that pupils would benefit from reading a wider variety of material. Controlled exposure to newspaper and magazine articles as well as to non-standard books could be accomplished through selected reading exercises.

---

[1] Reading ages predicted by Fry ranged from 12 years (PROJECTILES) to 18 years (READING ALOUD)

When selecting from a number of passages on the same topic in different textbooks, other criteria apart from reading difficulty to bear in mind are the liveliness of the prose, interesting examples given, diagrams or illustrations which could form part of the interrogation of the text and sub-headings or paragraphing which may make the text easier to handle.

Cloze

The three close exercises had high reliability (0.95 or greater). However, it is not clear precisely what the cloze results are measuring, apart from the ability to do cloze tests. Good correlation was found between cloze exercises based on standard A level textbook material, given a few weeks apart from each other. Correlation between the cloze exercises given at the beginning and at the end of the first year A level course was low, but this may be because the passages were so different, not only in style but even in the proportion of lexical / grammatical words.

Identifying pupils reading at the Frustration level (scoring less than 40%) can be achieved fairly simply with a cloze exercise. Analysis of the mistakes a pupil makes by classifying the items could help to diagnose the latent problems of even moderately successful readers.

Tasks

Evidence supporting the idea of specific skills such as, ability to "underline key words" or "draw a diagram based on written information" was not found. However, there are certainly differences in the facility and discrimination of items which seem to be related to the demand made by tasks / questions. For example, questions which ask for information which cannot be extracted or readily inferred from the passage had uniformly poor facility and discrimination.

A series of questions asking for underlining and diagram drawing economise on the time taken to frame individual questions and can eliminate the problem of supplying textual "clues" with the question. Questions that require underlining in particular, have good discrimination.

Distinguishing between items which rely on context at the phrase or sentence level and items which need a broader knowledge structure (which I have called Reading and Inferring respectively) could be used to establish two tiers of question difficulty which may help in the planning of questions about a particular passage.

9.3.3 (iii) The responses - A Level/ tests/ homework interface

Relating results to pupils' physics achievement

Since competence in the subject is judged ultimately by the A level examination, how do the reading exercise results compare with the A level grade and other means of assessing pupil performance which are available to the teacher?

Many of the reading exercises correlate significantly with the A level grade obtained by pupils, although the closest correlation of A level grade is with the pupils' results in class tests followed by pupils' homework scores. However, the correlation between reading exercises and A level results is closer than the correlation between reading exercises and class tests / homework.

This suggests that reading exercise results are a valid addition to homework and test scores in assessing pupil's physics competence.

One further point is that the content of the passage chosen for a reading exercise does not have to be totally syllabus-specific. This means that reading exercises could be a useful adjunct to entrance or aptitude tests for physics A level courses, or in assessing new entrants to a class. Also, apart from exercises such as READING ALOUD the exercises are paper-and-pencil tests which are administered fairly simply.

9.4 Review of methodology

Action Research

The constraints of working with four physics groups in different schools in a way which did not interfere with the normal running of the class, to minimize burdening pupils with what might be considered irrelevant work and to maintain harmonious relations with the teachers, can be considered as two-fold:

Firstly, the problem of finding **passages of text which were relevant** to the scheme of work used in each school. This could have produced a situation where there was insufficient overlap in the topics studied to provide a reasonable sample of pupil results for each exercise. In the event, only two exercises were affected by this, INTERNAL RESISTANCE where one group did not participate because they did not study electricity in the first year course, and HEAT RADIATION which this group only did instead.

I did not use passages which were not in some way related to physics, to be true to the aim of not distracting the participants from the subject. However, using at least one "standardized" reading exercise could have helped me to make a more objective assessment of pupils' reading in general, and I now feel this was an opportunity missed.

Secondly, and related to the above, is the problem of not being able to **repeat passages** where the results seemed important or needed clarification, due to limiting the number of exercises[2] and agreeing that the teacher decide when the exercises were given to pupils. I would have preferred it if all the exercises were done in class so that I could

[2] One to two exercises per half term for the first two terms and one in each half of the summer term

have been (a) aware of the **time allocation** for each exercise, (b) sure that there had been no "sharing" of answers and (c) able to have a more **complete record of work** for each pupil, all of which were affected by the vagaries of pupils being given "homework". Although the reliability of the tests was not a particular problem, the question of some pupils working more slowly than others did arise, with reading speed affecting test performance.

English groups

As the involvement of the english groups was limited to two exercises, the first and the last, I felt that there would be more tolerance for using material which was not related to the Literature syllabus, and the english teachers involved were agreeable to the passages being physics-related. The results were useful in that they seemed to show how much more, relatively, **the english pupils had improved during the course of the year** and the **differences between the english and physics groups in terms of how items were responded to**. However, as mentioned above, perhaps the study would have profited if one of the two exercises given to both the english and the physics groups had been non-subject specific, in order to obtain some sort of independent reference of reading ability for all the pupils involved.

Variety of tasks

One deliberate aspect of the study was incorporating several types of reading exercise with a view to **evaluating the relative strengths and weaknesses of each type**. Some surprises emerged in that exercises such as READING ALOUD which were thought to have only a possible theoretical significance was found to have possible practical applications.

The other point about the variety of exercises is that it has been possible to look in detail at the **breakdown of tasks** involved and see common features and discrepancies between them. For example, knowing that asking a pupil to underline the important phrase in a paragraph involves him/her in, say, "Reading and Inferring" then results from items from another exercise which have nothing to do with underlining but which are also related to "Reading and Inferring", could be used for comparative purposes.

Use of published texts

Using published passages of text had three main purposes, firstly, to **save time** in composing pieces, editing, constructing diagrams and so on. Secondly, to introduce a flavour of the **different styles** and presentation of prose that are widely available. Thirdly, to **look objectively at the criteria** which should be considered when a teacher chooses a suitable passage for a reading exercise.

I looked at teachers' opinions of some of the passages and found that teachers tended, overall, to make predictions of passage difficulty which corresponded to the Fry and Flesch indices, which themselves tended to slightly overestimate difficulty. In retrospect, I feel that it would have been useful to obtain opinions on all the passages from a larger sample of teachers, so that I could have included a more systematic study of passage selection.

Item analysis

Item analysis was undertaken systematically for the three cloze tests in particular. The analysis looked at whether the item was a **grammatical or lexical word** as defined by Halliday and Martin (Halliday, 1993 #10) and what kinds of strategies pupils might use to find the missing word. The actual facility and discrimination of items was compared with those hypothesized on the basis of these criteria.

Scattergraphs of the facility and the discrimination of items in each exercise were drawn, and sorting the items into grammatical / lexical categories or others based on "tasks" helped to clarify why some items were easier or more discriminating than others.

Looking at the pattern of distribution of grammatical and lexical items between parallel exercises allowed the overall structure of the exercises to be compared *post hoc*.

One trend which was noticed was that **grammatical items tend to discriminate better than lexical items** for physics pupils at least, which suggests a real **variation in reading skill** independent of knowledge of content in this group.

However, where items were sorted into physics and non-physics categories, **physics items are shown to be less easy and more discriminating** than non-physics items, which is to be expected.

Classification of errors

Some use was made of analysing the errors pupils made in answering questions, to get a profile of the kinds of **mistakes made by low-scoring as opposed to high-scoring pupils.** There is a standard classification of the errors made in cloze tests which I considered using, but as many of the "errors" in the cloze exercises were blanks I abandoned this with cloze and concentrated on other exercises where pupils were more likely to give a response. The main purpose of looking at errors is the possibility that identifying problems that readers are experiencing could be a first step in trying to solve or alleviate the situation.

I classified errors into two categories, those showing a "low level of skill" and a "higher level of skill". "Low level" errors were those where instructions had not been followed properly, for example, where two sentences had been underlined instead of one. "High level skill" indicated that the answer was a "near miss", in that some of the information was provided by the pupil but not enough to obtain the mark. Overall, high-scoring pupils tended to give more complete answers showing a "high level of skill" even when they obtained no mark for the question.

Cross-referencing

I thought that a fuller picture of the uses of reading exercises and a more solid case to base recommendations to try them could be achieved by **integrating homework, test scores and A level grade** for each pupil with the results of the reading exercises. The physics teachers from each school kindly gave me a photocopy of their mark book and thus I was able to compute a Homework score and Test score for each pupil's work over the first year of the course. Together with the A level grade these two scores gave a reference framework from which to comment on the results of the reading exercises.

In fact, the majority of the **reading exercise results correlated with A level results** at a statistically significant level.

The reading exercises correlated better with the test scores than with the homework results. Many of the reading exercises were done by the pupils for homework, which suggests that they may be a more objective assessment than "normal" homework.

9.5 Suggestions for physics teachers

This section offers some points covering four topics arising from the study which might be relevant to teachers of A level physics who wish to promote reading with their pupils.

Widening the variety of reading material

Encouraging reading becomes more realistic if material is readily available for pupils to read. Apart from buying books for the school or class library, borrowing books or periodicals from local libraries which are connected to aspects of the work covered in class, is one alternative. Library shelves full of science books may be intimidating to some pupils and it is probably best to introduce a few selected titles at a time. Photocopying extracts from books or articles from magazines and newspapers is another possibility.

Finding subjects which pupils are involved in, related to hobbies, or anticipated careers are perhaps obvious examples, and this is a useful way of interesting pupils in text and thus of getting reading started. News-making items such as recent discoveries in space exploration and quantum mechanics can be exploited for their interest-stimulation value and subsequent articles can be used with groups or individuals.

The objective here is not for the pupil to read vast amounts of text or glean, single-handedly, all the information necessary for the A level course. Rather, that there should be a controlled introduction to a range of reading material, so that pupils experience written discourse in ways which reflect the various styles of scientific communication. The purpose of pupils reading this array of material is that they become **better readers of the subject**, both from the point of view of future reading for learning and, to put it bluntly, because better readers seem to be more successful in their examinations.

Selecting text

The text selected in a particular case will depend greatly on how the passage is to be used. Where an important part of syllabus-related physics is being addressed, the simpler the terms used in the passage the better. If the passage covers interesting but peripheral matters that fall into the category of "background reading' then simplicity is not such an important criterion. Anecdotal evidence points to even reluctant readers tackling surprisingly difficult material when the subject is of particular interest. However, the assessment of difficulty of a text by an individual from an intuitive point of view has been found to be very inaccurate. Some means of objectively measuring reading difficulty is useful to establish a reference base of difficulty and for the purposes of comparing texts.

I suggest using the **Fry method** (Harrison, 1982 #35). This gives an estimate of the probable difficulty of a passage in terms of "reading age" which is straightforward to interpret and the results are fairly consistent with student performance.

If a passage is to be studied in some depth, when comparing passages from various books with similar predicted reading difficulty, look also at the presentation and layout. Features such as sub-headings, use of bold type for emphasis and paragraphs that are, or could conveniently be, numbered, are some of the factors which can make a difference to readability. Look at how the topic is introduced relative to how this was done with your class and finally, check that terms or information which you consider important are given sufficient weight and clarity.

It is possible for a passage to have a reasonable reading age and yet be difficult to understand, so it is particularly important when a passage is to be closely scrutinized by pupils to check both the **content and the presentation**.

Indentifying readers' problems and problem readers

Reading can be assessed by **listening to pupils read**. Although this is an unlikely sounding activity at this level, I have found students to be co-operative and to seem to enjoy participating. The process does not necessarily have to be lengthy, and with a medium sized group, of, say, ten pupils, the recording process could be accomplished in one practical session if pupils are allowed seven to eight minutes each. For longer sessions, all sorts of other combinations are possible - over a series of lunchtimes perhaps. The important things are to have a quiet, undisturbed place so that the pupil feels at ease, and to have a means of recording the session.

If time is limited, the most valuable things to take note of are the **time the pupil takes to read the passage and the number of hesitations** made. Five hundred words takes approximately five minutes to read aloud. I do not advise further time saving (of teacher time) by trying to dispense with the tape recorder and relying on a stop-watch while the pupil is reading, as the pupil may be tempted to read faster than usual.

Chose a passage which is not too heavily syllabus orientated, which the pupils are likely to find interesting and with is "slightly challenging" in terms of difficulty. I recommend spending slightly longer on this exercise and asking as many questions as possible about the passage. Of course, the pupil should be informed of this beforehand, as this might influence his/her rate of reading.

As far as interpreting the results is concerned, we know that a slow rate of reading, and, or, a high hesitation rate are consistent with students who have the most difficulty reading and whose physics achievement might well be affected by this. A convenient rule-of-thumb is to be aware of pupils who take more than 30% longer than the mean time. For a five hundred word passage, this would include pupils who take 390 seconds or longer.

Knowing which pupils may have difficulty with texts, early on in the course, should affect the kind of reading material these pupils are provided with, and, if necessary these pupils could be given practice reading assignments using progressively graded passages.

Cloze exercises can be an alternative to an oral exercise for assessing reading. Cloze exercises at the beginning and end of the first year could be a good way of monitoring progress in reading. In this case, ensure that both passages are of similar styles e.g. from standard text books or a particular magazine. Regularly deleting every seventh word in a passage which occupies approximately one side of A4 paper, about 350 - 400 words will give around 50 blanks or test items.

Pupils who score less than 20 (40%) in such a cloze exercise, are thought to be reading at the Frustration level and again, some provision should be made for giving these pupils extra time to help to improve their reading.

Having said this, most pupils will read reasonably quickly and read at the Instructional level or better. However, these pupils also need to be introduced to the literature and be encouraged to read. It is with this process also that reading exercises could help in the classroom. Reading exercises provide a means for checking that reading has been done adequately and have potential for **diagnosing problems** that might be impeding progress such as retrieving information, recognising key words or phrases in a paragraph and making inferences between what is written and what the author assumes is "understood", amongst others.

Assessing pupils' physics knowledge

Reading Exercises provide a useful means of indicating pupils' progress in the subject. This is partly because "reading physics" seems to be a **coherent rather than a fragmented process which reflects both a pupil's reading and physics skills**. At least we know that Reading Exercise results have good correlation with A level results yet not such good correlation with other teacher-marked work such as homework and class tests, which might mean that Reading Exercise results tell us something useful about what the pupil has learnt that other tests do not.

9.6 Implications

I would like to make two suggestions as to how the subject of reading in the A level curriculum could be further investigated. The suggestions are both related to findings or observations made in the course of this study. The first concerns the problem of how passages of text are selected for suitability and the second, the relationship between reading speed and performance in the subject.

9.6.1 The problem of text selection

In order to make more precise our descriptions of how pupils are reading, we need to **look more closely at the passages of text** we are setting for the reading exercises. In this study, I used text assessments such as Fry, Flesch and SMOG to measure the syllable load of words and length of sentences of passages, while acknowledging that these measurements give only one indication of difficulty. It is possible to have short sentences with relatively few syllables that are still very difficult to comprehend. For this reason, I stipulated other criteria which I used to decide if a passage was suitable. These were features such as content, relevance to syllabus, type of examples used, sub-headings and so on (see chapter 4 section 3).

Despite this, it has to be admitted that the choice of passage was heavily dependent on my "intuitive" assessment. In most cases this method was satisfactory and reasonable results were obtained from the reading exercises. It was when comparing results from similar exercises that it became clear that the *type* of passage used was an important variable. I offered the suggestion that if students could be more familiar with a wide variety of passage types as well as standard text books, the variability in results between reading exercises could be reduced. This is hardly a solution to the problem of making valid assessments of science texts, and it would be helpful if a workable, systematic method could be devised to assist the individual science teacher in making a more objective assessment of any passage.

Of course, it is unlikely that there will ever be a simple formula which could solve the problem. However, linguistic features of text discussed by Halliday and Martin and mentioned in chapter 2 of this thesis (Halliday, 1993 #10), such as the ratio of grammatical to lexical words found in a given passage, have been used to explore some of the data[3] from the reading exercises in this study. The results have indicated that measurement of grammatical and lexical items is important and the ratio between the two does reflect some aspects of the difficulty of the texts used.

Halliday and Martin's analysis specifies seven categories of features of scientific texts which give rise to difficulties. These seven categories are: *interlocking definitions, technical taxonomies, special expressions, lexical density, syntactical ambiguity, grammatical metaphor and semantic discontinuity.* It is possible that linguistic features such as these could be used to differentiate levels of text difficulty which are more closely aligned to how difficult texts are to **comprehend.**

9.6.2 Reading speed and performance

One aspect of the results which emerged unexpectedly was the variability of **reading speed** amongst pupils and the fact that this seems to be related to examination success. The relationship between reading speed and achievement in physics could profit from being tested further with a view to investigating, initially, what the causal relations between them are. Ultimately, of more relevance to the physics teacher, would be knowing whether slower readers would benefit from being taught to read faster, and furthermore how this could be done as efficiently as possible. On the other hand the case for giving some pupils a longer time for tasks involving reading, if this was shown to be a significant impediment to their performance, could be considered.

9.7 Final remarks

Its seem to me that two general conclusions can be drawn from this study:

Firstly, although it is clear that a small proportion of pupils who study physics at A level might have reading difficulties, probably the vast majority are perfectly capable of reading the kind of material that is available for them. Indeed, it seems that pupils are better at

---

[3] Halliday and Martin's Writing Science (Halliday, 1993 #10) was published after the exercises had been selected and given to pupils, hence I could only use their linguistic analyses for reviewing my data.

reading than their teachers assume. However, there seems to be a case for not only improving the skills of the weakest pupils but for allowing all pupils to hone their reading skills and to read more. My experience is that A level pupils find it valuable to do reading exercises connected with physics. I think that **introducing the literature of the subject to A level pupils** through reading exercises could help to raise awareness of the importance of reading and increase pupils' confidence and motivation in extending their reading habits.

Secondly, results from this study suggest that investigating pupils reading at this level *is* possible and that further research in these areas might be profitable. One reason for this is that despite being *capable* of reading the literature, many pupils avoid reading. Trying to determine the causes for pupils' reluctance to read may well help in producing reading materials which are more attractive to young people.

BIBLIOGRAPHY

Alvermann, D. (1991). *Science Learning: Processes and Applications*. Newark, Delaware: International Reading Association.

Arnold, H. (1984). *Making sense of it.* London: Hodder and Stoughton.

Barnes, D. (1972). *Language and Learning in the Classroom.* InLanguage in Education Milton Keynes: Open University Press.

Bernstein, B. (1990). *The structuring of pedagogic discourse.* Routledge.

Blalock, H. (1981). *Social Statistics.* McGraw-Hill.

Brown, J. (1983). *A closer look at cloze: validity and reliability.* In J. Oller (Ed.), Language in Education: Testing the Tests USA: Newbury House Publishers.

Bruner, J. (1972). *The Course of Cognitive Growth.* In Language in Education Milton Keynes: Open University Press.

Bullock (1975). *Bullock Report* London: H.M.S.O.

Bulman, L. (1985). *Teaching Language and Study Skills in Secondary Science.* London: Heinemann.

Carré, C. (1989). *Language, Teaching and learning.* Cambridge: Cambridge University Press.

Child, D. (1975). Essentials of Factor Analysis. Holt, Reinholt and Winston.

Chomsky, N. (1972). *Language and the Mind.* In Language in Education Milton Keynes: Open University Press.

Crocker, L., & Algina, J. (1986). *Introduction to Classical and Modern Test Theory.* Orlando: Harcourt Brace Jovanovich.

Davies, F., & Green, T. (1984). *Reading for learning in the sciences.* Edinburgh: Oliver and Boyd.

Driver, R. (1981). *Alternative Frameworks in Science.* European Journal of Science Education, 3(1), 93-102.

Driver, R. (1985). *Childrens' Ideas in Science.* Milton Keynes: Open University Press.

Gibbs, K. (1988). *Advanced Physics.* Cambridge: Cambridge University Press.

Halliday, M., & Martin, J. (1993). *Writing Science: Literacy and Discursive Power.* London: Falmer Press.

Harrison, C. (1982). *Readability in the Classroom.* London: Heinemann.

Hutchings (1990). *Physics.* London: Macmillan.

Irving, A. (1985). *Study and information skills across the curriculum.* London: Heinemann.

Johnston, P. (1984). *Reading Comprehension Assessment: A Cognitive Basis.* International Reading Association.

Kempa, R. (1986). *Assessment in Science.* Cambridge: Cambridge University Press.

Koch, & Eckstein (1991). Improvement of reading comprehension of physics texts by students' question formulation. *International Journal of Science Education, 13(4), 473-485.*

Kress, G. (1990). *Linguistic processes in sociocultural practice.* Oxford: Oxford University Press.

Kress, G. (1996). *Reading Images:The Grammar of Visual Design.* London: Routledge.

Lunzer, E., & Gardner, K. (1979). *The effective use of reading.* London: Heinemann.

Ogborn, J. (1991). Towards an ontology of common-sense reasoning. *International Journal of Science Education, 13(1), 69-85.*

Project, C. A. t. S. E. (1993). *Better Learning*: An account of the Cognitive Acceleration through Science Project.

Reid, D., & Beveridge, M. (1990). Reading illustrated science texts: a micro-computer based investigation of children's strategies. *British Journal of Educational Psychology, 60, 76 - 87.*

Rosen, H. (1972). *The Language of Textbooks.* InLanguage in Education Milton Keynes: Open University Press.

Rowe, D. (1988). *The Successful Self.* London: Fontana.

Rye, J. (1982). *Cloze procedure and the teaching of reading.* London: Heinemann.

SchoolsCouncil (1975). *Reading for Learning in the Secondary School* No. Department of Education and Science.

Shayer, M., & Adey, P. (1981). *Towards a Science of Science Teaching.* London: Heinemann.

Solomon, J. (1984). Prompts, cues and discrimination. *European Journal of Science Education, 6(3), 277-284.*

Stubbs, M. (1985). *Language,schools and classrooms.* London: Methuen.

Sutton, C. (1980). *Language and Meaning.* School Science Review, 62, 47.

Sutton, C. (1992). *Words Science and Learning.* Milton Keynes: Open University Press.

Teachers, A. o. L. (1969). *London Teacher* Policy Document .

Vygotsky, L. (1966). *Thought and Language* (Hanfmann,E &Vakar,G, Trans.). Massachusetts: M.I.T. Press.

Watson, G., Wright, V., & De l'Aune, W. (1992). The Efficacy of Comprehension Training and Reading Practice for Print Readers with Macular Loss. *Journal of Visual Impairment, 86(1), 37-44.*

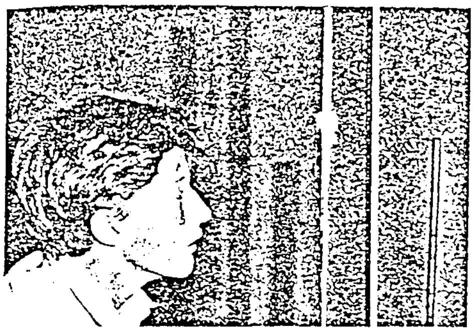
Wellington, J. (1991). A Level Textbook Review. *Physics Education, 26, 313-316.*

Winch, C. (1990). *Language, Ability and Educational Achievement.* London: Routledge.

Wittrock, M. (1991). *Testing and cognition.* New Jersey: Prentice hall.

Woolnough, B., & Allsop, T. (1985). *Practical Work in Science.* Cambridge: Cambridge University Press.

Systematic and random uncertainties Uncertainty can be of two types (1) or random. A systematic uncertainty will (2) in all the readings taken being (3) in one direction. Using a stopclock (4) is running fast will result in (5) time readings being too big; using (6) ammeter with a zero reading of −0.2A (7) result in all readings being 0.2A (8) small. Calibration errors will result in (9) uncertainty, but experimenters are somewhat too (10) of assuming that any systematic uncertainty (11) be due to the apparatus they are using. This is not necessarily (12) .



Systematic uncertainty can be introduced (13) an experiment by poor experimental technique. (14) experimenter in the picture will be (15) all his length readings incorrectly because his eye is not on the same level (16) the mark on the ruler. He (17) introducing a parallax error which will (18) all of his readings in the (19) way.
Systematic uncertainty is difficult to (20) and eliminate , but there are some (21) procedures which can reveal it. Two ammeters (22) in series must have the same current (23) through them. If readings are (24) the same then there must be (25) systematic error in one of them. (26) a third ammeter if you are (27) sure which one is in error. (28) systematic error can be done by (29) good experimental technique and by varying (30) instrumentation being used. Systematic uncertainty can (31) be eliminated by taking repeated readings (32) the same built-in faults.

Random (33) as their name implies, results from (34) inability of the observer to repeat his/her readings (35) . If the period of oscillation of (36) pendulum is being measured, an experimenter (37) be timing 50 swings. There are (38) things which cannot be reproduced exactly (39) time. (40)

*the reaction time on the stopclock vary a little.
*the start of (41) first swing and the end of (42) fiftieth swing may not be noted .
*the same starting amplitude may not (43) used each time so although the (44) of oscillation is nearly independent of amplitude (45) is a small influence of amplitude (46) period.
*the hand of the stopclock (47) not be viewed from quite the (48) angle, so introducing a random parallax (49) .

Accuracy and precision These two words are often taken (50) mean the same thing. It is (51) however to have readings taken with (52) precision which are not accurate. This (53) happen if there is a systematic (54) . Similarly it is possible to have (55) that are accurate but not very (56) . This will occur if there is (57) a small random error in the (58) taken.

A precise reading will be (59) to a large number of significant (60) , but be careful to use instruments (61) appropriate precision. It would be (62) unsuitable to measure out food for (63) recipe using a balance capable of (64) to a milligram. It would take (65) to get exactly 100,000 milligrams of butter (66) a mixing (67) , and then some of it would (68) to the sides. Similar absurdities can (69) the physics lab with students spending (70) long time taking unsuitable readings. While (71) aim of doing any experiment is (72) be as accurate as possible, there is no point in taking (73) readings to a very much higher (74) of accuracy than others in the (75) experiment. Ideally, for each of the (76) taken, the fractional uncertainty of each (77) should be known, at least approximately.

Appendix 2 ERRORS results

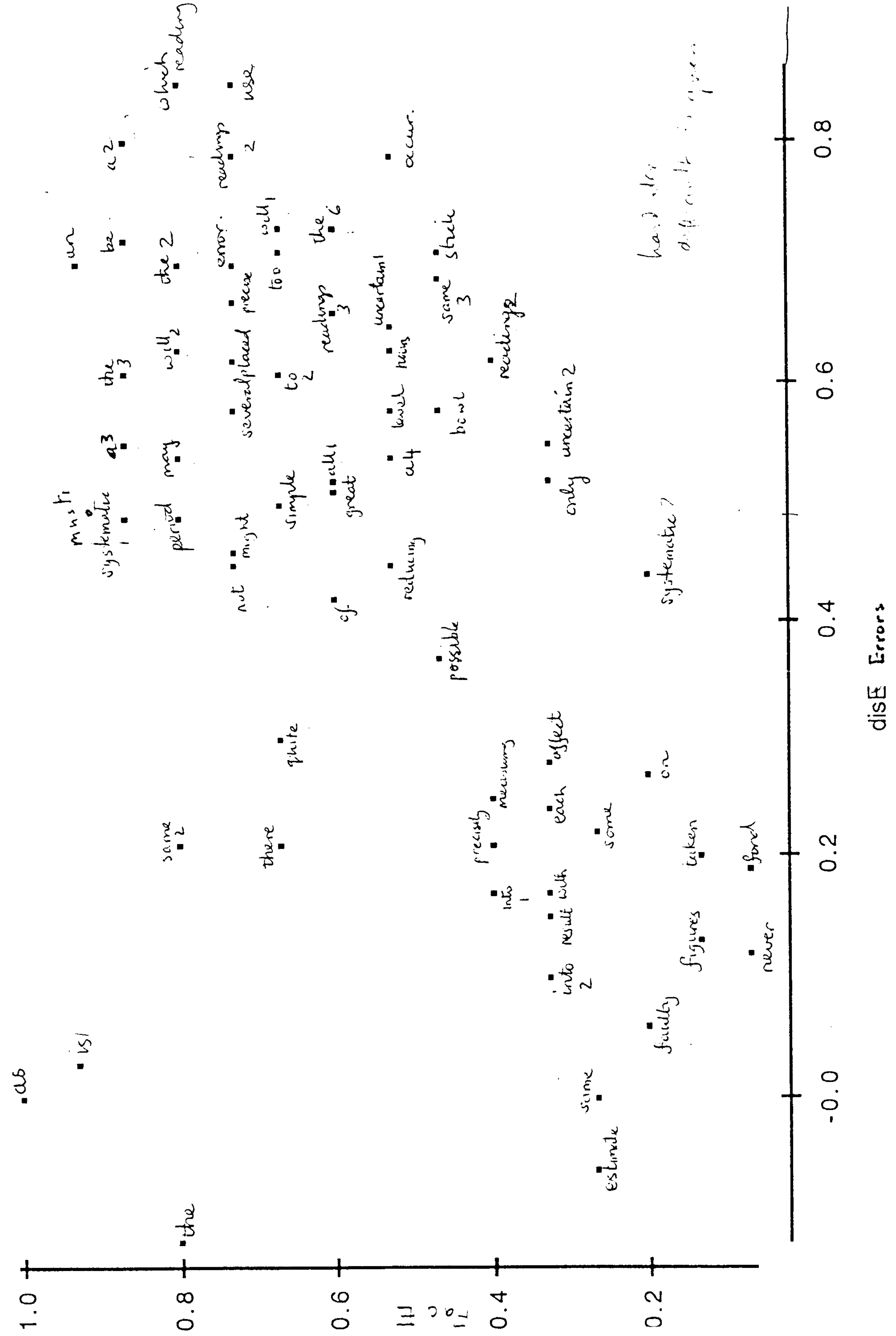
ITEM	dewa	mipa	chst	vius	nmi	rba	cdi	kbra	sch	libr	anve	name	clst	alra
SYSTEMATIC	0	1	1	1	1	1	1	0	1	1	1	1	1	1
RESULT	-	0	0	0	1	1	0	0	0	0	0	1	0	1
FAULTY	0	0	0	0	1	-	0	0	0	0	1	0	0	0
WHICH	0	1	1	1	1	1	0	0	1	1	1	1	1	1
ALL	-	1	0	1	1	1	-	0	1	1	0	1	1	1
AN	1	1	1	1	1	1	0	1	1	1	1	1	1	1
WILL	0	1	1	1	1	1	0	0	1	0	1	1	0	1
TOO	0	1	1	1	1	1	-	0	1	1	1	0	0	1
SYSTEMATIC	0	0	1	0	0	1	0	0	1	0	0	0	0	0
FOND	-	1	0	0	-	0	-	0	0	0	0	0	-	0
MOST	-	1	1	1	1	1	1	0	1	1	1	1	1	1
SO	-	1	1	1	1	1	-	-	1	1	1	1	1	1
INTO	1	1	1	1	0	0	0	0	0	1	0	0	1	0
THE	0	1	1	1	1	1	1	1	0	1	0	1	1	1
READING	0	1	1	1	1	1	-	0	1	1	1	1	1	1
AS	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IS	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AFFECT	0	1	1	0	0	0	0	0	0	0	0	1	0	1
SAME	0	0	0	1	0	0	0	1	0	0	0	1	0	1
ESTIMATE	-	1	0	0	0	0	0	1	0	1	0	0	0	0
SIMPLE	1	1	1	1	1	1	0	0	1	-	1	-	0	1
PLACED	1	1	1	1	1	1	0	0	1	-	1	1	0	1
FLOWING	1	1	1	1	1	1	-	1	1	1	1	1	1	1
NOT	1	1	1	1	1	1	-	0	1	0	0	1	1	1
A	1	1	1	1	1	1	-	1	1	1	1	1	1	1
USE	0	1	1	1	1	1	-	0	1	1	1	1	-	1
NOT	-	1	1	1	1	1	-	0	1	1	1	1	1	1
REDUCING	-	0	1	0	1	0	-	0	1	1	1	1	0	1
USING	-	1	1	1	1	1	-	0	1	1	1	1	-	1
THE	-	1	1	1	1	1	-	1	1	1	1	1	-	1
NEVER	0	0	0	0	0	0	-	0	0	1	0	0	0	0
WITH	1	0	1	0	-	0	-	0	1	1	0	0	-	0
UNCERTAIN	-	1	1	0	1	1	-	0	1	1	1	1	0	0
THE	1	1	1	1	1	1	-	1	1	1	1	1	0	1
PRECISELY	-	0	1	0	1	0	-	0	0	1	0	1	0	1
A	1	1	1	1	1	1	-	0	1	1	1	1	1	1
MIGHT	0	1	0	1	1	1	-	1	1	1	1	1	1	1
SEVERAL	1	0	1	1	1	1	-	0	1	1	1	1	0	1
EACH	1	1	0	1	0	0	-	0	1	0	0	0	0	1
MIGHT	1	1	1	1	1	1	-	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	-	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	-	1	1	1	1	1	1	1
BE	-	1	1	1	1	1	-	1	1	1	1	1	1	1
PERIOD	-	1	0	1	1	1	-	1	1	1	1	1	1	1
THERE	0	0	1	0	1	1	-	1	1	1	0	1	1	1
ON	-	0	-	0	0	0	-	0	1	0	-	1	-	0
MAY	-	1	1	1	1	1	-	1	1	0	1	1	1	1
SAME	1	1	0	1	1	1	-	1	1	1	1	0	1	1
UNCERTAIN	-	-	1	-	0	1	-	0	1	-	1	1		0
TO	-	1	1	1	1	1	-	0	1	1	1	1	1	1
POSSIBLE	1	1	0	1	0	0	-	0	1	0	1	1	0	0
GREAT	-	1	1	1	0	1	-	1	1	1	1	0	0	-
WILL	-	1	1	1	1	1	-	1	1	1	1	1	1	1
ERROR	1	1	1	1	1	1	-	0	1	1	1	1	-	1
READINGS	1	1	1	1	1	1	-	0	1	1	1	1	1	1
PRECISE	-	1	1	1	1	1	-	0	1	1	0	1	1	1
ONLY	-	1	1	1	0	1	-	-	0	0	1	0	0	0
READINGS	-	1	1	1	1	1	-	0	1	1	1	1	1	1
TAKEN	0	0	0	0	0	0	-	0	1	0	0	0	0	-
FIGURES	-	0	0	0	-	0	-	0	1	0	0	0	1	-
OF	-	1	1	1	-	0	-	1	1	1	1	0	0	1
QUITE	1	1	0	1	-	1	-	1	1	1	1	1	1	-
A	1	1	1	1	-	1	-	1	1	1	1	1	1	1
MEASURING	1	-	1	1	-	-	-	-	1	0	0	1	1	-
HOURS	-	0	1	1	-	1	-	-	1	1	1	1	1	-
INTO	1	0	1	1	-	-	-	-	0	-	1	0	1	-
BOWL	-	1	1	1	-	1	-	-	1	-	1	-	1	-
STICK	-	1	1	1	-	1	-	-	1	1	1	0	0	-
OCCUR	-	1	1	1	-	1	-	-	1	1	1	1	-	-
A	1	1	0	1	-	1	-	-	1	1	1	1	-	-
THE	-	1	1	1	-	1	-	-	1	1	1	1	1	-
TO	1	1	1	1	-	1	-	-	1	1	1	1	1	-
SOME	1	0	0	0	-	1	-	-	1	0	1	0	0	-
LEVEL	1	1	1	1	-	1	-	-	1	0	1	1	-	-
SAME	0	1	1	1	-	0	-	-	1	1	1	1	-	-
READINGS	1	1	1	1	-	1	-	-	1	1	1	1	-	-
READING	0	0	1	1	-	1	-	-	1	1	1	0	-	-
TOTAL	30	58	59	60	44	58	5	24	65	54	57	56	39	47

sba	ANN	BEN	ANNG	ARFA	RABI	SANG	REZI	BIMA	MIMO	CLARE	DAN	EMILY
I	I	I	I	I	I	I	I	-	I	I	I	-
I	I	show	I	I	arise	be	-	-	I	show	increase	-
I	ropogate	ncentrat	I	only	-	-	-	-	-	going	constant	-
I	I	-	I	I	-	I	I	I	I	-	I	-
0	recorded	the	-	I	-	at	the	the	random	-	taken	-
I	I	an	I	I	I	I	I	I	-	-	-	-
I	I	the	I	I	the	I	I	-	I	-	-	-
I	I	are	I	I	I	I	I	I	being	-	-	-
0	ncalculat	the	-	I	this	I	I	-	random	-	sI	-
-	vague	-	sure	sure	scheptica	sure	random	-	uncertain	-	cautious	-
I	ncountere	will	will	may	will	can	will	I	may	would	will	-
I	I	-	I	I	I	I	I	I	I	I	I	-
0	I	in	I	in	-	from	as	I	in	as	in	during
I	I	-	I	an	I	I	I	I	I	I	I	-
I	I	-	alibratin	alibratin	-	I	I	recording	I	recording	I	I
I	I	I	I	I	-	I	I	I	I	I	I	I
0	I	I	I	I	-	I	I	I	I	I	-	-
I	-	I	I	I	have	obscure	I	I	isinterpr	I	I	-
0	-	-	I	I	I	I	I	I	I	I	I	opposite
I	calculate	measure	discern	trace	trace	conceal	avoid	detect	reveal	find	detect	analyse
I	periment	various	proven	importan	specific	-	-	other	certain	perimen	scientific	I
I	I	put	I	joined	working	used	joined	-	arranged	put	set	I
I	I	past	running	passing	running	running	I	passing	passing	running	going	I
I	I	I	I	I	I	-	I	I	I	I	I	-
I	I	I	I	I	I	I	I	I	I	I	I	-
I	connect	I	I	connect	I	I	join	I	add	I	put	-
I	certainly	I	I	I	I	I	I	I	I	I	I	-
I	liminatin	finding	I	reducing	any	-	avoiding	liminatin	a	I	-	-
I	ndertaking		I	I	any	-	-	-	a	using	-	-
I	some	I	I	I	I	I	I	I	all	I	I	-
0	deffinatly	not	also	therefore	therefore	I	-	further	also	shown	-	-
I	of	I	avoiding	using	on	by	-	of	on	showing	-	-
0	I	ncertaint	I	I	I	I	I	I	readings	I	-	-
I	I	I	-	I	I	I	I	I	I	I	I	-
I	ccurately	-	-	ccuratel	correctly	-	-	ccuratel	stematica	-	-	-
I		the	I	the	-	the	I	the	I	I	a	swinging
0		will	may	may	could	will	will	will	may	-	-	measure
I		some	certain	certain	various	certain	certain	some	I	I	-	similar
0		on	all	all	on	in	-	-	all the	like	-	-
I		will	may	may	will	can	will	I	can	-	-	change
I		I	I	I	I	I	I	I	I	I	-	top
I		I	I	I	I	I	I	I	I	-	-	bottom
I		I	I	I	I	I	I	I	I	-	-	-
I		time	I	I	I	I	I	time	I	-	-	period
I		-	-	I	I	I	I	I	I	-	-	-
I		-	-	I	each	-	-	over the	scillatio	-	-	-
I			I	I	I	cannot	I	may	I	-	-	-
I			-	-	I	right	I	I	I	-	-	-
0			-	-	helps	-	-	-	I	-	-	averagly
I			I	I	I	I	I	I	importan	I	I	false
I			I	I	alright	correct	I	I	-	unlikely	difficult	-
I			-	I	some	-	-	some	may	-	exact	may
0			I	may	may	-	I	I	I	may	wont	change
0			I	I	I	-	I	I	I	I	I	-
0			I	I	I	I	I	some	accurate	I	I	-
I			I	I	I	I	I	I	-	-	I	-
0			-	but	I	-	-	-	-	-	-	-
0			I	I	I	I	I	asureme	I	-	I	-
I			calculated	related	rounded	accurate	rounded	calculated	accurate	-	-	accurate
-			I	aspects	I	periment	I	places	precision	-	-	perieme
I			I	I	with	which	-	with	with	that	-	allowing
0			-	most	rather	I	-	I		very		definetly
I			I	any	I	I	I	I		I		domestic
0			I	I	-	-	rounding	I		accuracy		I
-			long	long	time	one	accuracy	years		precision		few
-			I	I	in	in	in	in		for		-
-			I	I	I	I	-	-		-		-
-			I	I	I	I	I	slip		I		I
-			I	I	arise	-	happen	I		I		I
-			-	I	rather	-	-	I		I		-
-			I	I	I	I	I	I		I		-
-			I	I	I	I	I	I		I		pecisely
-			-	any	inaccura	accurate	-	the		the		wrong
-			point	I	I	I	I	I		point		I
-			I	I	I	I	I	I		-		I
-			-	I	I	I	I	I		I		I
-			-	I	I	I	I	I		I		experimen
45	18	14	47	47	36	38	44	40	27	29	18	11

ITEM	VIRA	RUHO	PASH	DHPA	GOBE	BROD	SHVA	RUKO	AMIN	BESH	RASH	JASI	ANSA	BARU	KARA	SIWI	LANA
SYSTEMATIC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	RANDO
RESULT	0	1	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1
FAULTY	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	0	1
WHICH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ALL	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
WILL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TOO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SYSTEMATIC	1	0	1	0	1	0	0	1	0	1	1	-	AS	1	1	1	1
FOND	0	0	1	1	0	0	0	0	0	1	-	1	1	1	1	1	1
MUST	1	1	1	1	1	1	0	1	1	1	1	1	-	1	1	1	1
SO	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
INTO	1	1	1	1	1	1	1	0	0	0	1	1	IN (	1	0	1	0
THE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
READING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AFFECT	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	SHOW	1
SAME	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ESTIMATE	0	0	0	0	0	0	1	1	1	0	1	1	AVOI	0	0	0	0
SIMPLE	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	1	0
PLACED	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
FLOWING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NOT	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
USE	1	1	1	1	1	1	0	1	1	1	-	1	1	1	1	1	1
NOT	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1
REDUCING	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	AVOI	AVOI
USING	1	1	1	1	1	1	1	1	0	1	-	1	1	1	1	1	1
THE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NEVER	1	1	1	0	1	1	0	1	0	0	1	1	1	0	THUS	ALSO	THUS
WITH	1	1	1	0	1	1	0	0	0	0	0	0	THUS	0	0	0	OF
UNCERTAIN	1	1	1	1	1	1	1	1	1	1	0	0	OF	1	1	1	1
THE	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
PRECISELY	1	1	1	1	1	1	1	0	0	0	1	1	1	1	AGAIN	1	AGAIN
A	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
MIGHT	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
SEVERAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EACH	0	0	0	0	0	0	0	0	0	0	1	LIKE	LIKE	1	LIKE	LIKE	LIKE
MIGHT	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
BE	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
PERIOD	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
THERE	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
ON	1	0	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
SAME	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1
UNCERTAINT	1	0	1	1	1	1	1	0	0	0	1	-	-	1	1	1	1
TO	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
POSSIBLE	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0
GREAT	1	1	1	1	1	1	0	1	0	0	1	0	0	0	1	1	0
WILL	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
ERROR	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
READINGS	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	READI
PRECISE	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
ONLY	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
READINGS	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	0
TAKEN	1	0	0	0	0	0	0	0	0	0	0	0	-	0	0	1	0
FIGURES	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1
OF	1	0	1	1	1	1	1	1	0	0	1	1	FOR	1	1	1	1
QUITE	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0
A	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1
MEASURING	0	1	1	1	1	1	0	1	0	1	1	1	1	1	1	CCUR	1
HOURS	1	1	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1
INTO	1	1	1	1	1	0	0	0	0	0	1	1	FOR	1	1	1	1
BOWL	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
STICK	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1
OCCUR	0	1	1	1	1	0	1	0	0	0	-	0	1	1	1	0	0
A	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
THE	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1
TO	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
SOME	1	0	0	0	0	0	0	0	0	1	0	0	ALL	THE	1	1	1
LEVEL	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
SAME	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
READINGS	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
READING	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1
TOTAL	68	64	68	65	68	66	61	64	27	51	61	62	62	67	66	67	60

UK 1	UK 2	PRVA	RARE	BHSH	SHLA	ANBO	DASC	ROST	MAMC	HADA	INDA	PRPA	JAMA	ANTH	MUMU	KAOS	DANI
I	I	I	I	I	I	I	I	I	I	S	I	I	I	I	I	I	S
I	I	S	S	I	g	s	S	S	S	S	G	S	G	S	S	S	S
I	I	S	-	S	s	s	I	S	-	-	I	S	S	S	S	I	G
I	I	-	-	g	I	I	I	I	I	I	I	I	I	I	I	I	-
I	I	I	s	s	I	I	I	I	I	I	I	S	I	I	I	-	S
I	I	I	-	I	s	I	I	I	I	I	I	I	G	I	I	I	I
I	I	I	-	I	I	I	I	G	I	I	I	I	G	I	I	I	I
I	AS	I	-	I	I	-	I	-	I	I	I	-	G	I	G	I	-
I	I	-	-	I	I	I	I	S	I	S	S	-	-	S	S	S	I
I	LEAN	-	-	s	s	g	-	G	-	S	S	-	S	-	S	G	-
I	I	-	-	I	I	I	G	G	I	G	G	I	G	G	G	I	-
I	I	-	-	I	I	I	I	I	I	I	S	I	I	I	I	I	-
IN	IN	G	-	g	g	g	G	I	G	G	G	-	G	G	G	I	I
I	I	I	G	I	I	I	I	I	I	I	I	-	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	-	I	I	I	I	G
I	I	I	G	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	G	s	I	I	I	S	I	I	G	S	S	I	I	I	I	I
I	I	I	S	s	I	I	S	I	I	G	I	S	I	I	I	I	G
AVOIL	AVOIL	G	-	s	s	s	S	S	S	I	S	S	S	I	S	S	S
I	I	S	-	g	-	I	-	-	G	-	I	S	S	I	I	-	I
I	I	I	-	I	-	I	-	-	I	I	-	I	I	-	I	S	I
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	S	I	I	-	I	I	I	I	I	I	S	I	I	I	I
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	S	-	s	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	S	I	s	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	S	-	I	I	s	I	S	I	I	-	I	S	S	G	I	I
I	I	S	-	I	I	s	I	S	I	I	S	I	G	I	I	I	G
I	I	I	-	I	I	s	I	I	I	I	I	I	I	I	I	I	I
THUS	THUS	S	-	s	I	s	I	S	I	-	S	S	I	S	I	S	I
OF	OF	S	-	s	I	s	I	S	I	I	S	I	I	I	G	G	I
0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	-	I	I	I	I	I	I	I	I	I	S	I	I	I	I
0	I	S	-	s	s	s	S	S	S	I	S	S	I	S	S	S	S
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	g	I	I	I	I	I	I	I	I	I	I	-	I	I	I
0	I	I	I	I	I	I	I	S	G	I	I	I	I	I	I	I	I
0	0	S	g	s	I	I	G	G	I	S	S	S	I	S	S	S	G
I	I	I	-	I	g	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	S	s	I	s	I	S	I	I	I	I	I	I	I	I	I	S
I	I	-	-	I	I	I	I	I	I	G	I	I	I	I	I	I	I
I	I	-	I	I	I	I	I	G	I	G	I	I	G	G	G	I	G
I	I	I	-	I	I	I	I	I	I	I	I	I	I	I	I	I	G
I	I	-	-	s	I	I	I	I	I	I	I	S	-	I	I	I	S
-	-	-	-	I	-	-	I	-	I	I	I	-	-	-	I	-	-
I	I	S	g	I	I	I	I	I	I	I	I	I	I	I	I	I	I
0	0	I	-	s	I	I		I	I	I	S	-	G	S	S	S	S
NO	0		-	s	-	-		I	I	I	I	I	I	I	G	I	S
I	I		I	I	I	I		I	I	I	I	I	I	I	I	I	I
I	I		I	I	I	I		I	I	I	I	I	I	I	I	I	I
I	I		-	I	I	I		I	I	I	S	S	I	I	I	G	I
I	I		-	I	I	I		I	I	I	I	I	I	I	I	I	I
NOT	NOT		-	-	-	-		I	-	-	-		-	S	I	I	-
I	I		s	I	I	I		I	I	-	I		I	S	I	I	S
CLOSE	I			I	I	I		-	I	I	S		G	I	I	S	-
VALU	NUMBE			I	I	I		-	I	I	I		-	I	I	I	I
I	TO			I	g	g		-	I	I	I		S	I	G	I	I
I	I			I	-	I		I	-	I	I		I	I	I	I	-
I	I			I	I	I		I	I	G	I		I	I	I	I	I
I	I			g	s	I		I	I	I	G		I	-	I	I	I
I	LONG			I	I	I		I	I	I	I		G	I	I	I	I
I	FOR			g	I	I		I	I	-	S		-	G	I	G	I
I	I			I	I	I		-	-	-	S		-	I	-	-	I
I	I			I	I	I		I	I	S	I		S	I	I	I	I
I	-			I	g	I		I	I	I	I		G	I	I	G	I
I	I			I	I	I		-	-	I	I		I	I	-	I	I
I	I			g	I	g		I	I	I	I		I	I	I	I	I
I	I			I	I	I		I	I	I	I		I	I	I	I	I
THE	ALL			g	-	g		S	-	-	S		S	S	I	I	-
I	I			g	I	I		I	I	I	I		G	I	I	I	I
I	I			I	-	I		I	-	-	I		S	S	I	I	I
I	I			I	I	I		I	I	I	I		I	I	I	I	I
I	I			I	I	I		-	S	I	I	I	I	I	I	I	-
62	60	26	10	54	57	58	38	51	62	55	54	37	46	56	59	59	49

Appendix 3 ERRORS Discrimination / Facility graphs



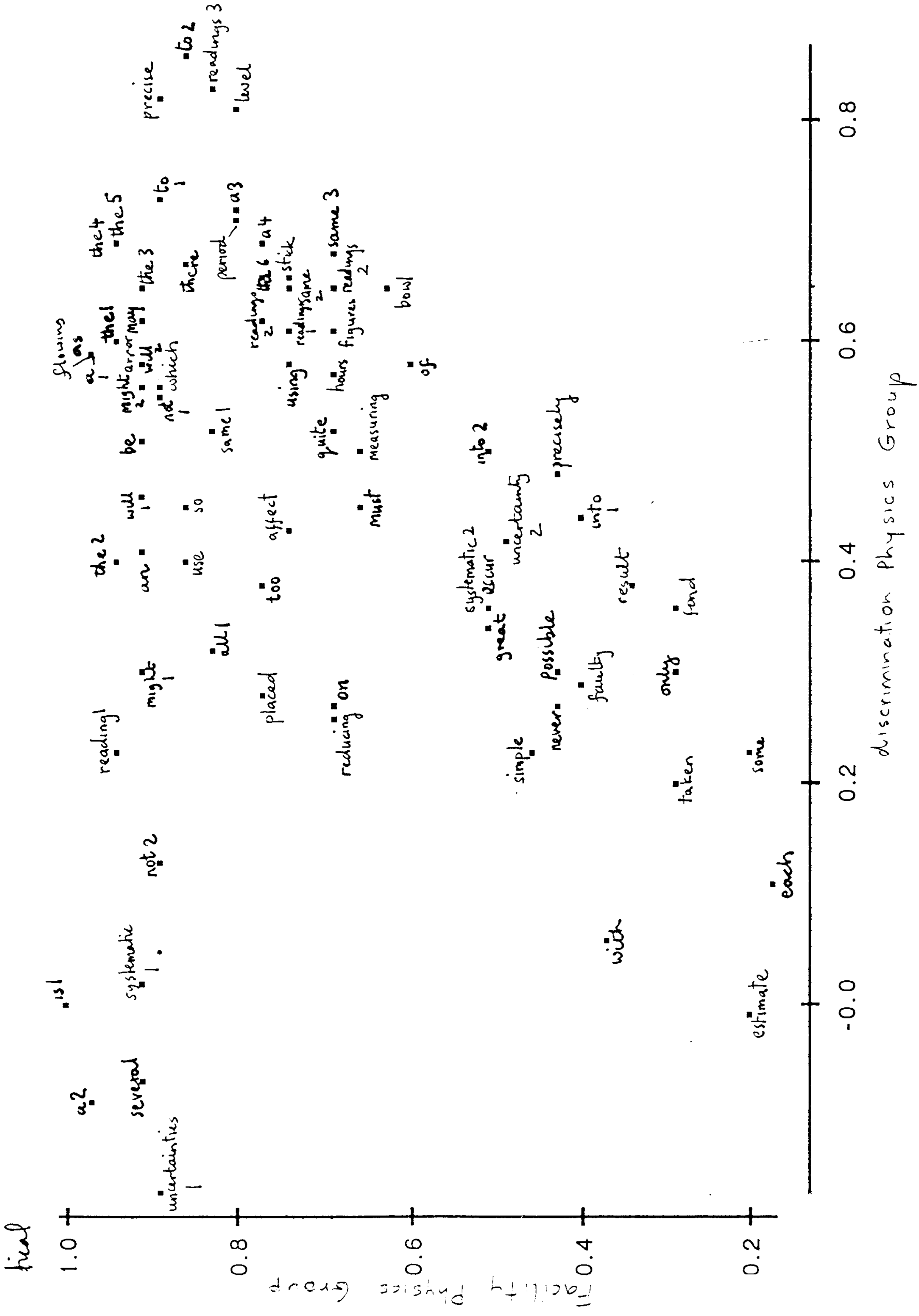

final
Facility Physics Group
1.0
0.8
0.6
0.4
0.2
Discrimination Physics Group
-0.0
0.2
0.4
0.6
0.8

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

[redacted]

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Appendix 5 TIME results

RESPONS	AH	HC	CAG	AO	BHS	MUN	KET	CLS	VIU	MIP	ALR	AV	AW	HB	AM	AC	VAM	LIB	HIM	VIW	DE	DR	MIL	SH	DEP	FAD
THE	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
BREATH	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0
AS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1		1	1	0	1	1	1	0	0
OTHER	0	0	1	1	1	1	0	1	1	0	0	0	1	1	0	1	1	1	1	0	1	1	1	1	0	1
DIFFERE	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	1
ANY	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	0	0
RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1
TRAVEL	1	0	1	1	0	1	0	1	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0	1	0	1
BACKWA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
LAWS	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
GO	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1
EQUALL	0	0	0	0	0	1	0	1	0	1	1	1	0	1	1	0	0	1	1	1	0	1	0	1	0	0
TIME	0	1	1	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	0	0	1	0	0	0	0
YET	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
TIME	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1
IF	1	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0
ALLOW/I	1	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	1	0
A	1	1	1	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PHYSICIS	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1
WITH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PAST	0	0	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1
IF	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1
CALCUL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1
JOURNAI	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	1	0	0	1	1
MACHIN	1	0	1	0	1	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	0	0	1	0	0
CONCEP	0	1	1	0	1	1	0	0	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1
DISTORT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0
OBJECTS	1	0	1	0	1	0	0	0	1	0	0	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0
SPEEDS	1	0	1	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
IS	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TACK	1	1	1	0	1	1	0	0	1	0	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1
AND	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
TIME	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
THE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	1	1	1	1
TRAVEL	1	0	1	1	0	0	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	0
THAT	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1
CORE	0	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
INFINITE	0	1	1	0	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	1	1	1	1	1	0	1
HOLE'S	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	1	1	1	0	0	0	0	0	0
WARPED	1	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0
SMALL	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	1	1	1	0	1	1	1	0	0	0	1
LEAD	1	0	1	0	0	0	0	0	1	0	0	1	0	1	0	1	1	1	0	1	1	1	0	1	0	0
UNIVERS	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	0	1	1	0	1	1	0	0	0	1	0
INSTANT	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	1	0
SPECIAL	1	0	1	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	1	1	1	1	0	1	0	1
PAST	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1
THIS	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
MUCH	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0
SURVIVE	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0
HOLE	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SMALLEI	1	0	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
A	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	0
OF	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
MEANS	1	0	1	1	0	1	0	0	1	0	1	1	1	0	0	1	1	1	0	1	0	1	0	1	1	0
PROPPIN	1	0	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	0	1	0	1	0	1
GOT	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0
COULD	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
SIMPLER	1	0	1	0	1	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	0	1	1	1
WORM H	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1
LIGHT	1	0	1	1	0	1	0	1	1	1	1	1	1	1	0		1	1	1	0	1	1	1	1	1	1
A	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	0	1	0	0	1	1	0	1	1	0
MAY	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	0	1
AT	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	0	1	0	0	1	1	0
CASE	1	0	0	0	1	0	0	1	1	1	0	1	0	0	0	1	1	0	0	0	0	1	1	1	1	0
THE	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	1	0	1	1	1
UNIVERSE		0	1	0		0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	1	0	0	0	1	1

RIGHT	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1
THIN	1	1	0	0	0	1	0	1	1	1	1	1	0	1	0	0	1	0	1	0	1	1	0	1	1	1
SURVIVE	0	0	0	0	0	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	0	1
COOLING	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0
THESE	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
AND	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
TONS	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1
LENGTH	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
GRAVITY	0	0	1	0	0	1	1	1	0	0	0	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1
SPACE	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1		1	1	0	1	0	1	0	0	1
LENS	0	1	1	0	1	0	1	0	1	1	1	1	0	0	0	1	0	1	1	0	1	1	0	0	1	0
SOURCE	1	0	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0
IN	0	1	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1
EACH	0	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	1	1
END	1	0	1	0	0	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0	1	1	0	1	0	1
SIGNIFIC	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0
THE	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
LENGTHS	0	0	1	0	0	1	1	0	1	1	1	1	1	0	0	1	1	1	0	1	0	1	0	1	0	1
LIGHT	1	1	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
AT	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1
LIGHT	1	1	1	0	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
THE	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
IS	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SETS	0	0	1		1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	1	0	0	0	1	0
SPACE	1	1	1		0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SPEED	0	0	1		0	1	0	0	1	1	1	1		1	0	1	1	1	1	0	1	1	1	1	1	0
TWO	1	0	1		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
THE	0	1	1		0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
EXACTL	1	1	1		0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
RAY	0	0	1			1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0
THE	1	1	1			1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
LIGHT	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
IT	1	1	1			1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1
FOR	1	1	1			1	0	1	0	1	1	1	0	1	1	1	0	1	0	0	0	1	0	1	1	1
MAKE	1	1	1			1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1
AND	0	1	1			1	0	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	0
DO	0	0	1			1	0	0	1	1	1	0	1	0	0	1	1	0	0	0	0	1	0	1	1	1
EACH	1	1	1			1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
LIGHT	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
WORK	0	0	1			1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1	1	1
THE	1	1	1			1	1	1		1	1	1	1	1	0	1		1	1	1	1	1	0	1	1	1
BELIEVE	1	1	1			1	0	0		1	1	1	1	1	1	0		0	1	0	1	1		1	1	1
BUT	1	1	1			1	0	1		1	1	1	1	1	1	0		1	1	0	1	1		1	0	1
IN	1	0	1			1	0	0		0	0	1	0	0	1	0		1	0	0	0	0		0	0	0
PHYSICS	1	0	1			1	0	0		0	0	1	1	1	1	1		1	0	0	1	1		0	0	1
ACTION	1	0	0			0	1	0		0	0	0	0	0	0	0		0	0	0	0	0		1	0	0
IF	0	0	1			1	0	0		1	1	1	0	0	0	0		1	0	0	0	1		0	0	0
SCIENCE	1	0	1			1		0		1	1	1	1	1	0	1		1	1	1	0	1		0	0	1
PAST	1	0	1			1		0		1	1	1	1	1	1	0		1	1	0	0	1		1	1	1
AT	1	1	1			1				1	1	1	1	1	1	1		1	1	1	1	1		1	1	1
SEEMS	1	0	1			1				0	0	1	1	0	0	0		0	0	0	0	0		1	0	0
MUST	1	0	1			1				0	1	1	1	1	0	0		1	1	1	0	1		0	1	1
IDEAS	1	1	1			1				1	1	1	1	1	1	1		1	1	1	0	1		1	1	0
BE	1	1	1			1				1	1	1	1	1	1	1		1	1	1	0	1		1	1	0
IN	1	0	1			1				1	1	1	1	1	1	1		1	1	0		0		1	1	0
BE	1	1	1			1				1	1	1	1	1	1	1		1	1	1		1		1	1	0
TOTAL	88	66	109	40	47	107	49	70	89	98	95	103	91	89	77	97	86	97	86	71	88	103	49	98	78	77

ZAMA	STJO	BROI	MIAW	DHPA	SAMI	KUBI	MOKI	UK	KARA	NIFE	RASI	KAMI	SIWI	BARI	RABA	NISH	RUKO	BESI	MUBI	AMIN
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0
1	1	1	0	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	1	0	1	1	0	0	0	1	1	0	0	1	0	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1
1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	0
1	0	1	1	1	1	0	1	1	0	0	1	0	1	1	0	1	0	0	1	0
0	1	0	0	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
0	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
0	1	1	1	1	1	0	0	0	1	0	1	0	1	0	1	1	1	1	1	0
1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
1	0	1	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1
1	1	0	1	1	1	0	0	1	1	0	0	0	1	0	0	1	1	0	1	0
1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1
0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0
1	0	1	1	1	1	0	0	0	0	1	0	1	1	0	1	0	1		1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1
1	0	1	1	1	1	0	1	0	0	0	1	0	0	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0
1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1
1	-	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0	1	1		0	1	1	1	1	0	1	1	1	0
1	0	1	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0
0	0	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0
1	-	1	0	1	1	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0
1	-	1	1	1	1	1	0	0	1	1	0	0	1	0	0	1	1	0	1	0
0	-	0	0	1	1	0	0	0	1	1	0	1	1	0	0	0	1	0	0	0
0	1	0	0	1	1	1	1	0	1	0	0	0	1	0	1	1	1	0	0	0
0	0	1	1	1	1	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1
0	1	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	1	0	1
1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1
1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
1	1	1	0	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1
0	1	1	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0
1	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	1	1	0	0
1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0
1	1	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1
1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1
1	1	1	0	1	0	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1
1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1

MAY	1	1	1	1	1	1		1	1	1	1	1	0	1	1	1	0	0	1	1
AT	1	1	1	1	1	1		1	1	1	1	1	0	1	1	1	0	1	1	1
CASE		0	1	1	1	0		1	0	0	0	0	0	0	0	1	0	1	1	1
THE		1	1	0	1	1		0	1	1	1	1	0	1	1	1	0	1	1	0
UNIVERSE		1	1	0	1	0		0	1	1	0	0	1	1	1	0	1	1	1	0
RIGHT		0	1	1	1	0		0	1	1	0	0	0	0	0	0	1	0	0	1
THIN		1	0	0	1	1		0	0	1	1	1	1	0	1	1	0	1	0	1
SURVIVED		1	1	1	1	0		0	0	1	0	1	0	0	1	1	1	1	1	0
COOLING		0	1	1	1	0		0	1	1	0	0	0	0	1	1	0	1	1	0
THESE		1	1	1	1	1		0	1	1	1	1	1	1	1	1	0	1	0	1
AND		1	1	1	1	1		1	1	1	0	1	1	1	1	1	1	1	1	1
TONS		1	1	1	1	1		0	1	0	0	0	0	0	0	0	1	1	1	1
LENGTH		1	1	1	1	1		0	1	1	0	1	1	1	1	1	1	0	1	1
GRAVITY/REGION		1	1	0	1	0		1	0	0	0	0	0	0	0	1	0	1	0	1
SPACE		1	1	0	0	0		0	1	1	0	1	1	1	1	1	0	1	1	1
LENS		0	1	0	0	0		0	1	0	0	0	0	0	0	0	0	1	0	1
SOURCE		1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1
IN		1	1	1	1	1		0	0	1		1	1	1	1	1	0	1	1	1
EACH		0	1	1	0	1		1	1	0		0	0	1	0	1	1	1	1	0
END		1	1	1	1	1		0	0	0		0	1	0	1	1	1	1	1	1
SIGNIFICANT		1	0	1	1	1		0	1	1		1	1	1	1	1	1	1	1	0
THE		1	1	1	1	1		0	1	1		1	0	1	1	1	1	1	1	1
LENGTHS		0	0	0	1	0		0	0	0		0	0	0	0	1	0	1	1	0
LIGHT		1	1	1	1	1		1	0	0		1	0	0	0	1	1	1	1	1
AT		1	1	1	0	1		0	0	0		1	1	0	0	1	1	1	1	1
LIGHT		1	1	1	1	1		0	1	1		1	1	0	0	1	1	1	1	1
THE		1	1	1	1	1		0	1	1		1	0	1	1	0	1	1	1	1
IS		1	1	1	1	1		0	0	1		1	1	1	1	1	1	1	1	1
SETS		1	1	0	1	0		1	0	1		1	0	1	1	1	0	0	1	0
SPACE		1	1	1	1	1		0	0			0	1	1	1	1	1	1	1	1
SPEED		1	1	1	1	1		0	1	1		1	1	1	1	1	1	0	1	1
TWO		1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	0	1
THE		1	1	1	1	1		0	0	1		1	1	1	1	1	1	1	1	1
EXACTLY		1	0	1	0	1		1	1	0		0	0	0	0	1	1	1	1	1
RAY		1	1	0	1	1		1	0	1		1	0	0	0	0	1	1	0	1
THE		1	1	1	1	1		0	1	1	0	1	0	1	1	1	1	1	1	1
LIGHT		1	1	1	1	1		0	1	1	1	1	1	1	1	1	1	1	1	0
IT		1	1	1	1	0		0	1	0	0	0	0	1	1	1	1	1		1
FOR		0	0	0	0	1		0	1	0	0	0	0	1	1	1	1	0		1
MAKE		1	1	1	1	1		1	1	0	1	1	1	1	1	1	1	1		1
AND		1	0	1	0	1		0	0	1	1	1	1	1	1	1	1	1		1
DO		1	1	1	1	1		1	0	0	1	0	0	0	0	0	0	1		1
EACH		1	1	1	1	1		1	0	0	1	0	0	1	1	1	1	1		1
LIGHT		1	1	1	1	1		0	0	1	1	1	1	1	1	1	1	1		1
WORK		0	0	0	1	0		1	0	0	0	0	0	0	0	0	0	0		1
THE		1	1	1	1	1		1	1				1	1	1	1	1	1		1
BELIEVE		1	1	1	1	1		1	0				0	1	1	1	0	1		1
BUT		1	1	1	1	1		1	1					1	1	1	1	1		1
IN		1	1	1	1	1		1	0					1	1	0	1	1		1
PHYSICS		1	1	0	1	1		1	0					1		1	0	1		1
ACTION		0	1	0	1	1		1	0							1	0	1		0
IF		0	1	0	1	1		0	0							0	0	0		0
SCIENCE		0	1	0	1	1		0	0							1	1	1		1
PAST		1	1	1	1	1		0	0							1	1	1		1
AT		1	1	1	1	1		0	0							1	0	1		1
SEEMS		1	1	1	1	1		0	0							1	1	1		1
MUST		1	1	1	1	1		1	0							1	1	0		1
IDEAS		1	1	1	1	1		1	0							1	1	1		1
BE		1	1	1	0	1		1	0							1	1	1		1
IN		1	1	1	1	1		1	0							0	0	0		0
BE		1	1	1	1	1		1	0							0	1	1		1
TOTP	50	104	101	91	98	104	45	78	73	79	52	77	58	78	84	101	87	103	77	97

ZAMA	STJO	BROI	MIAW	DHPA	SAMU	KUBI	MOKI	UK	KARA	NIFE	RASH	KAMI	SIWI	BARU	RABA	NISH	RUKC	BESI	MUBI	AMIN
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0
1	1	1	0	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	1	0	1	1	0	0	0	1	1	0	0	1	0	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1
1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	0
1	0	1	1	1	1	0	1	1	0	0	1	0	1	1	0	1	0	0	1	0
0	1	0	0	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
0	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
0	1	1	1	1	1	0	0	0	1	0	1	0	1	0	1	1	1	1	1	0
1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
1	0	1	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1
1	1	0	1	1	1	0	0	1	1	0	0	0	1	0	0	1	1	0	1	0
1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1
0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0
1	0	1	1	1	1	0	0	0	0	1	0	1	1	0	1	0	1		1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1
1	0	1	1	1	1	0	1	0	0	0	1	0	0	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0
1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1
1	-	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0	1	1		0	1	1	1	1	0	1	1	1	0
1	0	1	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	0	0
0	0	1	1	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0
1	-	1	0	1	1	1	0	0	1	0	0	0	1	1	0	1	1	1	1	0
1	-	1	1	1	1	1	0	0	1	1	0	0	1	0	0	1	1	0	1	0
0	-	0	0	1	1	0	0	0	1	1	0	1	1	0	0	0	1	0	0	0
0	1	0	0	1	1	1	1	0	1	0	0	0	1	0	1	1	1	0	0	0
0	0	1	1	1	1	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1
0	1	1	1	1	1	1	1	0	0	0	1	0	1	0	0	1	1	1	0	1
1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1
1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
1	1	1	0	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1
0	1	1	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0
1	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	1	1	0	0
1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0
1	1	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1
1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1
1	1	1	0	1	0	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1
1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1

1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	0	1	1
1	0	1	1	1	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	0
0	0	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1
0	0	1	0	1	0	0	0	0	1	1	0	0	1	0	1	0	1	1	1	
0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0
0	0	1	0	1	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0
1	0	0	1	0	0	1	1	0	1	0	1	0	0	0	0	1	0	0	1	1
1	0	0	0	1	1	1	1	0	1	0	0	1	1	1	0	0	0	0	1	0
1	0		0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0		0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1
1	0		0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
1	1		1	1	1	0	1	0	1	1	1	1	1	1	0	0	0	1	1	1
1	1		1	1	1	0	1	0	1	0	1	1	1	1	0	1	1	0	1	1
1	1		1	1	1	1	1	0	0	0	0	0	1	0	1	1	1	0	0	1
1	1			1	1	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0
1	0			1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0
1	1			1	0	0	1	0	0	0	1	1	1	1	1	1	0	1	1	0
1	0			1	1	1	0	0	1	0	1	1	1	1	0	1	1	1	1	1
1	1			1	1	0	0	0	1	1	1	0	1	1	1	0	1	1	0	1
1	1			1	1	1	1	0	1	1	0	0	1	1	1	0	1	1	1	1
1	1			1	1	1	1	0	0	1	1	1	1	1	1	0	0	1	1	1
1	1			1	1	0	0	0	1	0	1	0	1	1	1	1	0	0	1	1
1	1			1	1	1	1	0	1	0	1	1	1	1	1	0	0	1	1	1
1	1			1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0
1	1			1	1	0	1	0	1	0	1	1	1	1	1	0	1	1	1	1
1	1			0	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	0
1	1			1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
1	1			1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1
1	1			1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1
1	1			1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0			0	1	1	0	1	1	1	0	1	1	1	1	1	0	0	1	1
1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	1			1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1
1	1			1	0	0	1	1	1	1	0	0	1	1	1	0	0	0	0	1
0	1			1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
1				1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	0
				1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
				1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
				1	1	1	1	0	0	1	0	1	1	1	0	1	1	1	1	0
				1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
				1	1	0	1	1	0	1	1	0	1	0	1	1	1	1	1	1
				1	1	0	1	1	0	1	0	1	1	0	1	0	1	0	1	0
				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
				1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
				1	1	1	0	1	0	0	0	1	0	1	1	0	1	0	0	1
				0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1
				0	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1
				1	1	0	1	1	0	0	1	1	1	1	1	1	1	0	1	0
				1	0	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1
				1	1	1	1	0	1	0	0	1	1	0	1	1	1	0	1	1
				1	1	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0
				1	0	0	0	0	0	1	0	1	1	1	1	0	0	0	1	0
				1	0	1	1	1	1	1	0	1	1	0	0	1	1	1	1	1
				1	1		1	1	1	1	0	1	1	1	0	1	1	0	1	1
				1	1		1	1	1	0	1	1	1	1	1	1	1	1	1	1
				1	0		0	0	1	0	0	1	1	0	1	0	1	0	1	0
				1	1		1	1	1	1	1	1	0	0	1	0	1	1	1	1
				1	1		1	1	1	1	0	0	1	1	1	1	1	1	1	1
				1	1		1	1	1	1	1	0	1	1	1	1	1	1	1	1
				1	1		1	1	1	1	0	1	1	1	1	1	1	1	1	1
				1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	68	56	47	112	98	72	90	73	93	70	71	90	111	85	95	89	98	78	102	80

INVESTIGATING FREE FALL One way of investigating the free fall of a steel ball is to make a multiflash photograph of the ball's flight, as shown in diagram 1. The photograph must be taken in a dark room. The camera shutter is kept open while the ball falls. A stroboscope essentially a regular flashing light is used. Each time the light flashes on, the ball is on the camera film. Thus, the ball's position against the scale is recorded at intervals of ,

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL

[redacted]

The photograph clearly shows that the ball's speed as it falls. Measurements may be taken from the film to find out if the ball accelerated uniformly. The displacement s of the ball from its position of release is given by

$s = 1/2\ a\ t^2$

if the is constant and t is the time from The initial speed is zero, assuming it was released from rest. By measuring the the rate of flashing from the stroboscope scale, the interval between flashes can be calculated. Thus the time t from release of each "image" on the film can be

Multiflash photo of free fall. The actual scale is shown by the cm rule in the photograph. The stroboscope was operated at 31 Hz. The first 3 images overlap. Measurements from the photographs are plotted on Figure 1.19

The graph of s against t^2 ought to give a straight line if the acceleration is In fact diagram 2 shows the graph for the photograph, which gives a straight line through the plotted points.

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

[redacted]

From $s = 1/2\ a\ t^2$ the gradient of the graph must be equal to 1/2 a Thus the acceleration can be determined.

The gradient of the graph is

$4.9\ m s^{-2}$

so the acceleration value is

In fact, all freely falling objects fall at a constant acceleration of

$9.8\ ms^{-2}$ This value is denoted by g.

There are slight variations in the value of g over the Earth's surface Its value at the North pole is

$9.81\ ms^{-2}$ which is slightly than its value at the Equator

$9.78\ ms^{-2}$

Projectile motion Throw a ball into the air at any non-zero angle to the vertical, and the ball will follow a path. The exact path is determined by the initial speed and angle at which the ball is thrown. Gravity does the rest and takes the ball on its path. The motion of any object acted upon by only is called projectile motion.

Consider the example of a ball rolled down a ramp on a table, then rolling off the table at the edge. The ball follows a flight path which is initially where it rolls off the edge. Then its path becomes steeper and steeper as the pull of gravity acts on it alone. Suppose someone just 'nudged' a second ball resting near the edge, causing the second ball to fall off the table at the same time as ball A. The second ball, ball B, falls at the same rate as ball A. Both A and B hit the floor at the same time- assuming the floor is
A multiflash photograph of the above example is shown below.

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES
[redacted]

This shows that A, the projected ball, falls at the same rate as B, the ball which drops straight down. Each flash of the has pictured A at the same level as B. Thus they fall at the rate. However, whereas B drops straight down, A moves across at the same time as it falls. In fact, the photograph shows that A moves across at a steady rate. In other words, A is pictured at horizontal spacing.

For any projectile, its vertical motion is at constant acceleration g, its horizontal motion is at constant speed.

This means that the horizontal component of its velocity stays constant but the vertical component changes at a rate of

In the multiflash photograph above the position of ball A is shown at each flash interval, the velocity vector has also been shown, using its and vertical components.

The horizontal component is unchanged throughout. However the vertical component increases by the same amount from one position to the next.
The path therefore becomes as the ball falls.
Why should the horizontal motion be unchanged? The reason is that the pull of gravity acts only downwards and not
So the pull of cannot affect the (sideways) ie. horizontal motion.

ITEM	SIFE	SHVA	RUHO	ESEB	DAWI	KUBH	SAMU	VIRA	ZAMA	DHPA	PASH	STJO	MOAH	BROD	GEBE	AMIN	RUKO	BESH	LANA	RASH	NIFE
PICTURED	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TIME	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0
INCREASES	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	0	1	1	0	1
ACCELERATI(	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
RELEASE	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	0	0	1	0	1
TIME	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	1
ESTIMATED	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0
CONSTANT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
9.8 MS -2	1	1	1	0	1	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	0
MORE	1	1	0	1	0	0	1	1	1	1	0	1	0	1	1	0	0	0	1	1	1
CURVED	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1
GRAVITY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
HORIZONTAL	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	1	1	0
LEVEL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
STROBOSCOP	1	1	1	0	1	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0
SAME	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
REGULAR	0	1	1	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0
9.8 MS-2	0	1	1	0	1	1	1	1	0	1	0	0	1	0	1	0	0	0	1	1	1
HORIZONTAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
STEEPER	0	1	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	1	1	0	1
SIDEWAYS	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0
GRAVITY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
TOTAL	17	22	19	12	18	13	15	14	13	17	18	17	15	15	21	10	10	11	19	13	14

PROJECTILES RESULTS GRID (1)

RABA	BARU	KARA	JASI	GUCH	DASW	HAYA	RAREK	MUMU	ANTH	KARIM	ANBO	MAMO	PRVA	INDA	SHLA	BISH	ROSO	DACL	JAMA
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	1	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	1	0
1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	0	0	1	1
1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	0	1	0	1	0	1	1	1	0	0	1	1	1	1	0
0	1	1	0	0	1	1	0	1	0	1	1	1	1	1	0	1	0	1	1
1	1	1	1	1	1	0	0	0	1	0	0	0	1	1	1	0	1	1	1
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1
1	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	1	0	1	1
1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1
0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0
1	0	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1
1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1
1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1
0	1	1	0	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	0
1	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0
1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	18	20	19	14	15	13	5	13	9	16	12	16	13	15	16	16	15	15	14

PROJECTILES RESULTS GRID (2)

Appendix 8 READING ALOUD exercise

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

[redacted]

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Appendix 9 READING ALOUD results

READING ALOUD RESULTS										
name	time(s)	esitatior	Q1	Q2	Q3	Q4	Q5	Q total	causal	mother tongue
AMIN	330.00	23.00	1	0	0	1	1	3	0	Punjabi
ANBO	277.00	13.00	1	0	1	1	1	4	0	Russian
ANCH	284.00	16.00	1	0	1	1	1	4	0	English
ANSA	272.00	32.00	1	0	0	1	1	3	0	Gujarati
BARU	360.00	35.00	1	1	0	1	1	4	0	English
BESH	309.00	40.00	1	0	0	0	0	1	0	Hindi
BHSH	332.00	21.00	1	0	0	1	1	3	0	Gujarati
BROD	255.00	30.00	1	1	1	1	1	5	0	English
DACL	296.00	15.00	1	1	0	1	1	4	0	English
DASC	255.00	11.00	1	1	0	1	1	4	0	Hebrew
DHPA	275.00	35.00	1	1	1	1	1	5	0	Hindi
GUCH	367.00	75.00	1	1	1	0	1	4	0	Punjabi
HAYA	465.00	35.00	1	1	1	1	1	5	1	Hebrew
INDA	372.00	39.00	1	0	0	1	1	3	0	Punjabi
JAMA	391.00	25.00	1	0	1	1	1	4	0	Punjabi
JASH	305.00	34.00	1	1	0	0	0	2	1	Punjabi
KAME	315.00	49.00	1	1	0	1	1	4	0	?
KAOS	313.00	15.00	1	0	0	1	1	3	0	Arabic
KARA	300.00	18.00	1	1	1	1	1	5	0	Gujarati
KUBH	282.00	49.00	1	0	0	1	0	2	0	Punjabi
KURU	295.00	53.00	1	1	1	1	1	5	0	Punjabi
LANA	322.00	45.00	1	1	0	1	1	4	0	Punjabi
MAMO	342.00	18.00	1	1	0	1	0	3	0	Hebrew
MUBH	292.00	30.00	1	0	0	1	1	3	0	Urdu
MUMU	295.00	24.00	1	1	1	1	0	4	0	Baluchi
NIFE	437.00	14.00	1	1	0	1	1	4	0	Singhalese

NISH	412.00	39.00	1	0	1	1	1	4	0	Gujarati
PASH	267.00	35.00	1	0	0	1	1	3	1	Gujarati
PRVA	326.00	21.00	1	0	0	1	1	3	0	Gujerati
RABA	302.00	32.00	1	1	0	1	1	4	0	Punjabi
RASH	341.00	35.00	1	1	0	0	0	2	1	Gujarati
ROMA	295.00	56.00	1	1	0	1	1	4	0	English
ROST	313.00	23.00	1	0	0	1	0	2	0	Farsi
RUHO	312.00	42.00	1	1	0	1	1	4	0	Dutch
RUKO	287.00	23.00	1	1	1	1	1	5	0	Punjabi
SAMU	300.00	48.00	0	1	1	1	1	4	0	English
SHLA	334.00	18.00	1	0	1	1	1	4	1	English
SHVA	180.00	23.00	1	1	1	1	1	5	0	Urdu
SIFE	272.00	24.00	1	1	0	1	1	4	1	Italian
SIWI	283.00	18.00	1	1	0	1	1	4	1	English
STJO	400.00	79.00	1	1	1	1	1	5	0	Kikuyu
SUNNI	425.00	25.00	1	0	0	1	0	2	1	Gujerati
VIRA	300.00	38.00	1	0	1	1	1	4	1	Gujarati
ZAMA	283.00	34.00	1	1	0	1	1	4	0	Urdu
FAC			**0.98**	**0.59**	**0.39**	**0.91**	**0.82**			
DISC			**-0.06**	**0.58**	**0.66**	**0.44**	**0.65**			

READING ALOUD results continued

Appendix 10 FORCES exercise

1 Some words is physics have a meaning which is more closely defined than the word's meaning in everyday use. There is a multitude of words in the English language which represent force. Some examples of these words are: push, pull, hit, tension, knock, shove, effort, load, strength, power, vigour. In a science it is essential to be careful in the use of words so that when a word is used its meaning is clear. For instance, in the above list, some of the words are scientifically inaccurate. Power means work done per unit time; it does not mean force. Other words in the list are simply descriptions of particular situations where forces occur; tension, effort and load come into this category.

2 When dealing with types of forces however we find, surprisingly, that outside the nucleus of atoms there are only two possible types of force; these are:

* electromagnetic force
* gravitational force

3 Electromagnetic forces exist between moving or stationary charges. Since all atoms have charged particles within them, it is electromagnetic forces which bind atoms together in solids and liquids. On some occasions the electrical nature of a force is important, sometimes the magnetic nature is important. In these cases there is not usually any problem in pin-pointing where the force exists. In the vast majority of mechanics problems however, it is the electromagnetic forces between atoms which are of prime importamce. Whenever the atoms of one object are close to the atoms of another object, there will be a contact force between them. All forces of contact are electromagnetic forces. In the list given above push, pull, hit, shove, knock, effort and load are all examples of contact forces. Tension is also a contact force, but is used in rather a special way involving internal electromagnetic forces between atoms in a string as well as the contact force between the string and the object to which it is attached.

4 Gravitational forces exist between any two masses and can usually be neglected unless one of those masses is very large. The gravitational force which a car exerts on a trailer it is pulling is negligible: the electromagnetic force of contact which the car exerts on the trailer is the force which pulls the trailer along. In practice the only gravitational force which usually concerns us is the gravitational attraction of the earth.

FRICTION

5 Consider a stone resting on a road. If the contact between the road and the stone is examined closely it can be seen that the two rough surfaces make close contact only at relatively few places. Where contact is made, the road will exert a force on the stone.

6 The sum of all these forces, the resultant contact force, is a single force which acts vertically upward.

7 If however the stone happens to be sliding across the road to the left say, we find there are more forces in the direction opposite to the

direction of travel than in the forward direction.

8 This results in the contact force which the road exerts on the stone being tilted. The tilted force can be considered as being the vector sum of a horizontal and vertical component. the horizontal component is called the frictional force and the vertical component is called the normal contact force.

9 Friction itself is usually a component of a contact force. The distinguishing feature of friction is that it is in the opposite direction to the direction of motion. Friction is usually regarded as a nuisance but it is often crucially necessary. There are times when friction needs to be minimised, but without friction everything would collapse, literally. If two surfaces could only exert forces on each other at right angles to the surface, i.e. if there was no friction there would be no nails, no nuts and bolts, no screws, no glue, no sewing, no knitting, no fabrics, no buildings, no cars, no people. The list is virtually endless. Friction is an extremely useful force.

INSTRUCTIONS

Each paragraph of the passage is numbered. Read each paragraph and then:

a) For each of the paragraphs 1-4 underline one sentence or phrase which you feel is the most important.

b) For each paragraph 5-8, SKETCH AND LABEL a diagram which shows what the written information means. Use arrows to indicate forces.

c) Explain what the author means in paragraph 9 by, "if there was no friction there would be no nails, no nuts and bolts, no screws " etc.

PARAGRAPH 5 DIAGRAM

PARAGRAPH 6 DIAGRAM

PARAGRAPH 7 DIAGRAM

PARAGRAPH 8 DIAGRAM

PARAGRAPH 9 EXPLANATION

Appendix 11 FORCES results

NAME	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	TOTAL
AMIN	2	0	2	2	1	0	1	0	2	**10**
ANBO	1	2	2	2	1	1	1	1	2	**13**
ANSA	2	2	2	0	3	2	0	0	0	**11**
ANTH	2	2	0	0	2	1	0	2	0	**9**
BARU	2	0	0	0	3	2	0	1	1	**9**
BESH	2	0	0	2	2	0	1	0	0	**7**
BHSH	2	2	0	0	2	1	1	1	1	**10**
DACL	2	2	0	0	2	1	0	2	0	**9**
DASC	1	2	2	0	2	1	1	1	1	**11**
HAYA	2	2	0	2	2	0	1	2	2	**13**
INDA	2	0	2	2	2	1	2	1	1	**13**
JAMA	1	2	2	2	2	1	2	1	2	**15**
JASI	2	0	0	0	0	0	0	0	0	**2**
KAME	2	0	0	2	3	0	0	1	0	**8**
KARA	2	2	0	0	3	1	0	2	1	**11**
KARI	2	2	2	0	2	2	1	1	0	**12**
LANA	2	0	0	0	3	1	0	1	0	**7**
MAMO	0	2	0	0	2	2	2	0	2	**10**
MUBH	2	2	2	2	0	1	2	2	2	**15**
MUMU	2	0	0	2	2	1	0	1	1	**9**
PRVA	1	2	2	0	2	1	1	1	0	**10**
RARE	1	2	0	0	0	1	1	0	0	**5**

RASH	2	2	0	0	3	0	0	0	1	**8**
ROSO	2	2	2	2	2	1	0	2	1	**14**
RUHO	2	2	2	2	2	0	0	0	3	**13**
RUKO	2	2	2	2	1	1	0	1	2	**13**
SHLA	2	2	2	0	2	1	2	1	0	**12**
SIWI	2	2	0	2	3	0	0	1	0	**10**
Facility T	0.875	0.714	0.464	0.929	0.643	0.429	0.339	0.464	0.298	
Discrimination	-0.04	0.476	0.683	0.462	0.064	0.236	0.402	0.446	0.598	

FORCES results continued

A high resistance voltmeter connected across a cell on open circuit records its e.m.f. (very nearly) Fig.1 Let this be E. If the cell is now connected to an external circuit in the form of a resistor R and maintains a steady current I in the circuit, the voltmeter reading falls; let this be V, Fig.2

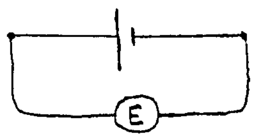
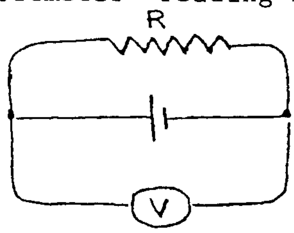


Fig 1



V is the terminal p.d. of the cell (but not on open circuit) and it is also the p.d. across R (assuming the connecting leads have zero resistance). Since V is less than E then not all the energy supplied per coulomb by the cell (i.e. E) is changed in the external circuit to other forms of energy (often heat). What has happened to the "lost" energy per coulomb?

The deficiency is due to the cell itself having some resistance. A certain amount of electrical energy per coulomb is wasted in getting through the cell and so less is available for the external circuit. The resistance of a cell is called its internal resistance (r) and taking stock of the energy changes in the complete circuit including the cell, we can say, assuming conservation of energy:

energy SUPPLIED per coulomb by cell	=	energy CHANGED per coulomb by external circuit	+	energy WASTED per coulomb on internal resistance of battery

Or, from the definition of e.m.f. and p.d.

e.m.f.	=	p.d. across R	+	p.d. across r

In symbols

E	=	V	+	v
e.m.f.		useful volts		"lost" volts

where v is the p.d. across the internal resistance of the cell, a quantity which cannot be measured directly but only by subtracting V from E.
From the equation $E = V + v$ we see that the sum of the p.d.s across all the resistance in a circuit (external and internal) equals the e.m.f.

Since $V = IR$ and $v = Ir$ we can rewrite the previous equation

$$E = IR + Ir$$

thus $$E = I(R + r)$$

The internal resistance of an electrical supply depends on several factors and is seldom constant as is often assumed in calculations. However, it is sometimes useful to know its rough value and estimates can be made by taking p.d. and current measurements and substituting into the formulae given above.

Sources such as low-voltage supply units and car batteries from which large currents are required must have very low internal resistances. On the other hand if a 5000 V E.H.T. power supply does not have an internal resistance of the order of megaohms to limit the current it supplies it will be dangerous.

The effect of internal resistance can be seem when a bus or car starts with the lights on. Suppose the starter motor requires a current of 100 A from a battery of e.m.f. 12 V and internal resistance 0.04 Ohms to start the engine.

1. How many volts are lost?
2. What is the terminal p.d. of the battery with the starter motor working?
3. Why do the lights dim if they are designed to operate on a 12 V supply?

The terminal p.d. of a battery on open circuit as measured by even a very high-resistance voltmeter is not quite equal to the e.m.f. because the voltmeter must take some current, however small, to give a reading.
A small part of the e.m.f. is therefore "lost" in driving current through the internal resistance of the battery. A potentiometer can be used to measure e.m.f. to a very high accuracy

INSTRUCTIONS

READ THE PASSAGE, ANSWER THE QUESTIONS 1,2 AND 3 IN THE SPACES BELOW, SHOWING HOW YOU WORKED OUT YOUR ANSWERS. ANSWER QUESTIONS 4-9

1.

2.

3.

4. The phrase "energy supplied per coulomb" occurs several times in the text. Explain what you understand by this phrase.

5. The symbol V is called "useful volts". Is this perfectly true, explain.

6. There is another word in the passage used to describe lost volts, what is it?

7. What is a "low-voltage supply", where and why are you likely to use one ?

8. To measure e.m.f. precisely an instrument is required which draws ____________ current.

9. It is suggested that internal resistance is not constant. Name one factor which might affect the internal resistance of a cell.

Appendix 13 INTERNAL RESISTANCE results

INTERNAL RESISTANCE COLLATED RESULTS										
RESPON	1	2	3	4	5	6	7	8	9	TOTA
RUKO	2	2	2	0	1	0	0	1	1	64
BESH	2	2	2	-	-	-	-	0	-	43
MUBH	1	2	2	1	2	0	-	1	0	64
AMIN	2	2	2	1	2	1	0	1	1	86
MAMO	2	2	1	0	2	1	0	1	1	71
ROSO	2	2	1	0	1	0	0	1	1	57
ANCH	2	2	1	0	0	1	0	1	0	50
MUMU	1	1	0	0	2	0	0	0	1	36
HADA	1	0	1	0	2	1	0	0	0	36
DASC	2	2	2	0	2	1	0	0	1	71
INMA	2	2	0	0	2	1	0	1	0	57
SHLA	2	2	0	0	2	1	0	1	1	64
INDA	1	1	0	1	2	1	0	0	1	50
PRPA	2	2	0	1	2	1	0	1	0	64
PRVA	1	2	1	0	0	0	0	0	1	36
DACL	2	2	0	0	2	1	0	1	0	57
RARE	2	2	0	0	1	-	-	-	-	36
BHSH	2	1	2	0	0	1	0	1	1	57
KARI	2	2	2	0	0	1	0	1	1	64
ANBO	2	2	1	1	2	1	0	1	1	79
ZAMA	2	0	2	1	2	1	1	1	1	79
RUHO	2	0	1	1	2	0	1	1	0	57
ROME	2	2	2	1	2	1	1	1	0	86
SAMU	2	2	1	0	1	0	0	0	0	43
SHVA	2	2	1	1	1	0	0	1	0	57
VIRA	1	0	1	0	1	0	0	1	0	29
PASH	2	2	2	1	1	0	0	1	0	64
KUBH	2	0	1	0	1	1	0	1	2	57
SIFE	2	2	2	1	1	1	1	1	0	79
MOAH	2	0	2	0	2	0	0	0	0	43
BROD	2	2	2	1	1	1	0	0	0	64
MOKE	2	2	2	1	0	1	0	1	1	71
STJO	2	0	1	1	0	0	1	1	0	43
DHPA	2	2	2	1	2	0	0	1	0	71

NAME	TOT%
AMIN	86
ANBO	79
ANCH	50
BESH	43
BHSH	57
BROD	64
DACL	57
DASC	71
DHPA	71
HADA	36
INDA	50
INMA	57
KARI	64
KUBH	57
MAMO	71
MOAH	43
MOKE	71
MUBH	64
MUMU	36
PASH	64
PRPA	64
PRVA	36
RARE	36
ROME	86
ROSO	57
RUHO	57
RUKO	64
SAMU	43
SHLA	64
SHVA	57
SIFE	79
STJO	43
VIRA	29
ZAMA	79

displacement

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

1. Read the passage DAMPED OSCILLATION carefully.

2. Find the following phrases and explain in your own words as fully as you can, what they mean:

   a) "the total mechanical energy of the oscillating system"

   b) "the amplitude is reduced in a large number of oscillations"

   c) "the damping is slightly under critical damping"

   d) "damped by a shock absorber".

   e) "active suspensions"

3. The passage says "Not only does friction have an effect on the amplitude, but it also has the effect of reducing the frequency slightly." Why should this be so?

4. Describe briefly, in your own words, a car's suspension system.

5. How do the thighs and calves of a good skier act like a damped spring?

Appendix 15 DAMPED OSCILLATIONS results

OSCILLATIONS COLLATED									
Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	TOTAL
AMIN	1	1	0	1	0	2	1	2	8
ANBO	0	1	0	1	0	0	2	1	5
ANCH	0	1	0	1	0	1	1	0	4
ANKU	1	1	2	2	0	0	1	1	8
ANSA	1	2	1	2	1	2	1	2	12
BARU	1	2	1	2	2	0	1	1	10
BESH	2	2	1	1	2	0	3	0	11
BROD	0	2	2	2	2	0	2	0	10
DASC	1	1	0	0	0	0	1	1	4
GUCH	0	1	2	1	1	0	1	2	8
HAYA	2	2	2	0	0	0	1	0	7
INDA	1	1	0	0	0	0	2	3	7
JAMA	1	1	2	2	0	0	2	0	8
JASI	1	2	1	2	2	2	3	0	13
KAME	1	2	2	2	1	0	3	0	11
KARA	1	2	1	2	2	0	2	3	13
KUBH	0	2	0	0	2	0	1	0	5
KURO	0	1	0	1	0	1	3	0	6
LANA	1	2	0	2	2	0	3	0	10
MAMO	1	2	1	0	0	0	2	3	9
MIAW	0	2	0	1	2	0	3	1	9
MOAH	0	2	2	2	2	0	2	1	11
MOKE	0	1	2	2	2	0	2	2	11
MUBH	0	2	1	2	2	0	3	0	10
MUMU	0	1	2	2	0	0	3	2	10
NIFE	0	1	2	1	0	1	3	1	9
NISH	1	1	2	1	1	2	3	1	12
PAVA	0	1	0	0	0	0	2	0	3

PEY	1	1	1	0	0	0	2	0	5
PRPA	0	1	2	2	0	0	0	0	5
RABA	1	2	0	0	0	0	3	1	7
RASH	0	1	0	2	1	1	2	3	10
ROSO	1	1	1	2	0	0	3	0	8
RUHO	1	2	1	1	2	0	0	3	10
RUKO	0	0	1	2	0	0	3	0	6
SAMU	0	1	1	1	2	0	2	0	7
SHLA	2	1	1	2	0	0	2	0	8
SIWI	1	1	1	2	2	2	3	3	15
STJO	0	1	2	2	0	0	3	0	8
SUNN	0	1	1	2	0	0	1	1	6
UK	1	2	1	2	2	0	2	0	10
VIRA	1	1	0	0	2	0	1	0	5
ZAMA	0	0	0	0	2	0	3	0	5

DAMPED OSCILLATIONS continued

Appendix 16 HEAT RADIATION exercise

All bodies emit radiation, the intensity and wavelength distribution depending on the nature of the body itself and its temperature. Although we may speak of something as being red-hot, strictly speaking true heat or **infrared** radiation is invisible to the human eye. The detection of heat radiation is used in certain types of satellites, by the military in night glases, for spotting areas of high heat loss from buildings and by the electricity boards in detecting hot spots in power cables.

Heat radiation was first detected by Herschel in 1800, when he showed that there was radiant energy beyond the red end of the visible spectrum.

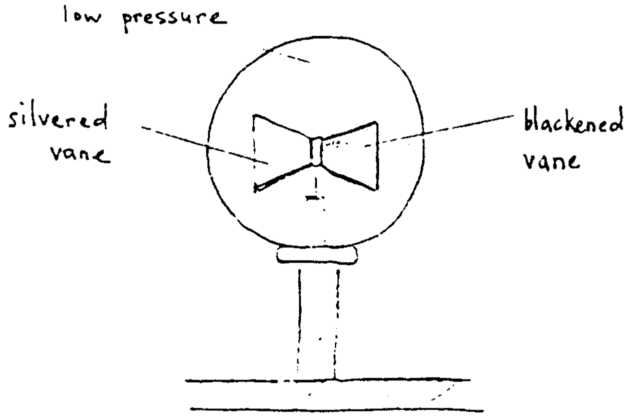
Infrared detectors

You can easily detect heat radiation with your hand but there are much more sensitive methods.

1. A liquid-in-glass thermometer with a blackened bulb
   Heat is absorbed by the bulb and the liquid rises.

2. The ether thermoscope
   This consists of a tube with a glass bulb at either end; one is clear and the other blackened. The tube is partly filled with ether and therefore both bulbs contain a mixture of air and ether vapour. When heat radiation falls on the apparatus more is absorbed by the blackened bulb than the shiny one, and the pressure inside this bulb rises and pushes the ether along the tube.
   Sketch and label a diagram of the ether thermoscope.

3. Crookes' radiometer



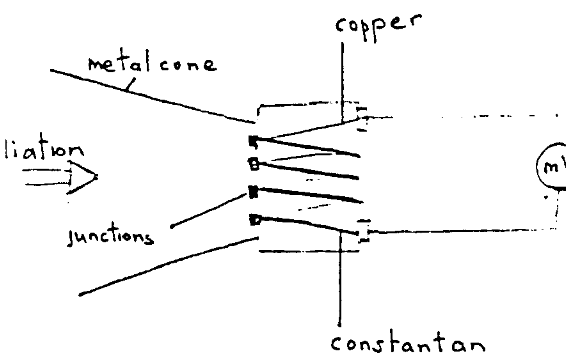
A vane mounted on a pivot is enclosed in a glass bulb filled with air at low pressure. One side of each part of the vane is blackened and the other is silvered. When heat radiation falls on the radiometer the black surfaces absorb more energy than the shiny ones and so become hotter. The air molecules hitting one of these blackened surfaces will gain energy and rebound with an increased velocity, so pushing the vane round, with the black surface trailing.

However, if the air pressure inside the bulb is very much reduced to almost a vacuum, then rotation is in the opposite direction. This is due to the pressure of radiation on the shiny surfaces.

4. The bolometer

This consists of a blackened strip of platinum. The resistance of the strip changes according to the amount of radiation falling on it, so the bolometer must be connected to an electric circuit for measuring resistance, eg. a Wheatstone bridge.

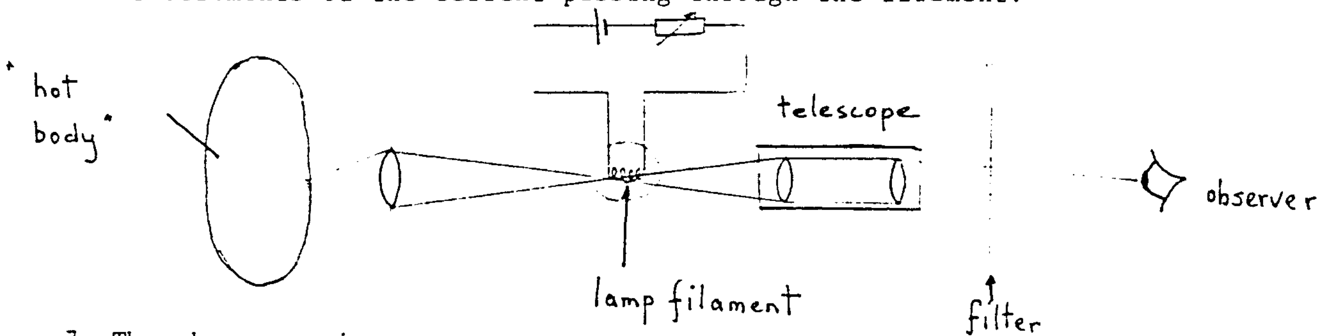
5. Tne thermopile



A thermopile is formed by several thermocouples connected in series. Each thermocouple junction is blackened, and the radiation which falls on them causes the e.m.f. of the thermopile to change. The thermopile has been used to measure radiation from faraway bodies such as planets, and from these measurements the temperature of the planet's surface can be found.

6. The disappearing filament pyrometer.

Pyrometers are particularly useful for measuring radiation coming from very hot objects (above 2000 K). A telescope is set up to view the object of interest eg a furnace. A lamp filament is placed in the focal plane of the eye-piece of the telescope, and the source and filament are viewed through red glass.. The current passing through the filament is adjusted until it seems to "disappear", that is, has the same colour as the source. The source and filament are then at the same temperature, and this temperature can be determined from measurements of the current passing through the filament.



7. The phototransistor

The leakage current of a phototransistor increases with temperature and hence the intensity of infrared radiation can be measured.

PREVOST'S THEORY OF EXCHANGES (1792)

ALL bodies emit heat radiation; however those which are hotter (at a higher temperature) radiate more energy than those at lower temperatures. Consider two bodies at different temperatures. Each will radiate energy to the other, with the hotter body radiating MORE energy than it receives from the cooler body. The cooler body therefore becomes hotter and the hotter body, cooler until they reach the SAME TEMPERATURE.
Use Prevost's theory to explain what happens now.

THE NATURE OF HEAT RADIATION

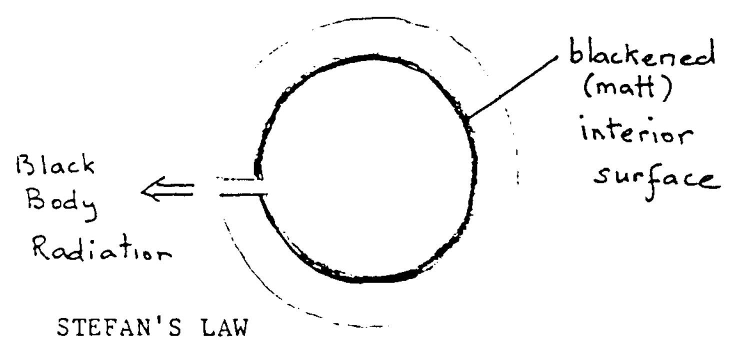
Heat radiation can be shown to be electromagnetic waves with wavelengths slightly longer than visible light. The infrared region of the spectrum extends from 750 nm to 400 000 nm.
(Red visible light has a wavelength of approximately ________nm.)

Like visible light, infrared radiation can be reflected and refracted, although it is slightly more difficult to demonstrate refraction of infrared as many materials are opaque to infrared radiation, that is, they absorb and do not transmit it. Glass is opaque to all but the shortest wavelengths of infrared (up to 3000 nm), rock salt however will transmit up to 15 000 nm and so could be used to refract infrared radiation.

When heat radiation falls on a body, there are three possible consequences:
(i) some might be reflected
(ii) some might be absorbed
(iii) some might be transmitted
Obviously, if a body reflects or transmits most of the incident radiation there will be little left to absorb; white or shiny surface are therefore poor absorbers. If the body has not absorbed much radiation there will be little left to emit, so poor absorbers will also be poor emitters.
Conversely, surfaces which are good absorbers, such as matt black surfaces will also be good emitters.

BLACK BODY RADIATION

An ideal absorber of heat, would be one that absorbed all the radiation that fell on it and hence also emitted the maximum amount of radiation possible for that area and temperature.
In the laboratory, the behaviour of an ideal absorber/emitter can be investigated using a sphere with a blackened interior surface and a small hole to allow radiation in and out.



Virtually all the radiation falling on the hole will be absorbed and then emitted as the body is heated This is also sometimes called "cavity radiation" for obvious reasons.

STEFAN'S LAW

The radiation of a black body, like the one above, over a range of temperatures, and for a variety of wavelengths, were summarised by Stefan as follows:

(i) THE TOTAL POWER EMITTED PER UNIT AREA BY A BLACK BODY IS PROPORTIONAL TO THE FOURTH POWER OF THE BODY'S ABSOLUTE TEMPERATURE

$$E = \sigma T^4$$

σ is known as Stefan's constant and has a value of

$$5.7 \times 10^{-8}\ W\,m^{-2}\,K^{-4}$$

(3)

(ii) If the body has a surface area (A), then the TOTAL POWER EMITTED IS:

$$E = \underline{\hspace{6cm}}$$

(iii) When the body is surrounded by an enclosure at a temperature T_o there will be an exchange of heat radiation between the two bodies, the net loss of energy by the body per second will be:

$$E = \sigma(T^4 - T_o^4)$$

(iv) If the body is not a black body, then the energy emitted at any temperature will always be less than that which would be emitted by a black body with the same area and temperature. The emissivity (e) of the surface which will always be less than one, must be included in the equation as follows:

$$E = e\sigma A T^4$$

QUESTIONS

1. Is infrared radiation visible? What do we mean when we say something is red-hot?

2. The passage lists four uses of detecting infrared radiation. Briefly describe ONE of these uses.

3. List 4 infrared detectors which have blackened surfaces. Explain why these surfaces are blackened.

4. The phrase "due to the pressure of radiation" is mentioned in the passage. Find this phrase and describe the observation it is explaining.

5. List three objects whose infrared radiation could be estimated using a disappearing filament pyrometer.

6 A black cloth and a white cloth are left out in the sun. After an hour, it is found that the black cloth is much warmer than the white cloth. Why is this so? Does this contradict Prevost's theory of exchanges? Explain.

7. A block of wood and a block of metal are at the same temperature. When the blocks feel cold, the metal block feels colder, but when the blocks feel warm, the metal blocks feel warmer. Why is this so? At what temperature would the blocks feel equally hot?

8. The passage says that glass is opaque to infrared radiation, yet on a sunny day, the inside of a glasshouse (greenhouse) is always warmer than the outside. Why?

9. The energy that the Earth receives from the Sun is about 1400 $Jm^{-2}s^{-1}$ this is known as the SOLAR CONSTANT.

(a) Will all this energy reach the surface of the Earth? Explain.

(b) Assuming that the Sun is a black body, state an equation which gives the total energy emitted by the Sun.

(c) Sketch a diagram to show how the Sun's radiation reaches the earth. Indicate on your diagram the radius of the Sun (r) and the Sun - Earth radius (R)

(d) Total energy emitted by the sun =

Solar constant X area of sphere radius R

1400 X $4\pi R^2$

Use this and the answers from (b) and (c) to find the temperature of the sun's surface. (Assume R = 220r)

Appendix 17 HEAT RADIATION results

APPENDIX 17

HEAT RADIATION COLLATED RESULTS																	
RESPONSE	I	II	III	IV	1	2	3	4	5	6	7	8	9A	9B	9C	9D	TOTAL%
NIFE	2	0	0	0	1	0	1	0	3	0	0	2	2	0	3	0	39
KAME	2	2	0	1	2	2	2	0	3	2	0	0	2	1	3	2	67
LANA	2	0	1	1	2	0	2	0	2	2	0	2	2	0	1	1	50
KARA	2	2	1	2	1	2	2	2	3	2	1	2	2	1	3	1	81
KURO	2	0	1	0	1	1	2	1	3	2	1	0	1	0	1	0	44
BARU	0	0	0	1	2	0	2	0	3	1	2	0	1	0	1	1	39
ANSA	2	2	1	1	1	2	2	0	3	2	0	0	2	1	1	1	58
JASI	2	0	1	0	0	2	2	1	2	0	0	0	1	0	1	0	33
NISH	2	0	0	2	0	1	0	3	2	2	0	1	0	1	1	0	42
RASH	2	2	1	2	1	1	2										31
SIWI	2	0	1	1	2	2	2	0	3	4	0	2	2	1	3	2	75
Facility	0.91	0.36	0.64	0.5	0.59	0.59	0.86	0.32	0.82	0.39	0.12	0.41	0.68	0.45	0.55	0.24	
Discrimination	0.23	0.39	0.19	0.29	0.42	0.57	0.27	0.05	0.54	0.65	0	0.45	0.68	0.77	0.72	0.78	

Appendix 18 Class teachers' homework and test results

SCHOOL Y

IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTH

	Christmas Test	% Term Homework	End of Term Test	Term Ave	Position
[redacted]	57	60	66	61	(2)
	39	60	41	47	(5)
	40	70	41	50	(6)
	37	66	41	48	(8)
	37	57	43	46	(11)
	30	66	45	47	(9)
	54	65	38	52	(5)
	42	65	40	50	(6)
	68	75	71	71	(1)
	50	53	59	54	(4)
	42	47	41	43	(12)
	42	75	53	57	(3)
		— NEWLY ARRIVED —			

SCHOOL: X

HOMEWORK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17a	17b	18	19	20	21	22	23 HWK A VERA	24 25 26
MAX	30	50	45	40		45	25	30	60	21	52			45	30	32	55	22	25	50	30	32			
IMAGE REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES [redacted]	15	37	22	26		29	9	26	26	13	33			36	20	13	42	21	21	35	14	28		72	230/32[illegible]
[redacted]	20	28	26	22		17	10	22	28	7	36			33	18	18	44	21	24	37	24	28		76	243/32[illegible]
[redacted]	16	45	38	27		24	20	24	?	9	49			43	19	27	49		25	44	23	26		26	251/3[illegible]
[redacted]	19	–	45	36		42	10	26																	
[redacted]	17	30	36	28		22	13	20	30	15	44			34	14	19	40	21	25	27	22	29		73	234/32[illegible]
[redacted]	13	31	23	24		20	16	22	41	8	42			23	13	20	34	20	23	29	21	24		65	201/32[illegible]
[redacted]	16	25	23	24		25	16	26	28	14	50			33	24	25	36	17	20	34	19	26		73	234/32[illegible]
[redacted]	14	29	24	33		35	18	14	36	11	19			38	18	21	51	13	23	31	16	25		68	219/32[illegible]
[redacted]	11	26	27	29		21	9	16	17	13	22			41	22	18	36		24	36	15	25		73	217/29[illegible]
[redacted]	20	33	38	29		35	12	23	38	13	50			24	20	27	41	21	25	45	25	30		80	258/32[illegible]
[redacted]	21	36	28	36		30	13	25	?	13	36			40	18	19	49	21	25	26	23	29		78	250/321
[redacted]	18	–	14	17		10	8	20																	
[redacted]	22	41	45	35		36	22	22	52	15	50			36	19	30	55	21	25	45	24	30		89	285/321
[redacted]	24	39	38	33		37	22	23	40	17	47			34	23	27	50	22	25	46	[illegible]	27		79	255/321
[redacted]	11	–	16	29		22	21	21																	
[redacted]																									
[redacted]	17	33	29	29		27	15	22	33	12	40			33	18	23	44	20	23	36	20	26			
[redacted]											47			23	15	19	48	25	25	34	19	28		72	216/299
[redacted]											36			27	12	18	39	20	20	35	18	24		66	213/321
[redacted]																	45	22	19	29	16	18			

WER SIXTH PHYSI

SCHOOL W

	Waves (16)	Questions (14)	(4)	Waves closed (16)	Oscillations waves (23)	Wave test (43)		Interference (19)	Diffraction (28)		% class marks	End of Term Exam Practical 52 (20%)	%	Paper 1 29 (20%)	%	Paper 2 66 (60%)	%	Effort	Term	Grand Total	
[redacted]	7½	16	4	16	19	25½	54%	13	28	103.5/118	88%	37	14%	18	12%	40	36%	A	A	62%	B
				NS	NS	28	65%	17	24	41/47	87%	32	12%	20	14%	44½	40%	A	A	66%	B
	3	5	2	9	19	19	44%	~~11½~~	13	62.5/118	53%	25	10%	12	8%	20½	19%	C	C	37%	O
						14	33%	18		13/118	15%	26	10%	9	6%	18/48	23%	B	B	39%	O
	8½	14	4	14	26	26	61%	14	28	102.5/118	87%	38	15%	15	10%	41½	38%	A	A	63%	B
	10	9	4	15	12	28	65%	18½	25	67.5/118	75%	29	11%	15	10%	38	35%	A	A	56%	C
				11		14½	34%			11/118	9%	23	9%	7	5%	7	6%	E	E	20%	F
	6½	5		16	25	11	26%	14½	23	49/118	42%										
	9	16½	0	14	18	20	47%	14	24	85.5/118	72%	32	12%	14	10%	34	31%	BA	B	53%	D
	9½	7	2	13	19	26	60%	16½	24	91/118	77%	37	14%	14	10%	22½	20%	BA	B	44%	E
	6	7	0	16	23			14	23	50/77	65%	29	11%	21	15%	45½	41%	A	A	67%	B
	7	12½	0	15	21	22½	52%	19	28	102.5/118	87%	13	5%	7	5%	31	28%	B	B	38%	O
	6	6½	4	15	6	34	79%	15½	24	77/118	65%	29	11%	17	12%	43	39%	B	BA	62%	B
	5	11½	4	10	18½	22½	52%	16		55/90	61%	32	12%	8	6%	10	9%	B	C	27%	F
				9	19	28½	66%	13	28	64/118	58%	25	10%	18	12%	~~41~~	37%	B	B	59%	C
	NS	NS	NS			14	33%		28	28/88	32%	24	9%	14	10%	31	~~28%~~ 30%	B	B	49%	E
	4 RUSTAM.											31	12%	18	12%	50½	46%	A	A	70%	B

To check !!

WAVES TEST

[redacted] 7 p	5	7	18	7%	9	6%	24½	22%	B	C	35%	O

AVERAGE. 50%

8	4	7
7	8	7
6 MAOR	7 INDERPAL.	6 DANIEL
5 PRAMOD, KARIM	6	
4	5	
3	4 RAJEEV	
2	3	
1 BANAL	2	
0 JASPAL.	1	
9 ANDREW	10	
8	9	
7	8	
6	7	
5	6	
4	5	
3	4 MUSTAFA	
2 HARAS PREMAL	3 ANTHONY, DANNY	
1	2	
	1	
	50	