

THE PHYSICAL SCIENCE TEXTBOOK SINCE 1800:  
A STUDY OF ITS LANGUAGE, STRUCTURE  
AND RHETORICAL STYLE

by

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This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any other university, and to the best of my knowledge and belief contains no material previously published or written by another person, except where due reference is made.

This thesis is my own work.

*Paul Strube*

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## ABSTRACT

Since the 19th century, when books for instruction in science became available in significant numbers, their place in the science curriculum has been contentious. The defenders of textbooks have tended to point out their informative or instructional role, generally failing to respond to criticisms of the quality of the text as a prose work. Recent concern with readability, and the place of reading in the science curriculum, has made more urgent the analysis of the textbook and its place in science education.

This thesis examines physical science textbooks for answers to questions dealing with the language of science textbooks as it relates to the history and purpose of science education. It is based on the premise that such language can be characterised not only by structural factors (such as sentence length and vocabulary) but also by what the language attempts to achieve. The latter is dependent on the purposes for which the text is written, and these are shaped by contemporary beliefs about the nature of science and science education, the particular science written about, and the intended readers of the book. Science textbooks emerge as prose works with a history that has shaped their characteristics.

The thesis explores the history of physical science texts since 1800, and uses that history to develop both a classification system for textbooks, and a framework against which to view the changing purposes of science textbook authors. It is based on a

large collection of such textbooks published in Great Britain, Australia, and the United States. Textbook characteristics are explored using three levels of analysis. Level 1 is historical, placing the texts in a context of contemporary opinion on the purposes of science and science education. It uses that context to develop a first order classification of textbook types. Level 2 uses techniques from literary criticism (notably genre-theory and stylistics) and rhetoric (the nature of argument and exposition) to match the first order classification in Level 1 to established theoretical results. This results in a second order classification of greater depth and power. Level 3 examines the textbooks for prose structures which are designed to meet the purposes of providing explanations for phenomena and instructing. These two purposes allow a third order classification to be developed, which can then be used to make judgements about the language of the text and its suitability for meeting the varied purposes of science education.

Such an analysis provides information about the development of the modern science text, uses past and present texts as mirrors of the long-standing debate about the place of the textbook in science education, and provides the classification and characterisation of textbooks needed for any further rhetorical consideration of the textbook as prose.

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Books and experiments do well together, but separately they betray an imperfection, for the illiterate is anticipated unwillingly by the labours of the ancients, and the man of authors deceived by story instead of science.

Edward Bernard (1671)

## INTRODUCTION

### PURPOSE AND METHOD OF ANALYSIS

This thesis is concerned with the relationships between the language of physical science textbooks and changing viewpoints regarding the nature of science and science education. It arose out of a professional concern as a teacher of senior level physics in Tasmanian schools, and from a research interest in figurative language and the communication of ideas. From the former came a common student complaint about the difficulty of reading the assigned texts; from the latter came an awareness of the lack of research attention paid to the critical analysis of non-fictional language.

In fact, little attention has been paid to the textbook as a work of prose, though considerable research has been done on finding ways of improving learning from textual material. The latter work has mainly been done by psychologists looking for ways of changing or adding specific structures (e.g., advance organisers) to improve comprehension. (Rothkopf, 1964, 1965, 1968, 1976; Ausubel, 1963; Ausubel and Robinson, 1969; Waller, 1977; Rickards and Denner, 1978; Annett, 1969; Frase, 1972; and Freedle and Carroll, 1972). What has not been done by any of the researchers listed above, however, is a systematic study of textbook language and how that language is related to the purposes of the authors; instead, researchers have tended to

concentrate on the readers. More specifically, what has not been recognised is the possibility of using the language of the physical science textbook as a mirror of changing views of the nature of science and science education; nor has the science textbook been classified and characterised with respect to those views.

This thesis begins the task of just such a classification and characterisation. It is concerned with three central issues.

1. What are the characteristics of textbook language?
2. How did they develop?
3. What can they reveal about science and science education as they are presented to readers at school?

These three issues demand an inter-disciplinary approach, seeking insights from the history of science education and from the area of rhetoric. From such insights an analysis emerged in the form of a multi-layered structure, one that is seen to be analogous to the traditional development of an empirical study. The response of the author is to present this thesis as three layers (or levels) of analysis as follows.

SECTION A, the first layer (Chapters 1, 2 and 3), is modelled on the empiricists' first order of analysis--sensory observation. It is historical, placing the textbooks in a context of time and opinion. Chapter 1 is a general history of science education from 1800 to the present. A more comprehensive treatment of the history of science education in that period has been ably done by others, notably Layton (1973) and Jenkins (1979). What Chapter 1 does, in contrast to the latter works, is to relate the major movements in ideas about the nature and purpose of

science education with debates about textbooks and the perceived importance of reading for learning science. This is followed in Chapter 2 by a more detailed history of the physical science textbook itself. Such an history is used to generate a classification of textbooks based, as a first approximation, on stylistic differences. This is, again, analogous to a first order taxonomic classification based on visible surface appearances. Chapter 3 supplements this historical analysis by examining the prefaces of the textbooks for evidence of authorial purposes. Thus the text is not only placed in a context of historical purpose, but the views of the authors explicitly reveal the varying purposes for which they wrote. These varying purposes are seen to be strong determinants of language choice and text structure.

SECTION B, the second layer (Chapters 4 and 5), takes the historical analysis a step further. Given the first order stylistic classification of textbooks generated by Section A, it becomes necessary to fine-tune the defining characteristics, relating them if possible to rigorously established results in the area of language studies (e.g., linguistics, rhetoric, grammar, or literary criticism). Continuing the empiricist analogy, this level of analysis seeks relationships between initial, sensory observation and the established results of the discipline; i.e., how does Section A's classification fit in with current understanding? The classification system developed in Section A is unique to this thesis, and therefore needs to be linked to a second order of analysis.

Chapter 4 is concerned with placing the textbook in a literary

context, where the language characteristics identified in Section A can be considered in more detail. The choice of genre-theory as the model used for setting that context needs some detailing. Firstly, genre-theory is itself based on a system of classification of literary types, and these types are characterised in the same manner as the textbooks--by both historical and stylistic features. Secondly, genre-theory relates the intended meanings of the author to the constraints imposed by the characteristic features of the genre; and in turn, the meanings that readers acquire are related to their familiarity with the generic features of the text. Thirdly, genre-theory has many important links with the descriptive and analytic methods of linguistics, and the resulting connections can then be made use of. However, genre-theory is more consistently applicable to discussion of complete prose works, rather than the more usual concern of linguistics with small units of spoken or written utterances. There is, however, another important consideration here. After all, a thesis concerned with the language of textbooks should, it would seem, pay close attention to the models and theoretical insights of linguistics, the 'science of language'. But this would be to misjudge the central purpose of this thesis. It is not the language of the text itself which is under critical analysis, but the relations between that language, science and science education. This, as will be shown in Chapter 4, genre-theory can more usefully assist with.

It can be seen that these considerations also argue against other established analytical procedures. For example, there exists a range of techniques used by researchers for textual



analysis, and most of them listed below can be seen to be inappropriate to the central purpose of this thesis, for the accompanying reasons.

(1) Readability (e.g., Klare, 1963, 1976; Stokes, 1978; Denbow, 1973; and Taylor, 1953) is a good predictor of reading difficulty, but there is little to be gained from repeating such techniques simply to establish the reading age demanded by modern physical science textbooks. This thesis is not directly concerned with how difficult such texts are to read, but with what such texts can reveal about science and science education.

(2) Quantitative content analysis, similarly, can inform us about what has been said, but cannot on its own reveal the relationships between language, science and science education looked for here. However, as it can help detect patterns in how things are said, or support claims made concerning the characteristics of language usage, it can be useful in defining the characteristics of textbook language. In general, it will be used in this study only in a minor way for verification of procedures and results.

(3) As mentioned earlier, experimental psychology (e.g., Rothkopf, 1965, 1968, 1970; Winter, 1977; Ausubel, 1960, 1963; and Rickards & Denner, 1978), while it has fashioned probes and theories of great complexity to analyse how students learn from reading, cannot provide the sort of answers being sought here. The concern of this study is with the language of textbooks, not with separate components of that language. In thinking of the textbook as a discourse, as a consistent way of speaking which is revealing of societal and authorial views, it is necessary to consider the text as a whole. Thus questions concerning such

smaller units as advance organizers, in-text questions, or mathemagenics would not seem to be an appropriate form.

(4) By the same argument, most linguistic analysis look at units of prose too small for our purposes. (e.g., Halliday & Hasan, 1976; Grimes, 1975; Kintsch, 1974; and Winter, 1977). Given the difficulties involved with: one, the limitations involved in using small sections of prose with small samples of readers; two, the theoretical disputes concerning what is said to be happening when students read and recall under experimental conditions; three, identifying single-unit factors which can clearly characterise texts; and four, the inability of such small studies to indicate relationships between language and purpose, it becomes clear that a larger rhetorical analysis is more suited to the purposes of the study.

Chapter 5 continues the language-based analysis by considering the question of textbook style. Stylistic questions naturally arise from those of genre, as style forms one of the defining characteristics of generic classification. Also, textbook style is often regarded as one characteristic that influences reading comprehension, but this thesis will be more concerned with its relation to views of science and science education. Chapter 5 considers style from two viewpoints; that of stylistics, to see if further refining of the first order classification can be made, and historically, to see how stylistic concerns have, again, been shaped by authorial and social purposes. The analysis also examines the use of certain terms traditionally used to characterise and judge textbook language (eg., precise, formal, concise), relating them to authorial purpose.

SECTION C, the third layer (Chapters 6, 7 and 8), takes the historical and rhetorical analysis a final step further. The first and second order classifications in Sections A and B are now applied to prose structures found in the textbooks. This third level of analysis takes advantage of previously established results to make sense of two important purposes of the science textbook--to offer explanations, and to instruct. These two purposes, originally identified in Section A, and theoretically examined in Section B, are then detailed in Section C. In the empiricist analogy, this third level of classification corresponds to that of suggesting explanations for particular structures and functions, based on the insights gained from earlier classifications and theoretical background. Chapter 6 is concerned with the explanations for phenomena offered by textbook authors. Such scientific explanations are linked to views of what science is by virtue of the kinds of explanations offered. They are also linked to views of what science education is by virtue of the levels of explanation offered and expected to be learned. Chapter 6 begins with a brief discussion of the types of explanations most commonly encountered in science textbooks. This discussion is not intended to provide a critical account of the problematic nature of explanation in science, nor to suggest that one explanatory type is preferable to another, but rather to provide the necessary background for considering the implications of each type of explanation for revealing the authors' views of science and science education. The second half of the chapter examines the presentation and structure of explanations in the textbooks.

Chapter 7 looks at the instructional language of the textbooks, which may be thought of as how the authors explain their explanations. Again, this explaining and teaching purpose of the text clearly reflects views of what science education is by virtue of how it is to be learned; by enquiry, for example, or by rote learning of established conclusions. This can also be seen to reflect on views of what science is; as a method of exploring the physical world, or as a logical deductive system. Chapters 6 and 7, therefore, not only show the relationships between textbook language, science, and science education in finer detail than in earlier sections. They also provide the bases for a third level of classification of textbooks, centred on the types and levels of explanations offered, and on the instructional language characteristics of the text.

Chapter 8 uses quantitative content analysis of the structures found in Chapters 6 and 7 to ensure that the analysis presented in those chapters is not idiosyncratic or unrepresentative of the majority of textbooks. In a thesis of this type, qualitative measures must first describe and classify the important textual features (Section A), and then relate them to theory (Section B) before quantitative measures determine their relative frequency. The quantitative measures have a secondary, verificational role to play. It is important to guard against drawing conclusions about textbook language based on atypical texts. Quantitative analysis, based on results from larger numbers of texts, can establish that the texts discussed in all sections are typical and characteristic.

The thesis concludes with Chapter 9, which draws together and summarises the results of Sections A, B and C.

It should be emphasised that the method of analysis outlined above was not immediately obvious or inevitable. Perhaps by virtue of being a multi-disciplinary thesis, the resulting three-layer structure was not in fact clear until a great deal of reading and analysis had taken place. There were two immediate difficulties. One was the problem of structure, connecting in a coherent way historical and rhetorical methods. It was not until the links between the authors' views of science and science education (shaped by historical setting), resultant purposes for writing, and the powerful influence of purpose on language (both style and structure) were made that the thesis structure outlined was possible. The second major problem, common to all theses perhaps, but particularly to multi-disciplinary ones, was that of depth of treatment--an in-depth analysis in one area is sacrificed to a shallower analysis from several. This thesis attempted to confront that problem in two ways. Firstly, in order to bring together established results from varied disciplines, it was argued that only the broadest conclusions from those disciplines are likely to be useful, as more discipline-specific concepts often degenerate into purely metaphorical or analogical relations when applied to different areas. A similar problem, for example, is found in integrated general science courses, where logical and educationally useful connections must be found between, say, physics and biology. To truly reflect the purposes of a general science course, only concepts broad enough to be shared by both physics and biology as sciences (e.g., energy) will serve. The in-depth analysis of the links between physics and biology not

only pre-supposes detailed knowledge of both, but quickly leads to the analysis of a new, separate discipline, biophysics, with its own concepts and areas of research. This thesis can perhaps be seen as making a move towards the establishment of a form of textual criticism that draws broad but meaningful concepts together from literary criticism and various educational studies.

#### THE TEXTBOOKS USED

A few words must be said about the data base for this thesis, the textbooks themselves. A large number of them--over 300--now form a collection housed at the University of Tasmania's Centre for Education. A complete list of all the texts in this collection is attached as Appendix I. These, and all the others referred to in the thesis, were written in the English language and published in either Great Britain, Australia, or the United States. They were selected on the basis of two criteria. Firstly, they were, or are, well-known and well-used in schools. This was judged using publishing lifetimes, or references in reviews and journals. Secondly, they are typical, or representative, of the physical science textbooks of their historical period and stylistic type. This was judged by comparison with others of the same time and style, either within the collection or described in research literature. This comparative method was necessary due to the absence of an existing classification scheme for textbooks. It is made more rigorous, however, by the content analysis that takes place in Chapter 8.

It will be noted that no attempt was made to classify the

textbooks according to the supposed age of the readers of those texts. As will be shown in Section A, it is impossible in many cases to determine the ages of the readers of many 19th century texts with any certainty. Whenever possible, reference is made to textbooks known to have been used in secondary education. Physics and chemistry in the secondary school have tended to be examination courses (such as School Certificate, Higher School Certificate, 'A' levels, and 'O' levels), and so texts written for such courses tend to predominate. In turn, this means the modern general science texts are not considered. While it may be argued that the age of the intended reader is an important influence on the language and style of a textbook, it is not useful for a rhetorical classification of texts, but for judging the appropriateness of the textbook's language.

#### METHODOLOGICAL ASSUMPTIONS

The critical assumptions are these. One, there is such a thing as 'textbook language'. This assumption grew out of professional experience with textbook selection, and is borne out by the large number of research articles which take it as a given for research purposes (e.g., there are a considerable number of articles in the bibliography of this thesis which refer in their titles to 'textbook language'). Two, that textbook authors assume, rightly, that senior level science students are readers of average ability, an assumption based on perceptions of their reading ability in other school subjects. It may in fact be the case that the present system of schooling in Australia actually selects readers of relatively higher competence in reading to do senior level science. What this

thesis does not do is argue for or against social patterns of reading--i.e., the readers who may be disadvantaged due to social background. Three, it is assumed that textbook authors make honest attempts to write so as to be understood. Four, that attempts to analyse textual language are meaningful; that is, the results are not idiosyncratic or random, and also that the meanings which may be ascribed to text content and structure correspond to intended meanings by the author and understood meanings by the reader. Five, the assumption is made that knowledge about textbook structure and content as revealed by the analysis can legitimately support inferences and interpretations about non-textual events. This is one of the key assumptions of literary criticism. It is important to state, however, that this assumption in no way frees the analysis from the demands of rigour, reason and objectivity in drawing those inferences and interpretations.

#### THEORETICAL CONSIDERATIONS

The theoretical analysis presented in this thesis has three intimately linked components--PURPOSE, EXPLANATION, and INSTRUCTING. Each will be discussed separately, and the connections between them made explicit.

Fundamental to this analysis is the idea of Purpose. It is assumed that authors have clear purposes in mind when writing texts. Indeed, it may be the case that they have a variety of purposes in mind, some of which are in conflict. If the language of the text is to meet the purposes of the authors, it must be assumed that the authors try to find the most appropriate language, where appropriate is taken to mean 'best



suited to', in the sense of helping to realise, the purposes of the authors. This allows an important relationship to be established: a fundamental consequence of a purpose is that it is a powerful determinant of language use. It thus becomes crucial to identify purposes in texts. An examination of the origins and development of the texts is one way to do this, and that is the purpose of Chapters 1 and 2. A second way is to examine the authors' explicit purposes as revealed in the prefaces to the texts, which is the purpose of Chapter 3. Purposes in textbooks can and do reflect the purposes of educators and society, and the historical approach can locate those extra-textual purposes.

Purpose is not only a powerful determinant of language, but is a powerful selector of content. By content is not meant just the topics selected for study, but the emphasis given to particular views of science and science education. For example, choice of content is guided by views of the laboratory and its role in science and/or in science education. So, bound up with any examination of purpose must be considerations of what is presented to the readers. This aspect of purpose will be considered in some detail throughout Section A.

Purpose, however, cannot be assumed to be the sole determiner of language in textbooks. There are, for example, considerations of tradition, which can also be investigated historically. But an even more powerful whole-text determinant must be the nature of the scientific discipline itself. Science has a unique structure, way of arguing, methodology, assignment of truth and probability, as well as its unique results. It is these characteristics which make it distinctive. Textbook authors,

with a purpose of initiating learners into the nature and function of these distinctive features, are constrained to certain allowable patterns of language use. A choice had to be made as to which feature would be selected for close study, consistent with the central concern of relating textbook language, science and science education. Explanation proved to be a highly suitable choice for the following reasons. Explanations are whole-text features assumed to be a central concern of all textbooks, which must use explanations at various levels and of various types to explain phenomena and to justify the concepts developed by the text. Secondly, explanations are features demanding rhetorical attention when written, because they cannot be left implicit or to be inferred. Thus they are language-based features of relevance to this thesis' method of analysis. And thirdly, if the explanations offered are to be appropriate (as used in the the sense above), they must be appropriate in two ways-- not only to the structure of science as a discipline, but to the understanding of the reader. Explanations, therefore, have a dual role that must be expressed in language--they must be true to both science and to learning. Therefore they reflect the authors' views on 'both science and science education.

There is one other major determinant of language in textbooks besides purpose and explanation, and that is the reader of that text. Textbooks are directed at readers of different ages and levels of understanding, background knowledge and reading ability. It is clearly impossible to judge textbooks by reference to the whole range of possible reader characteristics, even if they could be identified. But one clear pedagogic

purpose assumed to be common to all textbooks is that of instruction. While this is clearly related to offering explanations, it is taken here to refer to the act of getting the reader to understand the explanations, and is thus meant to be synonymous with teaching. Again, it is a rhetorical act because it must be written not implied, and is thus available for examination. If language is to be appropriate to authors' views of science education, it must perform the act of instructing. Instruction, therefore, is seen to be directly related to views on science education, and also directly related to views of science, especially if authors wish to claim that the best way to learn science is to do science.

#### CONCLUDING REMARKS

This thesis views the textbook as a work of prose. As such, the text shares all the characteristics of works of both fiction and non-fiction. It has a history, both within science education, and as a work of prose--its generic history. Those histories in turn have been shaped by contemporary views, both social and authorial, of the nature of science and science education. The communication of these views forms the purposes of textbook authors. The combination of purpose and history creates a rhetoric, a language designed to persuade and/or inform. The result is not simply a collection of facts and illustrations, but a text with a given style. The analysis of textbook language, first historically (Section A), then rhetorically (Section B) and finally structurally (Section C) will then be revealing of the underlying purposes for which texts are written. More importantly to the concerns of this thesis,

however, the analysis allows us to use the language of textbooks as a mirror of changing views of science and science education.

## SECTION A

This is the first layer of the analysis. It sets the textbooks in an historical context of contemporary opinion on science and science education. It does so in three ways.

Firstly, it outlines a general history of science education, from about 1800 to the present. This sets the textbooks in historical perspective.

Secondly, it outlines the history of the textbooks themselves.

Thirdly, it examines the prefaces to the textbooks for the authors' expressed purposes.

The results of this historical analysis generates a first order classification of textbooks, based on authorial purpose.

## CHAPTER 1. GENERAL HISTORY OF SCIENCE EDUCATION

INTRODUCTION

In the Introduction to this thesis it was stated that a crucial feature of the analysis is the necessary link between the language of a textbook and the purposes for which it was written. It was argued that the purposes of the authors are reflected, not only in the content of the text, but also in the rhetoric employed. Rhetoric is defined by the Oxford English Dictionary as 'language designed to persuade or impress', which captures the notion of purpose in the term 'designed'. An examination of the development of the modern science textbook alongside changes in, and controversies about, the nature of science education since its inception in schools in the 19th century is, then, important to the analysis for several reasons. Firstly, one set of purposes will, it is argued, come from contemporary views on the nature of science and of science education. It is assumed that writers, if not always actively aware of and responsive to the educational and intellectual context of their times, were responding to their beliefs about the purposes of science education. For example, it becomes of interest to know whether science education has the primary purpose of training future scientists and technicians, or developing the mind, or bringing about social change, because each purpose will influence the authors' decisions about the most appropriate language to be used in meeting those purposes. Secondly, another set of purposes comes from educational beliefs

concerning the value of reading in learning science. Is the purpose of a text to inform, to instruct, to act as a resource, or to guide investigation? How an author answers such questions will influence the language of the textbook. An historical analysis provides an illuminative background for examination of the changing views of the importance and purpose of reading as an aid to learning in school science. If textbooks are not meant to be read in the traditional and usual sense of reading, as in normal storybook reading for example, the implications for the authors are considerable. Thirdly, it allows the opportunity to see if the role of the textbook as an essential component of meeting the purposes of science education has changed over time; i.e., has the text experienced a changing pedagogical purpose? Writers, it is assumed, will be responsive to such changes in how their texts are being used in schools. In considering these three different sets of purposes, it is necessary to trace the influences on the textbook of perceived beliefs concerning the purposes of science education in general.

As this historical analysis is intended to be limited to a general overview, it is confined to a period between the beginning of the 19th century and the present day. This time span was chosen because it marks the rise of science as a school subject, and corresponds to the emergence of the school science textbook. Within this approximately 180 year span, five distinct historical periods can be distinguished, and these are briefly outlined below.

1. Pre-1840, or the period of virtually no formal schooling for the majority of school-age children on a large scale, and

particularly not in science.

2. 1840-1900, or the rise of school science and the introduction of compulsory education.
3. 1900-1960, or the period of consolidation in school science, and its extension into all levels of formal schooling.
4. 1960-1970, or the period of large-scale national curricula movements in science; the post-Sputnik era.
5. 1970 to today, the contemporary period of science education with its conflicting views on enquiry-learning, process-science, hands-on science, and so forth.

Within each stage the major characteristics of science education will be identified and connections made with the textbooks of that time. Considering the enormous number of textbooks written during any period, only samples of characteristic works will be cited, though figures will be given to indicate the numbers of textbooks available to learners.

#### 1. PRE-1840

This period was characterized by the virtual non-existence of formal science teaching in the majority of secondary schools, and by a relatively small primary school population. There were a limited number of schools in which science was taught, and taught well (e.g., the Mayo's school at Cheam), but they were not common enough to leave their stamp on the education system as a whole. The schools most readily thought of as fore-runners in the teaching of science in England--King's Somborne with Richard Dawes, and Hitcham with John Henslow--were not involved in science education until the very late 1830's. (Layton, 1973). The education system in general, consisting of



day-schools, was soundly criticised by educationalists of the time.

(Teachers were) the refuse of other callings--discarded servants, or ruined tradesmen; who cannot do a sum of three; who would not be able to write a common letter; who do not know whether the earth is a cube or a sphere, and cannot tell whether Jerusalem is in Asia or America: whom no gentleman would trust with the key of his cellar, and no tradesman would send of a message. (Macaulay, 1847)

School subjects, for the younger pupils, were mainly limited to reading, writing and numeration, plus religious and moral instruction. In secondary level schooling, classical studies, history and geography were added to this base. Any scientific education, taking place outside of school, could be described as autodidactic, as men and women were largely self-taught through a fairly substantial number of books and magazines that were available. Layton (op. cit.) has indicated that at the time of British governmental intervention and control of state education, a wide range of reading material was at hand, which contained secular content. As well as periodicals such as Mechanics Magazine or the popular "Penny Magazine of Brougham's 'Steam Intellect Society' ", Layton mentions such books as Mrs. Jane Marcet's Conversations on Chemistry (1806) which "...achieved sixteen editions in less than forty years, sold more than 150,000 copies in America alone, and numbered the young Faraday amongst its admiring and grateful readers." (Ibid). Other secular works available included: Pinnock's Catechisms of the Arts and Sciences, published in pamphlet form from about 1822; The Cabinet Cyclopedia of the Reverend Lardner, 1830; The Peter Parley Series; i.e., Tales About Plants, 1839; and Joyce's Scientific Dialogues, 1840, "...the most popular and

instructive manual of science in the English language." (From the Advertisement to the 1846 edition). This significant number of publications must be considered in relation to the numbers of literate adults and children to read this material. Available figures indicate a very small literate population during this period. For example, in 1832, of 12,400 adults attending about a hundred schools in that year, only 3,148 were said to be literate as a result of their schooling (Hudson, 1851). Child literacy figures are not available. The large amount of reading material mentioned by Layton must be contrasted with the great lack of suitable materials of any type from which the young pupil could learn reading (Altick, 1957). It was not until late in the 19th century that comments such as the following from Matthew Arnold, in his school-inspector's report for 1860, began to be heeded by educational authorities.

Dry scientific disquisitions and literary compositions of an inferior order, are indeed the worst possible instruments for teaching children to read well...I have seen school-books belonging to the cheapest, and therefore the most popular series in use in our primary schools, in which far more than half of the poetical extracts were the composition of either the anonymous compilers themselves, or of American writers of the second and third order...(Quality literature) would be far better adapted than a treatise on the atmosphere, the steam-engine, or the pump, to attain the proper end of a reading-book, that of teaching scholars to read well... (Arnold, in Altick, op. cit.)

This passage indicates Arnold's belief that various works on secular topics, such as the atmosphere and steam-engines, were being used to teach reading rather than science. There is some evidence (Layton, op.cit.; Altick, op. cit.; Webb, 1955) that before 1840, twenty years before Arnold's report, the Bible would have been the sole book of instruction.

The books made available to readers in schools during this period had several distinguishing characteristics. Firstly, they were often either Catechetical (written in a question/answer form) or Conversational (written in story form, often centered around a family). Secondly, they were often published by organizations with religious affiliations; i.e., The Society for Promoting Christian Knowledge (SPCK). Thirdly, they appear to be intended chiefly as primary school readers and spellers, adopting secular and scientific themes, but chiefly designed for other educational purposes than the teaching of science. One of the best known of these early readers was the series written by Maria Edgeworth. One title in this series is Harry and Lucy concluded; being the Last Part of Early Lessons, 1825.

" 'Mamma, do you recollect, two years ago, when my father was explaining to us the barometer and thermometer, and when he showed us several little experiments?' said Lucy, and she sighed."

Later in the same chapter is this passage:

"But all will agree with your nameless gentleman, that when women pretend to understand what they do not, whether about science or anything else, they are absurd and ridiculous. And if they talk even of what they understand, merely to display their knowledge, they must be troublesome and disagreeable." (Edgeworth, 1825)

This passage is made especially revealing when it is recalled that both Maria and Richard Edgeworth were associated with the Radical Education movement in England, and with the science-orientated Lunar Society, which was founded in about 1766 (Simon, 1969). Secular reading books of this period were thus not written in response to any particular view of science education, or to meet the needs of science teachers. Instead

they were a response to the need to compensate for a lack of formal education in any widespread sense. Their purposes were to meet the needs of an autodidactic population of few readers. Even before 1840 those needs were varied. Some early textbooks were nothing but thinly veiled religious and moral exhortations (e.g., the Rev. R. Newton's Nature's Mighty Wonders); some were written with the need for specialised information in mind (eg., H. Reid's Elements of Astronomy, 1842; or British Fish and Fisheries, 1850); and some were in response to a felt need for popular works on natural history (e.g., J. Wesley's Compendium of Natural History, 1836). None were written to help a student pass an examination, or begin a course of study in a particular science.

What these texts all took for granted was that it was possible to learn science from reading. They are clearly written with the belief that there would not be a teacher present to guide or interpret the prose--the text itself must do the teaching.

"Much that would be tiresome and insufferable to young people, if offered by preceptors in a didactic tone, will be eagerly accepted when suggested in conversation, especially in conversations between themselves: in these there is always a certain proportion of nonsense; an alloy, which is necessary to make sense work well." (Edgeworth, op. cit.)

Maria Edgeworth was clearly convinced that children could actually learn better by reading her conversations than by formal teaching. The purpose of her book, and many others of the kind, was pedagogical, aimed at an autodidactic population of readers.

Only a handful of the early textbook writers reveal their purposes in the form of an Introduction or Preface; indeed, many

of the texts were entirely without such features. But from the ones that are available, and from an examination of in-text remarks, it is clear that many authors shared the conviction that the facts of science (Natural Philosophy) and natural history were of interest to children, and they were attempting to present those facts in an interesting and appropriate way. Some of the titles of books from this period are indicative of the range of purposes of these writers:

Scientific Dialogues intended for the Instruction and Entertainment of Young People: in which the First Principles of Natural and Experimental Philosophy are Fully Explained. (Joyce, 1821)

A Compendium of Natural Philosophy, being a Survey of the Wisdom of God in the Creation. (Wesley, 1836)

Chemistry of Science and Art, an Elementary Treatise on Chemistry, adapted for Self-instruction, Use in Schools, and Reading along with a Course of Lectures. (Reid, 1840)

These authors were concerned to get their facts right as well, and frequently mentioned in their prefaces that the work had been "...revised, corrected and adapted to the present state of science" or that "...to secure the strictest accuracy..the most approved modern authors have been consulted..." Some authors showed an interest in the processes now associated with the scientific method, "...to exercise the powers of attention, observation, reasoning, and invention..." (Edgeworth, op. cit.). But a discussion of the relationship between reading about these processes and learning them was not attempted. The reality of the schooling situation must have led many authors to the obvious conclusion that there were no other ways of acquiring this understanding at the time than by self-teaching.

A further point concerning reading can be made here. Pugh (1975) has traced the development of silent reading in a general

way since Classical times, and claims that reading aloud was the normal mode until the 19th century.

"Examination of factors related to the historical development of silent reading reveals that it became the usual and optimum mode of reading for most adult reading tasks mainly because the tasks themselves changed in character." (Pugh, 1975)

The tasks that Pugh goes on to identify involve the reading of prose to gain information, whether from the newspaper or books for self-improvement.

"Towards the end of the century there was still considerable argument over whether books should be used for information or treated respectfully...However, whatever its virtues, the old shared literacy was gone, and was replaced by the printed mass media and by books and periodicals for a specialized readership."  
(Ibid)

It should be noted that a great deal of autodidactic education for adults in science and other secular subjects was taking place in the various Mechanics Institutes and Literary and Philosophical Societies which appeared in Great Britain after about 1780 (Simon, op. cit.; Layton, op. cit.). The impact of these private societies was very important for the increasing demands to make science an important part of the school curriculum, and also for supplying a population of interested readers with information books of all types.

At the end of this period, vocal support was beginning to be heard for a change in the curriculum to include more secular material. 'Where, asks Frederick Hill, can the middle-class parent find for his child "the inducement, or even the opportunity, for the pursuit of mechanics, architecture, navigation, sculpture, chemistry, mineralogy, or that one among a dozen other branches of knowledge for which he may have

a special aptitude?' " (Hill, in Simon, op. cit.). The changes called for secular material to be made available to the majority of students at school, though the reference to 'middle-class' in the passage above is a reminder that there were some institutions where science was being taught, which were not open to all learners.

## 2. 1840 -- 1900

This was an extraordinarily interesting time for the development of science education and the science textbook. The year 1840 marked the establishment of the Committee of Council on Education, evidence of growing political concern over the state of schooling in Great Britain. For science education in particular, it saw the beginnings of the battle for the inclusion of science in schools, a battle waged against the dominance of Classical studies by such men as John Henslow, Henry Moseley, and Richard Dawes (Layton, op. cit.). It also saw the debate over what forms science education should take. Basically the opinions were divided between two alternatives. There were those who saw the chief value of science in its method. For them, the emphasis in science education was to be placed on 'doing' and 'experimenting'. One typical example of this view was the enthusiasm for object lessons and heurism. Because the advocates of this conception of science education de-emphasized reading, they were not keen either to publish or use textbooks.

"The teaching of the elements of experimental science must therefore accompany the teaching of reading. And great care must be taken that the palate for experimenting, for results, is not spoilt by reading. The use of textbooks must be

most carefully avoided at this time." (Armstrong, 1903)

But some proponents of the scientific method did realize the advantages of textbooks in classrooms as aids to mass education. Some even wrote them themselves: T.H. Huxley's Physiography (1891) is an example, and the whole Macmillan's Science Primers Series was in this heuristic tradition. The famous botanist J.D. Hooker expressed his views on the study of botany in the Preface to his Science Primer.

The study of botany is best commenced with the careful observation of the different parts of living plants, their positions and arrangements in reference to one another, the order in which they make their appearance, and their uses to the plant itself. It is hence often called a science of observation, in contrast to chemistry and other subjects of which the study must necessarily commence with experiment. (Hooker, 1876)

Hooker published his Botany textbook in 1876 as one of the Macmillan Primers. It went through 21 reprints and three editions up to 1920. In all fairness to Hooker, he did not intend his textbook to be the heart of a botany course. His preface lays emphasis on the actual collection and observation of living specimens.

In using this Primer the plants indicated are, whenever possible, to be put into each pupil's hand...Each pupil should have a pocket lens magnifying three or four times, a sharp penknife, and a pair of forceps; and he should be taught to preserve between sheets of paper the specimens he has examined, with a descriptive ticket attached... (Ibid)

Botany, claimed Hooker, is a different kind of activity than other school subjects; it is meant to be learned by doing (observing and experimenting) rather than reading. His textbook was designed to guide the reader through the processes of observing and experimenting, as well as adding information about



structures and process observed in the plant. It also provided definitions, descriptions of plant features, explanations of phenomena, and schemes of classification. It is entirely possible that Hooker's textbook was so popular because it contained all these adjuncts which are easily examinable. Hooker himself attempted to influence the course of science education through the examination system itself. (Layton, op. cit.) He was perhaps concerned to provide the necessary background knowledge essential for making sense of the observations central to a botany course. It is certainly true that he was speaking as a botanist about reading, unaware or unconvinced about the realities of classroom discussion. His text, and the other equally popular Macmillan's Primers, are characteristic of the more moderate view of the proponents of science education as a method. It is important to point out that there was also a debate among scientist/educators such as Hooker and Huxley over the differences between the sciences. The distinction was drawn between experimental sciences such as chemistry, and observational sciences such as botany or zoology. If this distinction could be maintained, the consequences for the ways in which the sciences are taught would be considerable. Both Hooker and Huxley wished to deny this distinction

(But) botany has also to be pursued as an experimental science; only the experiments by which the growth of plants, their modes of living and multiplying, and their relations to the soil and air are investigated, cannot be intelligently conducted until much has been learned by observation alone. (Hooker, op. cit.)

This denial was partly based on the belief in the doctrine of 'transfer training'; the skills of observing, comparing, classifying, and so forth learned in biology could be applied to

any other learning situation. It was therefore an important educational argument to be able to claim for the life sciences an assured place as sciences of equal rigour and value to physics and chemistry. The advocates of this view were eager to see science education in England take the direction of 'natural history' courses. (Jenkins, 1979).

This view of science as a method, and of the value in science education of using that method to teach the various sciences was, however, only one alternative, and historically it was short lived. Its successful rival was the view of science education as the transmission of a body of knowledge to be mastered by any means available. Representative of this view, which was associated with the movement for teaching 'the science of common things' (forerunner to General Science) were Dawes and Moseley (cf. Dawes, 1853; Moseley is discussed in Layton, op. cit.). These 'science as a discipline' advocates were quite happy to use textbooks, and they began to have a wealth of good books on which to draw: Johnson's Catechism of Agricultural Chemistry (1844), Wilson's Chemistry, and Oliver's Lessons in Elementary Botany are examples of texts which enjoyed extensive publishing lifetimes. For Moseley, the way in which knowledge was transmitted was not as important as the knowledge itself; consequently, little attention was paid to the debates about the learning of science by reading. He did, however, support the call for increased availability of texts of quality (Committee of Council on Education, 1845). Some textbook authors of the time, echoing Maria Edgeworth and perhaps reacting against Hooker and Huxley, claimed that reading is the best way to learn.

This book is compiled in such a way that it may be read again and again, but not learnt by heart. Reading aloud is the most beneficial of all exercises entered into at school for the purposes of learning. By reading in this way the scholar makes acquaintance with words which do not form part of his daily vocabulary, learns to express his ideas by imitating what he reads, and, what is of still greater significance, acquires much varied information which he would be unable to obtain in any other way. (Bert, 1899)

Paul Bert's First Year of Scientific Knowledge, from which the preceding was taken, was an enormously popular textbook, reaching at least 18 editions. Originally written in French, it was translated into English by the author's wife. Advertisements for the textbook claimed that there was a copy in every village school in France, and a copy has come to light from a small country school in Tasmania, marked with the inscription 'Inspector of School's copy'. Thus there was a real debate during this period concerning the place of reading as beneficial or hurtful to learning. Bert's opinion represented one extreme. Another quotation from Armstrong can be used to represent the other.

Don't look at a textbook; avoid most of them as you would poison. Their methods are as a rule detestable and destructive of all honest efforts toward development of powers of self-helpfulness; the worst offenders being such as are written by those who have 'felt a want' in connection with some particular examination. (Armstrong, op. cit.)

This is a forceful rejection of the role of reading, picturing books themselves as inappropriate to the purposes of science education. But the real nature of the condemnation is seen to be directed at poorly written books. Indeed, Armstrong himself called on writers of talent to implement a "new literature."

Books are wanted, written in a bright, attractive and simple style, full of accurate

information...Unfortunately those who attempt to write readable books are too frequently not those who are possessed of sound knowledge: it is time that it were realized by those who could write well and accurately that there is a duty incumbent upon them... (Ibid)

During this period a greater number of textbooks began to appear, specifically designed for school use, though it is unclear whether they were in the "bright, attractive and simple style" desired by Armstrong. The large publishing houses--Macmillans, Longmans, George Routledge, Dent--began to produce a wide range of textbooks for both elementary and secondary science students. The textbook history of these firms is yet to be written, but an examination of the numbers of textbooks advertised on the flyleaves and inside covers of published texts shows an increasing number and range being offered to the public. To give two examples; in the back of their 1898 edition of Watt's Geology for Beginners, Macmillan's lists eighty-six textbooks published in their Science Class Books series adapted to the South Kensington Syllabus, indicating that they were intended for use in schools. In 1900, Blackie and Son's "Brief List of Educational Works" included fifty-six titles for school science alone. In both cases these textbooks were available within twenty years of the advent of compulsory secondary education. A simple count of the number of advertised texts available for school use in science by 1900, taken from the textbook collection used in this thesis, reveals over 350 separate titles for use in Commonwealth countries. It must be kept in mind, however, that not all of these texts achieved popularity among teachers. Consequent upon this increased availability of textbooks are several points relevant

to science education at the time. Firstly, there was a decline in the religious content of the textbooks as the smaller, denominational publishers found themselves squeezed out of the market. They suffered as well from the new emphasis on secular content in the emerging school science curricula. Secondly, there was a demise in the autodidactic style of textbook. Trained teachers, examination demands and science educators all combined to remove the emphasis from the teaching voice of the text.

Comenius (1592-1670) saw the text as a dumb teacher. Like the teacher, its task is to impart knowledge (however defined) as efficiently as possible. It is useful to look at the text with the expectation that it might possess some of the skills and characteristics of the teacher. In practice, the description 'deaf' teacher is more accurate since, in a sense, the text speaks through the written word but is unaware of the success of its exposition. (Newton, 1983)

And thirdly, the large publishers were able to encourage notable scientists to write popular, elementary textbooks. T.H. Huxley, J.D. Hooker, W.A. Tilden, Balfour-Stewart, M. Faraday, S. Thompson (all members of the Royal Society and eminent in their own fields) and many others felt an obligation to produce distillations of the work in their area for students. Many also served as examiners for the Department of Science and Art (DSA).

Until the Elementary Education Act of 1870 most science teaching took place under the auspices of the D.S.A. Under the rigorous financial control of their examination results, such classes...tended to be non-practical, textbook-orientated and imbued with rote learning. Both Frankland and Huxley tried to stimulate practical science teaching by holding summer schools for science teachers during the 1870's, but the practical instruction they encouraged, and the practical textbooks which followed the wake, were of a manipulative and demonstrative

character. (Brock, 1973)

Some of these writer-scientists were also members of the "X-Club", the influential group of ten members of the Royal Society who exercised such a strong influence on the scientific activity of England in the latter half of the 19th century. (Jensen, 1970). Such was their reputation as scientists that they were able to have considerable effect on the character of science education as well.

It was also during this period that educational psychologists began to influence teaching and to develop theories of learning. Such studies entered the debate about science education in the form of Faculty Psychology versus Herbartianism and experimentalist psychology. (Ross, 1933). This is mainly of importance here in the way such arguments influenced opinion on the relative merits of 'reading' versus 'doing' for learning. During these early stages of educational psychology, the rival views were divided over two major concerns. Firstly, what are the pre-conditions for learning (i.e., is the child's mind a tabula rasa, or does it contain pre-set 'ideas' or 'faculties?'); and secondly, what are the possibilities of learning (i.e., what is the most we can hope for through education). Debate on these issues obscured questions on the methodologies of instruction. Hence educators such as H.E. Armstrong could use Faculty Psychology as a justification for heurism when in fact he had no evidence (other than his own experience) about how children learn from heuristic methods, or whether in fact they were better than reading. (Brock, op. cit.). The argument between science educators was often characterised by considerations apart from psychology because

often the real crux of the disagreement was about the value of science education to the individual and society rather than how science is best learned. Consequently, advocates of educational change often looked for a psychological theory that would justify pre-conceived ideas of what should be learned--method or information--and why.

Finally, this period also saw considerable increases in educational opportunities for large masses of students, and an increased number of schools, students and teachers through the introduction of compulsory education. The modern phenomena of large mixed-ability classes, compulsory subjects and organized timetables began to appear. The demands on teachers changed dramatically. This formalization of classroom science education saw a response by textbook writers. The Preface to A Class Book of Physics by Sir Richard Gregory and H.E. Hadley defends the textbook's place in such difficult circumstances.

In most cases the time available for a science course will not permit the go-as-you-please pace postulated by some educational reformers as essential to good work...How few pupils there are who possess the motive and purpose required for successful scientific study without assistance from the textbook is known only to the practical teacher. (Gregory and Hadley, 1941)

The reality of the school situation, then, as it did with the autodidactic style of textbooks, exerted considerable influence.

In summary, then, this period can be characterized by four major debates relevant to this thesis. Firstly, the debate over the place of science in the curriculum--it had to be justified by arguments claiming its usefulness and distinctiveness. Secondly, the debate over the nature of science education

itself--was the emphasis to be placed on method or content. Thirdly, the debate over the value of reading in science education--this was answered mainly by beliefs concerning the second debate above. And fourthly, the debate over the process of learning begun by educational psychology.

The school textbooks of the period tend to have scientists rather than school teachers or clergymen or writers of children's literature as their authors. Responses to all four of the debates listed above shaped the purposes of these scientist/authors.

### 3. 1900 -- 1960

Though the debates of the late 19th century continued into the early years of this period, the establishment of school science on a wider scale than before tended to ensure that, in general, this period would mainly be debating the form of science education rather than its right to exist on the school timetable. Modern schooling was in place and under way. Only a few main characteristics of this period, with reference to texts and science education, will be mentioned.

Firstly, there was a shift from scientist as authors of textbook to teachers and/or tertiary-level lecturers as authors.

At the beginning of the period (1870), almost 70% of (textbook) writers were professional physical scientists, that is, researchers who lectured in universities and equivalent institutions. As this percentage declined, that of school teachers rose. Furthermore, the proportion of teachers who taught in the private sector was unexpectedly high. (Newton, op. cit.)

As the number and level of training of science teachers



increased ( a result of the teacher-training Regulations introduced by the Board of Education in Great Britain in 1904), they legitimately claimed that textbooks should reflect what they thought students should know, and how they best learn it. Education and science grew apart, losing that interface previously provided by scientists keen to influence education. The effects of this on textbooks have been profound. Lacking the scientist's depth of understanding and sense of personal involvement with the discovery of new knowledge, the teacher/authors simply lifted from the scientist's textbooks whole sections of information, often leaving behind the carefully constructed arguments and doubts concerning such information, and merely re-arranged or shifted them about to make them more 'presentable'. A large number of textbooks of this period are simply re-written, cut-and-paste parodies of seminal texts, with questions added at the end of the chapters, an increased number of illustrations, a set of past examination questions in an appendix, and a few recipe-book experiments (Bassey, 1960). Typical of these texts are: Holmyard's A Higher School Inorganic Chemistry (1939); Hopkins et. al.'s Chemistry and You (1944); Smith and Smith's Intermediate Physics (1949); and Stump and Rowlands' Leaving Physics (1950). This pattern was apparently followed in America as well. Joseph Schwab comments on it in the first chapter of his Biology Teachers' Handbook, written for the Biological Sciences Curriculum Study. (Schwab, 1963). An even more political view of the process is given by Gerald Macdonald, who claims that the presentation of knowledge to the young is not under the control of either scientists or teachers, but editors. (Macdonald, 1976).

What is clear is that the change from scientist/authors to teacher/authors reflected a profound change in the purposes for which texts were written, and a consequent change in their language.

The textbooks of this period began to show a remarkable similarity in approach and style. Highly successful textbooks from this time would include the following, all of which are included in the textbook collection attached as Appendix I.

Gregory and Hadley's A Class Book of Physics, first edition 1909, and reprinted 18 times up to 1941.

W. Watson's A Text-Book of Physics, second edition 1900, and going through four editions.

C.J. Smith's Intermediate Physics, first edition 1932, reprinted 12 times up to 1944.

Parrish's Chemistry for Schools of Science, first edition 1899, reprinted 20 times up to 1925.

Mee's A Modern Chemistry for Schools, first edition 1938, last reprinted 1950.

Cavell's An Introduction to Chemistry, first edition 1940, reprinted 3 times and going through 3 editions to 1953.

The measure of their success is, of course, their long publishing lifetimes, but also their inclusion as required reading by examining authorities in some Australian states. One of the factors linking them together is their uniform commitment to existing educational practices and institutions.

This book has been written to provide a course of elementary physics to the standard required for the Intermediate Examination...We wish to thank the Public Examinations Board of the University of Adelaide for permission to take many of these questions from past Intermediate Examination papers. (Smith and Smith, op. cit.)

The inclusion of this (extra) material has enabled a complete course of Inorganic Chemistry to be provided for several examinations which are intermediate in standard between the advanced and ordinary levels of the General Certificate.

(Cavell, op. cit.)

...the allotment of space to individual topics is roughly in proportion to the frequency with which these topics appear in the examination papers. (Holmyard, 1939)

The purpose of the textbook in this period was to present a course of study to match the place of science as an examinable school subject (Jenkins, op. cit.). It was perhaps here that the purposes of the teacher/author as opposed to the scientist/author were most clearly seen.

Another area of similarity between the texts was the ordering of content, though this is apparently a consistency that can be traced back to the middle of the 19th century, and only began to show changes after the early 1960's. Newton (op. cit.) lists the content and their preferred ordering in physics texts over this time as: (1) Mechanics and properties of matter; (2) Heat; (3) Light; (4) Sound; and (5) Magnetism electricity and modern physics.

In this period, the role of the laboratory, as presented in the textbooks at any rate, is secondary. Experiments are designed to illustrate known laws (e.g., "Expt. 1. To verify the law of constant composition." Cavell, op. cit.), or to determine the value of physical constants (e.g., coefficients of thermal expansion, refractive indices, atomic weights and specific densities). Many texts early in this period designed the experiments so that they could be done as demonstrations by the teacher. The textbook authors placed little emphasis on the ways by which scientific understanding is obtained, stressing instead its completed results.

Finally, for the lower levels of secondary science the

curriculum emphasised General Science. The original claims for the methodologies of the separate sciences--that they were distinguishable as Observational and Experimental--were forgotten as the teachers and administrators now in control of science education came to see science as a single discipline which had generated an enormous number of useful facts. Earlier educational claims for important distinctions between the Natural History sciences and the Physical Sciences were minimized as demand grew for the whole range of Science to be given to all children. (cf. the discussion of the General Science movement and 'Science for All' in Jenkins, op. cit.). The effect on the textbook was to first of all create the demand for a new type of author, the generalist, whose task was to paint broad outlines. This of course widened the separation of scientist and textbook author even further. The second effect was a consequence of the belief that all students needed an introduction to Science. What were they to study, and what were they to achieve? What is common between botany, physics and geology at the elementary level? In attempting to answer these questions, the recognition of a whole new set of purposes for science education emerged, again with significant effects on textbook language. Also, textbook writers were forced to make selections from the ever-increasing content of the various sciences. Consequently, there was less room in the text for examining the processes of science. In addition, if all pupils are to do science, then textbooks must be written for a whole range of reading abilities, and in that sense, textbook language would be constrained by classroom realities.

#### 4. 1960 -- 1970

This period is characterised by the large scale national curriculum projects--American, British and Australian--among the best known of which are, perhaps, PSSC, Chemstudy, BSCS, Nuffield, ISCS, and JSSP. It is beyond the purposes of this chapter to attempt to detail their origins, philosophies and influences; yet, because their influence was, and is, widespread, some outline of their notions of science education is necessary here. A list of the major factors influencing their development would contain at least the following.

1. The increasingly professional development of teachers.
2. The increased numbers of well-equipped laboratories and teaching resources.
3. The increased influence of professional groups such as the Science Masters' Association in England (Ingle and Jennings, 1981)
4. The manpower concerns for the increased number and quality of scientists and engineers, especially after the launching of the Russian Sputnik in 1957.
5. Large scale financial support for curriculum change, either from private foundations or government.

The significant changes these national curriculum projects hoped to bring about included major restructuring of the content in order to emphasise structures of knowledge rather than simple information (e.g., Bruner, 1960); an increased emphasis on the laboratory as a basis for thinking and learning about science; an emphasis on skills (e.g., observing, recording, drawing logical conclusions) rather than on information alone; and the standardisation of the curriculum to make it accessible to

everyone in school. This last claim perhaps explains the willingness of Australian schools, for example, to use American or British materials in science, because the structures, principles and skills of science (as well as its results) were felt to be universal.

Their materials, including textbooks, were placed in front of enormous numbers of students.

...few people are aware of the important role some 250 million textbooks play in the education of 50,000,000 elementary and high-school students. For instance, during his school career your child will either commit to memory or attempt to absorb at least 32,000 textbook pages, and this does not include supplementary readings in social sciences, literature, or science. In the first grade he will complete at least four textbooks, and by the time he finishes his last year in high school, he will intensely study another sixty....During the school day itself, 75 percent of your child's classroom time and at night 90 percent of the time he spends on homework will be centered around textbooks...Textbooks..are still the single most important teaching tool. (Black, 1967)

In America, where the emphasis on the authority and use of textbooks can be much higher than in England or Australia (Fensham, 1980; Olson, 1980), the curriculum developers were often explicit about the role of the textbook.

This textbook is the heart of the PSSC course, in which physics is presented not as a mere body of facts but basically as a continuing process by which men seek to understand the nature of the physical world. (From the Preface to the PSSC textbook, 1960)

Once again, however, the link between reading a textbook and understanding the "continuing process" that is physics is not made clear. The original designers of Nuffield physics and chemistry, on the other hand, originally opted for no set textbook at all (with the exception of O-level biology) but instead produced a wide range of materials of various kinds.

A comprehensive package of material was made available in each project comprising guides for teachers, various forms of written material for pupils, as well as such supplementary material as film-loops and wall charts....(some) set standards of design and imaginative art production that had rarely, if ever, been achieved before in educational books in Britain. (Waring, 1979)

The Nuffield Chemistry Students' Book 1 makes only a brief reference to the role of reading in learning chemistry.

Not a textbook, not a background book, not a book of data--this book has been deliberately left in many ways incomplete. Like an outline map of an unexplored island, it will provide you with a series of starting points from which to explore the interior, to build up your own view of chemistry at this level. To do so, you do not merely need to read the book; you need to do the course...It is impossible to convey in a short section the great variety of interest and activity there is in modern chemistry. This you can find out only by doing chemistry, not reading about it. (Nuffield, 1970)

Because the Nuffield texts were written by different authors, and presented material in a variety of ways, there is a wider range of prose styles contained in any one text than in other representative textbooks of the same time--PSSC, for example. From the language point of view, textbooks of this period were influenced by the following considerations. Firstly, the direct influence of various psychological models of learning. Bruner, Ausubel and Gagne were directly involved in textbook design--Bruner with PSSC in 1960, Gagne with Science--A Process Approach in the early 1960's, and Ausubel through his critical role in the National Science Teachers' Association. Schwab was involved in BSCS in 1963, supervising the production of the highly successful textbooks of that course. Secondly, the textbooks were often integrated with laboratory work, work-sheets, outside reading and in-text questions. Because of

its integral role in a complete curriculum package, the text's language could begin to refer outside itself to experiences the reader could or should have had in the laboratory, or at home, or indirectly through reading historical extracts and primary sources. Thirdly, multiple authorship and editorship became common, removing the possibility of a single, personal style and language. The "I" of the scientist or teacher was replaced with the "we" of the curriculum team.

As mentioned, the role of the laboratory was strengthened during this period, with the larger curriculum designers producing a complete package of materials, equipment and practical guides. The textbooks could then reflect this experimental approach. Specifically, the primary purpose of science education was seen as the uncovering of the investigative nature of science as a human activity--the "continuing process" of the PSSC textbook. If in fact this was so, then the language of the text would be constrained by this purpose. The authors would place their emphasis on methodology, on the detailing of experimental design, standards, technological limitations, measurement and its errors, and the choice of apparatus and techniques. Yet even casual reading of these textbooks suggests that their real concern was with science as a body of knowledge. It is notable that laboratory work was often detailed in a separate lab manual containing things to do rather than things to think about.

It seems that many school chemistry texts, like the relevant examinations, have largely ignored the social dimensions of chemistry, despite detailed accounts of the processes underlying the chemical industry, and have virtually excluded all reference to the imaginative, personal and craft elements of scientific creativity. The emphasis has been upon chemistry as a body of knowledge, established by pure, self-justifying inquiry...



(Jenkins, op. cit.)

And finally, there was an enormous increase in the numbers of textbooks produced during the decade. The market for textbooks increased, of course, with the great increase of students at the upper end of secondary schools, and there was a need to produce textbooks that supported curriculum changes. Kellaway has provided some astonishing figures; in the area of school mathematics and science, he shows the numbers of books published annually in Britain alone, in the late 1960's, to be some 33,000. Physics and chemistry accounted for around 800 new titles a year. (Kellaway, 1970). This enormous output was not, as Kellaway makes clear, the result of wide experimentation with style, format and purpose. On the contrary, it hindered critical appraisal and overwhelmed any alternative writing for school science. Indeed, texts which failed to match traditional approaches to school science tended to be "swept from the bookshelves." (Bassey, op. cit.).

##### 5. 1970 -- PRESENT

Contemporary textbooks are harder to characterise because of their numbers and ever-increasing diversity. It is clearly difficult, from the research literature, to say what the distinguishing features of science education are today. For the primary school and the lower levels of high school, one common theme is enquiry learning--science as the personal act of discovery, with the British Schools Council 5/13 Science Project as an example. (Schwab, 1963; Rowe, 1972; Waring, op. cit.)

General science is still actively taught, with the debate

centering on questions of integrated science, levels of achievement, and schools' based activities in science--all in opposition to persisting arguments for a common core curriculum. (White, 1973; Kelly, 1980). These textbooks, in contrast to those of earlier periods, take for granted that the teacher will make judgements on how best to present and balance the materials from the textbook and the laboratory (e.g., "Only the teacher can decide which parts are relevant to the needs of a particular class." Jardine, 1969; and "It is assumed that teachers will respond to the excess of material by selecting from it to suit the level of ability, interests and academic requirements of those in their charge." Criddle, Izett and Ryan, 1975).

At the senior level of high school, physics and chemistry curricula are still operating with the notion of science as a body of knowledge, and examinations still strongly influence science curricula, especially for the more able students taking certificate courses. This is also reflected in the fact that national curricula are still being written, though the large curriculum packages have frequently been replaced with multiple-author textbooks (e.g., Mayfield, Parham and Weber's Fundamentals of Senior Physics; the varied Web of Life texts; or the Australian Academy of Science textbooks in chemistry and geology) which are written for a national, if not international audience.

The Foreword to the Australian Academy of Science's Elements of Chemistry (1983) reflects an awareness common to this period of the need for a broad approach to the role of the textbook.

(1) There is to be a "large laboratory component...closely integrated with the text material."

(2) But of course chemistry is "...very much a part of our lives, and not simply what is done in the school laboratory."

(3) The intent is also to "...familiarize students with common chemicals and their reactions, and take them from the concrete experience to the abstract idea."

(4) As well, the "...influence of chemical industry and technology in our daily lives.." is included as a purpose.

All of these purposes are valuable ones, and the text does argue that the over-riding emphasis is to be placed on chemistry as an experimental science, and that if it is approached in that way all of the purposes can be met. (Bucat et al., 1983). But it is not clear what the function of the textbook and reading are in a course which emphasises practical work. Nor does the text make clear in what fashion a discussion of the role of scientific thinking can take place alongside a treatment of the science/technology interface in a meaningful way for non-science students in a book about senior-level chemistry for examination candidates. This widened basis for science education has recently been emphasised by the Science For All movement, sponsored by UNESCO. At a conference in Bangkok in September, 1983, a set of 8 criteria for content selection were considered as important.

1. It should be perceived by the learners as immediately useful in their real world or as having social worth by its economic or community value.

2. It should improve the living standards of the learners, or increase their productivity and contribute to the well-being of the community and national development goals.

3. It should be based on the daily life experiences of the learners, relate to the resources of their real world and have obvious applications in their work, leisure or homes.

4. It should include natural phenomena which will

- create wonder and excitement in the learners.
- 5. It should enable the learners to acquire and master useful and employable skills.
- 6. It must consider cultural and social traditions and seek to complement these.
- 7. It should enable the learner to recognise and appreciate the importance of science and technology in national development.
- 8. It should enable the learners to utilize wisely their natural resources and to live harmoniously with nature and society. (Fish, 1984).

Such a comprehensive yet pointed set of criteria, if adopted, would clearly have considerable influence on the language and style available to textbook writers.

Uncertainty about the role of science and science education in society has recently begun to be expressed in the research literature. (Mathews, 1975; Margetson, 1982; Smolicz, 1974; Young, 1976; and Barnes and Edge, 1982). Typical of the sorts of questions being raised by this concern are these of Margetson.

...if the nature of science is as unclear as the arguments suggest (here he mentions Kuhn, 1970, Popper, 1968; Lakatos, 1970; and Feyerabend, 1975), then are there any grounds for the belief that there is such a subject as science at all? Are there any satisfactory criteria of demarcation by reference to which science can be distinguished from non-science? (Margetson, op. cit.)

Modern writers have not responded to these concerns within their textbook. Their main interest is with the presentation of a body of knowledge which is obtained by methods which are taken as unique and unproblematical (Bassey, 1961). The problem of initiating the learner into this body of knowledge is of much greater importance. As a result, most writers present, not a well-argued coherent view of science, but a series of activities for teachers to use as they see fit. It may be that these are no longer really textbooks at all, but 'study guides' or

'resource material'. This is not to say that such texts are haphazard. Most senior science textbooks still arrange their material in a supposedly logical order, and attempt some degree of comprehensiveness. What is missing is the thread of justification and purpose that ran all through earlier texts from the 19th century autodidactic religious readers to the PSSC and Nuffield projects. For 120 years, science writers and educators have been confidently saying that they know the purposes of science education in schools and in the lives of human beings. By contrast, the writers of modern textbooks have become responsive to a wide range of demands (e.g., the UNESCO criteria), some of which may be in conflict, making it unlikely that the text's prose can display a single clear purpose or coherent set of purposes. The needs of those going on to science as a career, and those terminating formal science education; the place of science in society, shown to be in question; the relations between science and technology, also unclear; the type of thinking and doing which is distinctly scientific; and the logical structure, ideas, principles and patterns of the particular science taught--all these place enormous demands on the textbook.

One important change that has taken place in textbooks during this period is in the amount of textbook space given to actual prose. The modern science textbook has omitted the text as much as possible, replacing it with diagrams, photographs, equations, charts, worked numerical examples and short sentence summaries. Undoubtedly, early textbook authors used a lot of prose describing what a modern photograph makes immediately clear. But early textbooks were not, on the average, any longer than

modern texts. Everett's Text-Book of Physics (1901) has 322 pages, was intended for use over two years, and had graphics on only 192 pages. Mayfield et al's Fundamentals of Senior Physics 1 (1973) has fewer pages (205), but is intended to be used in one year, and has at least one graphic on every page. Similarly, Roscoe's Chemistry (1875) had only 100 pages and had a small woodcut on almost every page; the Australian Academy of Science's text, Elements of Chemistry: Volume 1 (1983) has 445 pages, the majority of which are dominated by graphics of various types. Such a high incidence of graphics raises a whole series of new questions about reading a textbook. For example, how do children extract meaning from graphics; how important are the prose passage links between graphics for a coherent, sequenced understanding; how well do readers cope with the demands of shifting from written to graphic material and back again; and do graphics, in fact, aid the learning of concepts and abstractions, or do they simply guarantee that something different will be learned through the new medium? Without a strong, consistent textual component, the modern textbook may finally be moving away from its traditional role of supporting learning through reading and through telling the story of science.

### SUMMARY

This chapter has briefly outlined the development of the physical science textbook alongside major movements in science education since about 1800. The starting point was the suggestion that to better understand the language of textbooks, it is important to know their purposes. These purposes are

found, in some measure, in the authors' responses to prevailing notions of science, and the purposes and value of science education. In turn, those notions are found in the writings of scientists, philosophers and educators, and in the realities of the classroom.

The early 19th century writers adapted their autodidactic texts to school purposes in response to the growing numbers of children at school. Writers with particular views of the nature of science and science education wrote texts reflective of either science as enquiry or science as conclusions. Dissatisfaction with prevailing teaching practice and political manpower demands influenced the large national curriculum projects and their textbooks. Concern about the place of science in the life of the child and society, along with growing understanding of the processes of learning, have shaped the modern textbook and its language.

As a result, three major purposes have been identified. Firstly, that of writing for an autodidactic audience. This purpose was not specifically related to science education, but centred on religious views and/or the teaching of reading. Secondly, that of portraying to learners a particular view of science, such as a method of discovery. These were often written by scientists of considerable reputation to support their arguments for a particular type of science education. And thirdly, that of presenting to readers the results of scientific investigation, and the information necessary to succeed in examinations. These were generally written by teachers. This may reflect a perceived difference between what might be termed 'useful knowledge' and 'prerequisite knowledge', with the latter

becoming far more dominant in recent years. The next chapter links these purposes more explicitly with the textbooks written to match them.



## CHAPTER 2: HISTORY OF THE SCIENCE TEXTBOOK

INTRODUCTION

One of the central concerns of this thesis is determining the characteristics of textbook language. The development of the science textbook alongside major developments in science education was traced in the previous chapter, where it was shown that the textbooks of each of the major periods were influenced by historical factors and social trends in education generally, and science education in particular. This history was revealing of the translation of views of science and science education into sets of purposes. These purposes were identified in the writings of scientists, religious authors, educators, teachers and curriculum developers. It was also suggested that the characteristic language of the textbooks would reflect these purposes, but no attempt was made in that chapter to make this connection explicit. This chapter uses the historical framework begun in the previous chapter to examine the development of textbook language style and rhetorical character, concentrating on physical science texts

More specifically, this chapter has two important purposes within the thesis structure. Firstly, it develops a vocabulary to be used to characterise textbook language. This vocabulary is drawn from the rhetorical pattern of the textbooks, and it is then used to develop the first order classification for textbook types. Secondly, this chapter also traces the connections between the historical influences outlined in the previous

chapter and the language of the textbooks. It seems clear that today's physics and chemistry textbooks were strongly shaped during the very beginnings of school science, and many of their structural, linguistic and stylistic features have their origins in 19th century writing.

In addition, an analysis of early texts provides an opportunity for the examination of alternative approaches, not only to textbook language and style, but to science education, the role of reading, and the place of science in the life of the child.

The textbook did not, of course, suddenly appear in a fully developed form at the beginning of the 19th century. Science writing for the use of scholars can be traced to the Medieval period, and ultimately to fragments abstracted from the Greek natural philosophers. But writing which was meant for children, and which concerns itself with science, became widely available only in the 19th century. The obvious reason for this was the lack of a generally literate population of young people, and the creation of this population by the rise of popular education. Both these factors generated a demand for books with a pedagogical purpose. Such a purpose could be satisfied either by incorporating pedagogy into existing informational books, or by writing new, separate works. This new, pedagogical purpose provides justification for a working definition of a textbook: a textbook is any book written with the purpose of instructing and/or informing learners, whether autodidacts or those in schools. Such a wide definition is useful because not only does it encompass books written specifically for school purposes, but also a wide variety of works which might be termed

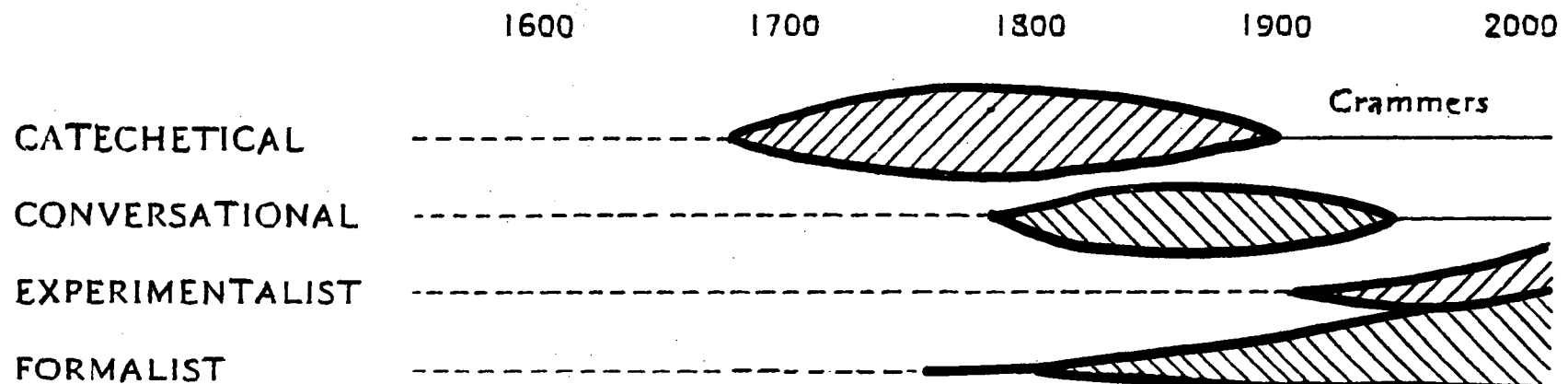
'popularizations'. The latter were used at the beginnings of science education, taken into the classroom because nothing more suitable was available. One difficulty with such a definition of 'textbook' is that it does not eliminate such works as dictionaries, encyclopedias or reference works. This problem is eliminated by referring to rhetorical arguments--the rhetoric of textbooks (their language used to persuade or impress) is distinct from that of a reference work.

Remembering that compulsory education did not begin in earnest in Commonwealth countries until the late 19th century, writers who, before then, wanted to give children access to science could not assume that they would be at school. They wrote what are termed here autodidactic works (meaning self-teaching texts) designed to provide information and/or instruction on a wide range of topics for readers outside of formal schooling. It is their works that were taken up by teachers and used in various ways.

Four main rhetorical types of textbooks have been identified, and will be referred to as CATECHETICAL, CONVERSATIONALIST, EXPERIMENTALIST and FORMALIST. The ordering from Catechetical to Formalist reflects a change over time, but it must be pointed out that the historical relationship between the four is not a linear one. Each grew out of its own set of influences; not quite independently of each other, but sufficiently distinct to make any argument for the transformation of one into the next difficult to maintain. It will be useful, however, to keep in mind the rough chronological setting of each type, as outlined below, and shown in Figure 1 (see following page).

The Catechetical texts were mainly written between the middle of

**Figure 1. The development of the four types of science text (catechetical, conversational, experimentalist and formalist) with time**



the 17th century and the end of the 19th, with the greatest numbers appearing in the early 1800's. They had all but disappeared by 1880, but the occasional text was still being written in this style as late as 1950 (e.g., Carter's Physics for Everyone, 1950). Also, the Teach Yourself Books, published by The English Universities Press, are reminders of the strong, unceasing interest in autodidactic texts (e.g., L. Wilkes' Teach Yourself Teaching, 1959). Hundreds of titles were published in this series. Of course, they are not written in the same style as the Catechetical texts, nor for readers necessarily without access to formal schooling, but their considerable publishing success is echoed by the growing number of self-teaching texts catering to specialised audiences. (Evans, 1983)

The Conversationalist texts appeared about 1750, peaked in production about 1858, and disappeared by the early 1900's. Their influence lingers on in such popularizations as Gamow's Mr. Thompson Explores the Atom (Gamow, 1951), and the now classic Flatland by A. Square (Abbott, 1952). Comic strips, too, are used to teach science, though not often at senior level. Butler and Raymond's Introduction to Physics (1974) is an exception, and some researchers have encouraged teachers to use this format in their lessons (e.g., O'Bruba and Campese, 1981). However, in spite of the growing interest in children's literature in the primary school, little increase is apparent in the amount published even for these younger readers in the area of story-book science. Examples of such literature for young readers includes Number Stories of Long Ago (Smith, 1919), The Stone That Loves Iron (Carter, 1963) and The Day of the

Diprotodon (Ruhen, 1976).

The Experimentalist texts appear about 1890, grow in numbers, and are then subsumed by the Formalist school texts, which appear at roughly the same time as the Experimentalists, but quickly came to dominate the field, a position they still hold today.

#### THE CATECHETICAL TEXTBOOKS

The Catechetical texts are in question and answer form. This suggests they may have their origins in the type of Socratic dialogue familiar in many Medieval religious debates and, for example, the dialogues of Galileo. Referring to the texts (rather than their format) as "...contributions to a literary vein of popular compilations of factual information...", David Layton claims "...they presented science in discrete, unstructured snippets designed for the amusement and edification of the curious." (Layton, 1973). They were very popular and much used in schools, whether as "reading lesson" books or specifically for science lessons. (Ibid).

The Catechetical style takes its name from the style used in writing religious catechisms. "It is...in this period (the second half of the 19th century) that the word 'textbook' was first used by analogy with the clergyman's 'text' which he set up and defended." (Newton, 1983). The word 'catechism' itself is from the Greek, meaning to "teach by word of mouth" (O.E.D.). It is therefore not surprising that this style is seen to resemble teacher/pupil verbal interaction in the classroom (i.e., Barnes, Britton and Rosen, 1971; The Bullock Report, 1975). It can be argued that this style was deliberately chosen

to match a traditional pattern of pedagogy (Newton, op. cit.; Thomsen, 1975); after all, if this was the method of instruction used by teachers, then it would seem reasonable for authors to simply write texts as though they were transcripts of classroom lessons.

The first abstract below is from Pinnock's Catechisms of the Arts and Sciences, published in stages from about 1822. Pinnock covered an encyclopedic range of topics in small pamphlets which were sometimes bound together into collected volumes. This example is from Volume 1 of such a collection which also contains sections on morality, health, logic and natural theology. The abstract shows two essential characteristics of these early catechisms; firstly, the strong religious content; and secondly, the simple reasoning from common experience without reliance on experiment.

Q. What is meant by absolute motion?

A. That which is measured with regard to an object at absolute rest, or where the space passed over is absolute space,--that which contains the whole universe, and which therefore cannot move.

Q. Cannot we measure or estimate a motion of this kind?

A. No; because we are not sure that any body is absolutely at rest. The water moves; the air moves; the earth moves, the moon and planets move; we know from the appearance and disappearance of the same spots on the disc, or face, of the sun, that the sun moves round an axis.

Q. Is not that taking rather too extended a view of the works of nature?

A. The wonders of creation are limited only by the powers of their CREATOR, and that is far beyond what our observation, or even our imagination, can survey. System may be joined to system, and constellation after constellation of systems may revolve round centres more powerful and roll in orbits more immense...for all that is there disclosed is but the altar upon which it behoves man to kneel down and adore the might and majesty of the God by whom the whole was made... (p.52)

Q. Whence do these variation and changes of motions proceed?

A. They are usually said to proceed from differences of FORCE.

Q. What do you mean by force?

A. Any phenomenon that is accompanied by change in the state of a body, whether that change from rest, or from one direction or degree of motion to another, is said to be produced by a force. We say, the force of the wind; the force of fire; the force of gunpowder; the force of a blow; and we never see anything in motion without thinking of the force that made it move.

Q. Are force and motion the same then? (Pinnock, 1828)

A second example also shows these two characteristics clearly. It comes from Dr. Brewer's Guide to Science. It provides an interesting contrast to Pinnock, and together they indicate something of the range of Catechetical types. Published in 1848, and going through at least 31 editions and 113,000 copies until 1873, Brewer's was a more substantial work of 446 pages, and contained an index and 106 unanswered questions at the back "for the ingenious reader to solve". By contrast, Pinnock's Catechisms were separate pamphlets of approximately 60 to 70 pages. Both these texts were very popular, and enjoyed long publishing lifetimes. The abstract below from Dr. Brewer comes from the 10th edition.

Q. What is the USE of SNOW?

A. To keep the earth warm, and to nourish it.

Q. Why does the snow keep the EARTH WARM?

A. Because it is a very bad conductor; in consequence of which, when the earth is covered with snow, its temperature very rarely descends below freezing point, even when the air is 15 or 20 degrees colder.

Q. Tell me the words of the PSALMIST (cxlvii.16) respecting snow; and explain what he means.

A. The psalmist says..."the Lord giveth snow like wool;" and he means not only that snow is white like wool but that it is warm like wool.

Q. Why is wool WARM?

A. Because air is entangled among the fibres of the wool; and air is a very bad conductor.

Q. Why is snow WARM?

A. Because air is entangled among the crystals of the snow; and air is a very bad conductor.



(Brewer, 1848)

It is important to remember that these catechisms were text, resource material, moral and ethical reader and dictionary all in one. It was quite clear to these writers that science had an important role to play in the moral as well as intellectual growth of the child.

The religious purposes are transparent. The world is carefully arranged in accordance with God's plan (eg., snow is designed to keep the earth warm and nourished). The emphasis on the practical uses of nature as revealed by the questions and answers hints that people are expected to use nature to advance themselves. These early catechisms contain little theory or discussion of the ways knowledge is uncovered by science. They are not speculative, in that readers are not expected to enquire into the subject any further. Their direct concern was to offer simple explanations for common phenomena, and provide definitions for scientific terms. The explanations offered, however, stopped at a purely nominalist level--they were concerned only with the immediate phenomenon. For example, the first question in Brewer's 1848 text is "What is heat?", and this is answered by "That which produces the sensation of warmth.", and the text is then immediately asking questions about its effects. Any questions concerning the meanings or purposes of the phenomena described or explained usually introduced God into the discussion. There is little doubt that a chief characteristic of these texts is to consider only what things do, or are constructed of, rather than with what they are. As the bulk of the questions ask "Why?", the view of nature that is given to the reader is strongly teleological.

Q. Is it always of the same length?

A. No, it is not; but its variations are known, and the difference between them and mean equal time, is called the equation of time.

Q. All the bodies which appear in the heavens do not belong to the solar system?

A. No. The greater number of them are the stars, or fixed stars.

Q. What is known of them?

A. Their degrees of light, and their situations with relation to the sun, and to each other.

Q. Are not their distances known?

A. No. They are too distant for being in any way the subjects of science.

Q. Are they of no use, then?

A. They are of the greatest use. The distances of the moon from stars is one of the best means of finding the longitudes of places at sea, and enabling mariners to know where they are, and thus to avoid dangers, and reach the places to which they wish to go.

Q. What is the general principle?

A. At a certain time and place the moon must appear at a certain distance from some particular star. The time and distance can be known, and from them the place can be found.

Q. Then much of human art depends upon astronomy?

A. Yes, the art of navigation, which has done more for the improvement of man than any other art, is dependent upon the principles of astronomy.

Q. What is the conjecture with regard to the fixed stars?

A. Conjectures are not science; but the conjecture

is, that each of them is a sun with a system of worlds around it; and that of these suns and systems there is no end;—that no observation could survey them all, and no arithmetic sum up their number; but that, after days, and years, and ages, had been spent in the task, that task would be no more nearly ended than the moment it was begun.

Q. What name is given to that wonderful structure?

A. It is called the universe; and the best definition of it is one of the oldest—"it has centre every where, and boundary no where."

Q. To what does that consideration lead?

A. It has been already mentioned, that the power of matter, as displayed in the vegetable and the animal tribes, have causes which do not belong to the mere matter of which they are composed; and it appears also that the diversities of those powers of matter have no end. But we find that in all their variety and number, they are adapted to their different purposes, and to each other, by laws which are so simple, so universal, and so well adapted for the support of each other, that the whole boundless extent must have been seen, in all its duration, before one of the countless millions of created things existed.

Q. Does that lead to any new branch of science?

A. Yes; it leads to

#### THE KNOWLEDGE OF GOD.

Q. Is any other name given to the knowledge of God?

A. That which is obtained from the study of the

B b

Figure 2. A page (actual size) from a characteristic Catechetical textbook:

Turner's Arts and Sciences, 1832

The view of science as a human activity that these textbooks implicitly convey is that of a rational pursuit of Natural Truth. It is also, more explicitly, a vehicle for the admiration of God. There is the by now familiar view of the world operating by virtue of the laws of motion and change implanted in it, once only, by God. Science, therefore, served a purpose greater than itself. The following selection of questions from Pinnock are typical of this use of science to lead the readers to admiration of God.

Q. In order to discover the traces of infinite wisdom and power in the works of creation, at what point should we begin?

Q. Leaving plants and animals out of consideration, can we find any evidences of Almighty power and wisdom in the earth itself?

Q. And does all that man knows or can do, result from the study of those qualities that have been implanted in substances by God? (Pinnock, op. cit.)

Part of the success of both these textbooks may be due to the instructional intentions of the authors, concerning which a few remarks are appropriate here. Their pedagogical intent is expressed in their respective prefaces: to produce works in a style which is "clear, simple, and easy, and will be found intelligible to the meanest capacity" (Pinnock); in "language so simple that a child may understand it, yet not so childish as to offend the scientific." (Brewer). Nevertheless they gained no thanks from the men of science. T.H. Huxley remarked that in works such as Brewer's "there was no means to lead the mind of a child to what might be called purely scientific considerations; the design of that education was pure information, no attention was made to use the information, that was the cardinal defect."

(Huxley, in Layton, op. cit).

For the purposes of teaching in schools, the question and answer style has a certain obvious appeal to the rote-learning school of pedagogy, and these texts may in fact be precursors to the late 19th century 'crammers'. The style is also suited to the practice of reading aloud, suggested to be the common pattern until late in the 19th century in England (Pugh, op. cit.), and even later in Australia. It must be kept in mind that these texts were not written under the impression that they would be used as school books. They were designed for the instruction of youth by writers and publishers of varying religious and political viewpoints (i.e., The Society for Promoting Christian Knowledge). Thus they did not refer to experiences in the laboratory, or suggest activities, experiments and practical work that need guidance from a teacher.

The idea that a question and answer format is appropriate for learning science has persisted into relatively modern times. The following extract is from E.F. Carter's Physics for Everyone, published in 1950.

Q. What is the difference between "force" and "energy"?

A. A force causes an object to move, and the object possesses energy by virtue of that motion.

Q. Under what conditions may force be applied to an object?

A. (a) To alter the direction of its movement. (b) To move it from a state of rest. (c) To overcome friction, and thus keep it moving at the same rate. (d) To increase its rate of motion. (e) To bring it to a standstill. (p.27)

Q. Why does a layer of snow protect vegetables from frost and cold?

A. Because the snow layer prevents the heat of the earth from being drawn away by the cold air above the snow. (p.67)

Q. Why does a layer of ice prevent the water beneath being further affected by air frost?

A. Because ice is a bad conductor of heat, and the

layer acts as a blanket, keeping the water below relatively warm. (p.221) (Carter, op. cit.)

These selections bear important similarities to the Pinnock and Brewer textbooks written over a hundred years prior to Carter's. In fact, the only significant difference is in the removal of the religious and teleological components; pedagogically the two are identical. Carter's text is also in the autodidactic tradition as it was not intended for school use: "...and the raison d'etre of this book is to popularise Applied Physics without cheapening or ridiculing it." (Carter, 1950). Even this statement from the Preface bears strong resemblance to that cited previously from the Brewer text, which claimed to be written so that a child may understand, "yet not so childish as to offend the scientific."

The Catechetical texts clearly reflect the purposes for which they were written; namely, to satisfy the need for autodidactic works treating secular or semi-secular themes; to adopt the common pedagogical pattern of instructing through controlled dialogue; and to inform the reader about the content by simply stating the correct, currently accepted view. It is difficult to reliably state how many of these Catechetical texts were printed, and of what types and influence, although Layton (op. cit.) states they enjoyed "wide popularity." An examination of the fly-sheets of copies examined suggests that certain publishers--Jarold and Sons; W. and R. Chambers; and Whittaker are examples--printed large numbers of such texts. Jarrolds published at least 33, and Chambers 50.

#### THE CONVERSATIONALIST TEXTS

The Conversationalist textbooks are very different in format to the Catechetical. As suggested in Chapter 1, it is probable that these textbooks were derivations of the school spellers and readers (cf., the Maria Edgeworth series).

The first example comes from First Steps in General Knowledge by Mrs. Charles Tomlinson. Its date of publication is unverified, but 1870 is written on the title page by an owner.

#### Conversation IV

##### The Planet Venus

Early the next morning, the children saw their papa walking in the garden alone, and they ran down from the nursery to ask for the history of another planet before breakfast. Their papa began thus: "Next to Mercury comes Venus, the most beautiful of all the planets, and the brightest that can be seen from the earth. Our great poet Milton thus speaks of her:-

'Fairest of stars, last of the train of night,  
If better thou belong not to the dawn,  
Sure pledge of day, that crown'st the smiling morn

Why thy bright circlet.'"

"Why does he speak of Venus as crowning the smiling morn? Does it ever shine in the morning?" asked Henry.

"Venus, in one part of her course is seen for more than three hours before sunrise, and in another for as long after sunset: this is why... (Tomlinson, 1870)

On the page preceding the one cited is a small table of data concerning the planet Mercury, the subject of Conversation III. This text, and others of the same kind, were beginning to accommodate themselves to school use. In addition to tables of data, important terms are italicized and defined in the course of the conversation; summaries are often included at the end of sections; and extensive use is made of textual adjuncts such as the above quotation from Milton. This is expressive of a belief that all knowledge should indeed be harmonious within the mind of the educated man. To be truly educated was to see and note

such relationships, which were reflective of a rational unity. It may have been influenced, as well, by the contemporary views on transfer training.

British educators interested in science, such as Richard Dawes and John Henslow, were anxious to provide reading materials with a secular content for school use. The original source of most such texts was the Commission of National Education in Ireland. (Layton, op. cit.). The Tomlinson text, however, was published by the Society for Promoting Christian Knowledge, whose output of scientific writing for the general public must have had a significant influence on general scientific awareness, and attitudes towards science, for many years.

It should be made clear that there was in fact no shortage during the 1850's of reading lesson or other books dealing with scientific knowledge. Typical of the reading books was the small volume entitled Natural Philosophy for Beginners and its companion, the more advanced collection of Reading in Science, which had been prepared under the direction of the Committee of General Literature and Education appointed by the Society for the Promotion of Christian Knowledge. (Layton, op. cit.)

Many of these textbooks were meant to introduce into schools a 'science of common things', intended primarily for the use of working-class schools, and under the inspiration of such Continental educationalists as Pestalozzi and Mayo. They were written around the notion of the 'object lesson' and the observation of nature. "He (Mayo) emphasised that the essence of the method was that all subjects and studies should arise from the experience of the pupil..." (Curtis and Boulton, 1977). Mayo's sister wrote a text called Lessons on Objects which, going through 16 editions, emphasised the role of observation. The publishing firm of Longmans, Green and Company

published a 'Ship' series of "Chatty Object Lessons" in Natural Science from about 1900. The extract below is from the Prefatory Note For Teachers from Hackwood's Object Lessons in Nature Knowledge, one of the volumes in this series.

Stage I., which is the Examination of the Objects themselves, must be the chief part of each Lesson, inasmuch as it arouses a living interest in the subject. The Teacher will merely guide the children in their comparisons and contrasts and in all their other efforts to discover things for themselves. (Hackwood, 1900)

This and similar texts were much better received by men of science, and some even wrote them themselves; John Tyndall, Professor of Natural Philosophy at the Royal Institution in 1853, and a noted science educator, wrote a set of 18 lessons on natural philosophy in reading lesson book form.

A second example of a Conversationalist text comes from the Rollo Series, and is part of the volume on AIR. There are fourteen volumes in the series, covering many general topics such as reading, travel and correspondance, and four on natural philosophy--Air, Water, Fire and Sky. They were fairly substantial, running to almost 200 pages. They were an American series, published in 1855.

Rollo seemed to be very much interested in this conversation. He had dismounted from his father's knee, and stood by his side, listening eagerly. His mother, too, was paying close attention. As for Nathan, he sat still; though it is not by any means certain that he understood it very well.

"Let us suppose," said his father, "that the mass of lead, as big as a load of hay, is fastened to one end of a stick of timber."

"That would not be strong enough to hold it," said Rollo.

"Well, then, to a beam of iron, as large as a stick of timber," rejoined his father.

"O", said James, "you could not get such a big bar of iron."

"No," replied his father, "only an imaginary one; and that will be just as good as any. Now,



Rollo's mother folded up a small piece of paper, and attempted to light the little lamp, which she was going to carry into the bedroom, with that.

But the wick would not take fire, and Rollo saw that, while his mother was continuing her efforts to make it burn, the flame of the paper was gradually creeping up nearer and nearer to her fingers. At last, finding that there would soon be danger of burning her fingers, she walked across the room towards a window which was open, still endeavoring to light the lamp. But it was all in vain. She reached the window just in time to throw the end of the paper out, and save her fingers from being burned.

"Why won't it light?" said Rollo.

Rollo's father was sitting upon the sofa, taking his rest after the labors of the day; and when he saw that the lamp failed of being lighted, he said, —

"You will have to get a longer lamp-lighter, unless you have got some spirits of turpentine to put upon the wick."

"Spirits of turpentine?" repeated Rollo.

"Yes," said his father. "In hotels, where they have a great many lamps to light, they



"But it was all in vain." p. 12

Figure 3. A page (actual size) from a characteristic Conversationalist textbook:

Rollo's Fire, 1855

suppose the great mass of lead is fastened to one end of this bar, and another one, just like it, to the other end, to balance it. Now suppose that the lower end... (p.148)

Rollo began to laugh aloud at this idea, and looked very much interested and pleased.

"O, then I wish there was no gravitation", said Rollo; "I do, really."

"But, then," continued his father, "if you should get up into the air, you could not get down again."

"Why not?" said Nathan, beginning to look a little concerned.

"Unless," said his father, "you had something above you, to push against, so as to push yourselves down. You would be just like a boy in a boat, off from the shore, and without any paddle or pole. He could not get back again."

"We might tie a rope to something," said James, "before we went up, and so pull ourselves down"... (p.150) (Rollo, 1855)

The above abstract illustrates the way science can be taught without practical work, through story-telling illustrated by objects of common experience. Since these works had begun to be taken up by teachers in schools, questions at the end of each conversation were included. These questions are still very much comprehension type questions rather than questions of fact and scientific understanding; e.g., "Why did the boys wish there was no gravitation?" and "Where was Rollo's father when he first asked him about the case?"

A variation on the strictly conversational style is illustrated by a third example, from Paul Bert's First Year of Scientific Knowledge, 1899.

#### MAGNETS

1. We can thus say that poles of similar nature repel each other whilst, poles of the opposite nature attract each other; the rule is the same as that applicable to electricity.

Henry was aware of the fact although unable to explain it, as his uncle brought him from town a small metal duck that floats on water and follows or flees from a magnetic needle according to the end presented to it; and this because in the duck's bill a piece of magnetised steel is hidden.

I asked Henry to bring me his toy, here it is, and you see how very docile the good duck is. Mariner's compass.--And now let us return to our suspended knitting needles. You see, of its own accord it has set itself in a certain direction; if I turn it aside it oscillates a while and returns to its first position. Now note in what direction it turns.

2. One end points to the north, the other of course to the south. (Bert, 1899)

This text is more of a monologue than a conversation. It emphasises the practical, experimental side of science through numerous demonstrations. Of course the experiments are still being read about rather than performed, but in the debate between science education as more concerned with 'pure' or 'applied' science (cf. Liebig, in Layton, op. cit.), textbooks such as Bert's were influential in emphasising the importance of practical work. The explanations based on these simple experiments and demonstrations take place within a discourse, and analogies are drawn from real life experiences. Like the Catechisms, the Conversationalist texts are concerned solely with simple phenomena, and not with abstract concepts. The style allows science a very human face--the reader has someone to empathise with, and acquires information along with the characters. These texts reveal a role of science in education as still part of a means-end relationship; science is simply one means of producing an educated, rational, moral adult. Today, such narrative forms would be seen as suitable only for the primary grades, where the content is seen as secondary to the comprehension. However, in considering this it is important to take into account changing views of childhood between the 19th century and today. The 19th century, for example, tended to view the child as an immature adult (Altick, 1957).

As mentioned in Chapter 1, many Conversationalist writers were convinced that reading was the best way of learning. There can be no doubt that the Conversationalist textbooks were meant to be read at least partly as works of the imagination. Thus their authors could claim that they were motivators of learning by writing texts that engaged the intellect in a way the Catechetical texts could not. The writing of Conversationalist textbooks was not confined to science; geography was also a popular subject for these authors. A large number of geography texts were written in the 19th century, in both the Catechetical and Conversationalist style, and some were very popular. Sir Richard Phillips, writing as the "Rev. J. Goldsmith" published An Easy Grammar of Geography for Schools and Young Persons which reached 31 editions. (Vaughan, 1972). More informal than this was "Grandfather Grey's" The Wonder of the Home: Eleven Stories (1852); Sherwood's Little Henry and His Bearers (1815); and Wakefield's A Family Tour through the British Empire. Many examples of such texts are given by Vaughan (op. cit.). These textbooks clearly reflect the conviction that content can be learned by reading about the subject.

In brief summary, the Conversationalist texts reveal a rhetorical style suited to the purpose of providing an autodidactic reader with an introduction to scientific content. This purpose forced them to present, in story form, simple experiments, demonstrations and examples of reasoning from evidence. They often had the additional purpose of moral instruction, providing the reader with examples of children in interaction with their parents, family members, and others in society, pointing out the correct way to behave in various

situations.

As teachers have, in some cases, done the author the honor to introduce some of the preceding works of this class into their schools, as reading books, &c., considerable reference has been made to this, in the form and manner of the discussion, and questions have been added to facilitate the use of the books in cases where parents or teachers may make the reading of them a regular exercise of instruction. (Rollo, op. cit.)

Clearly, these texts began to show adaptations to school use, including new questions, definitions and tables of data.

### THE EXPERIMENTALIST TEXTBOOKS

The Experimentalist text can be associated with the heuristic movement which came to prominence in the British school system towards the end of the 19th century. Championed by such influential figures as Henry Armstrong, T.H. Huxley and William Tyndall, this particular movement stressed the importance of what would now be regarded as enquiry-orientated teaching, placing emphasis on enquiry skills, observation and experiment. In considering these texts, two points from Chapter 1 must be kept in mind. Firstly, the heuristic movement is almost uniquely British, not European, and is tied to the 19th century British preoccupation with empiricism. Heurism has had and continues to have a powerful influence on science teaching in English and Commonwealth schools.

So the heuristic method worked and, despite the ever-increasing syllabus content, still works in the chemistry department of Christ's Hospital today. Call it 'the discovery method', 'the problem-solving approach', 'open-ended experimentation' or what-you-will, it is coming into favour today in a form very close to that advocated by its originator. (Richmond and Quraishi, 1964)

Secondly, textbooks were anathema for most heurists, their chief

concern being the possible misuse of the textbook as an inevitable consequence of its increased availability (cf. Armstrong, op. cit.). It is indeed very difficult to prevent textbooks from dominating and distorting curriculum issues, as the discussion of Hooker's botany text in Chapter 1 made clear. At the end of the 19th century there was an extreme shortage of qualified science teachers and as a consequence the aims of heuristic teaching could not be readily met. In response a set of ten science 'primers' was published in the mid to late 1870's by Macmillans to meet professional demands. They became extremely popular and were used for more than 40 years in British and Commonwealth schools. This was an extraordinarily long lifetime, and gave rise to a number of derivative texts, such as Perkin and Lean's An Introduction to Chemistry and Physics, 1906. Of the major primers, the most influential was Roscoe's Chemistry. The following extract is taken from the 1913 edition.

#### Fire I

2. What happens when a candle or a taper burns?

The wax as well as the wick of the taper gradually disappears as the taper burns, and at last all is gone--wick, wax and all. What has become of the wax? It has disappeared. Is it lost? So far as our eyes are concerned certainly it is lost but so is the ship which sails away on the sea, and yet we know the ship still exists even though we do not see it; and so the lump of sugar appears to be lost when we put it into a cup of hot tea, and yet we know that the sugar is not really lost, because the tea is made sweet. Now we must look for the wax of our taper in another way; we must put a question to Nature for her to answer, and we shall always find that our question, if properly asked, is always clearly and certainly answered. We must make an Experiment, and if this is properly made we shall never fail in the end to get the information we want.

EXPERIMENT 1--Let us burn our taper in a clean glass bottle with a narrow neck; after it has burnt for a few minutes we notice that the flame

grows less, and in a short time the taper goes out. This is the first thing we have to observe. We next have to discover why the taper goes out. For this purpose let us see whether the air in the bottle is now the same as it was before the candle was burnt. How can we tell this? Let us pour some lime-water... (Roscoe, 1913)

The commitment to observing and experimenting is clearly seen in this abstract, and is maintained throughout the book. Science in general, and chemistry in particular, is seen as a process in which careful attention to what happens in an experiment yields unexpected and important truths. The teacher would be expected to maintain that spirit of enquiry.

The primers were surprisingly small, by modern textbook standards; Roscoe's textbook contains only 96 pages, yet covered a broad range of topics. The content is ordered into the divisions Fire, Earth, Atmosphere, Water, etc.--divisions which would be consistent with the reader's world view of the apparent structure of nature. This is unlike the division in many more modern textbooks which perhaps force the scientists' world view too immediately on the new learner. With the Roscoe text one is conscious of a very well thought-out textbook with a clear rationale. Descriptions of apparatus and chemicals required are given together with the names of suppliers at the end of the book.

In spite of the intentions of the authors of the Experimentalist textbooks that the emphasis be placed on practical work, their books are presumably meant to be treated as a reading text; they are to be read from cover to cover, in sequence. This is clear from the rhetorical structure. These texts could not be dipped into at random, or have isolated sections used out of context, without destroying the sequential and directed argument of the

a solid which has the shape of the one bottle and force it into the shape of the other, although the size or volume of both is the same; nor can you take a solid of the size or volume of the first wooden block and squeeze it into that of the second, although the shape of both blocks is the same. A perfect solid will keep its figure, and it will also keep its size.

Bear in mind, however, that when we say we can not do a thing, we really mean we cannot do it without very great difficulty, and then not completely, but only to a very small extent; in fact, what we really mean is best explained by making a series of simple experiments.

EXPERIMENT 8.—Let me take a bar of iron; I will first of all try to break it in pieces by means of a blow, but it won't be broken.

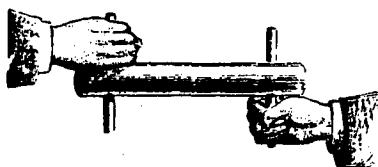


Fig. 5.

I will next try to stretch it out by hanging it up tightly by one end, and then applying to the other end a heavy weight, but it won't be stretched.

I will now, by means of two rods, fitting into the bar at its ends, as you see in the figure, try to twist round the one end, while I hold the other still, but it won't be twisted.

I will now set the bar endwise upon the table, and put a heavy weight above it, to try and squeeze it together, but it won't be squeezed.

And finally I will hang it up horizontally by both ends, and attach a weight to the centre, and I find it won't be bent.

Now the bar of iron which I can neither break by a blow, nor stretch, nor twist, nor squeeze together, nor bend, is a very good example of a solid body; and yet, if I applied an exceedingly great force, this bar might be stretched, or twisted, or squeezed, or bent. And in truth I did actually stretch, and twist, and squeeze down, and bend it, in the experiments I have just described, but not enough to make it visible to you. In fact the amount by which I stretch, or twist, or squeeze down, or bend the bar, depends upon the amount of force I use; and in Physics we try to find out the relation between the force which we use and the effects which we produce. I cannot tell you all about this subject, because it would take up a great deal of time, but we may take one operation, such as bending, and endeavour to find in what way its effects depend upon the force which we employ.

15. Bending. EXPERIMENT 9.—For this purpose let us support a wooden beam in a horizontal position by both ends, and let us hang a somewhat heavy weight from its middle or centre. Then let us measure upon a scale how far the centre has been bent down by the weight. Let us now double the weight that hangs from the centre, and mark the new position

Figure 4. A page (actual size) from a characteristic Experimentalist textbook:

Balfour Stewart's Physics, 1891



prose. But they were not to be the focus of the learning. They were by all accounts misused and came in for a considerable amount of criticism in later years, although the criticism really applies to the misuse of textbooks generally, rather than the Experimentalist texts particularly. What was happening was that students were being asked to 'learn' the textbook chapter by chapter.

Sir H.E. Roscoe described such a lesson in one of the larger public schools where it was the Latin master who taught chemistry: 'Now boys, have you all got your Roscoe?' Boys: 'Yes, sir.' Master: 'Well, pages 42-54.' Then he proceeds to correct the Latin exercises. Bell rings. Master: 'Well, have you read your Roscoe?' Boys: 'Yes, sir.' Master: 'Then you may go.' (Thompson, 1956)

It must be pointed out that the Experimentalist texts should not be thought of as laboratory manuals, or as equivalent to texts with a high practical work component but no spirit of enquiry. The following extract from a popular text of the latter sort, illustrates this difference. It is from A.M. Poyser's Magnetism and Electricity, the fifth edition (1894), and thus contemporaneous with the Primers.

#### Attraction of Iron by Magnets.

Exp. 7. Take an ordinary bar magnet, and dip it into iron filings. Observe that the filings do not adhere to all parts of the magnet, but that they accumulate in tufts near the ends.

Exp. 8. Take a strong bar magnet, and a number of small soft iron bars of equal size and weight.

(1) Near the end a of the magnet attach the greatest number of these bars that can be sustained. (2) Test a point b on the magnet near the centre. It will be found that the same number of bars will no longer be supported...

We therefore learn that--

(a) The attractive power of the magnet is greatest near the ends. Strictly speaking, there are two points, one near each end of the magnet, where the attractive power is greatest. These points are called the poles of the magnet.

(b) The portion between the poles has apparently less magnetism.

(c) All round the magnet, midway between the poles, there is no attraction. This is called the neutral line... (Poyser, 1894)

This text of course is first of all telling the student what they will observe, and then telling them what to make of their 'observations'. This is counter to the intended use of the laboratory and of experimentation advocated by heurism and the Experimentalists.

Briefly, then, these textbooks are clearly matched to the purpose of providing written material for school learners in support of a view of science education as a process of learning the methods and results of laboratory-based enquiry. They were written by scientists who showed a willingness to explore the uncertainties and consequences of the concepts developed in the enquiry process; that is, they reflect what Schwab has called the "narrative of enquiry" in contrast to a "rhetoric of conclusions".

The usual rhetoric embodies the conclusions of science as flat declarations that this and that are characteristic properties and behaviors of the subject elements in hand. A narrative of enquiry, on the other hand, develops the conclusions of enquiry as precisely that--formulations of the evidence made available by a series of enquiries. (Schwab, 1962)

While the nature and role of enquiry-based, 'heuristic' approaches is still being debated today, the Experimentalist textbooks were swamped by the great flood of texts that followed the large increase of students into secondary education and the advent of science as an examinable subject that occurred at the end of the 19th century.

#### THE FORMALIST TEXTBOOKS

The Formalist texts originated in the need to make both natural history and the separate disciplines of the sciences available to the masses. Books of science (Natural Philosophy) and natural history for general audiences have been available since before the 19th century. Works such as The Cabinet Cyclopaedia by the Rev. D. Lardner (1830); A Compendium of Natural Philosophy by J. Wesley (1836); Glimpses of Nature, Science and Art by W. Anderson (1872); and Fragments of Science by J. Tyndall (1879) and many others were available to the general reading public. Often they were simply compilations of information written to inform the public of the findings of science. As such, they were the fore-runners of the 'popularisations' of today, which also are not written for school purposes. It is not always easy with these 19th and early 20th century works to discriminate between those written with religious motives (e.g., the Anderson work above) and those which were truly popular accounts of particular sciences. In some cases, authorship or publisher can give indications of religious purposes. Of the strictly scientific, some represent the first attempts to distill and simplify the great classic works of science--Newton's Principia, for example, or the works of Dalton, Laplace, and Darwin. The dangers of attempting to do so are only beginning to be realized. It has recently been suggested that there are some quite standard misformulations and incorrect illustrative examples which continue to appear even in modern texts. (Warren, 1965). Leaving that aside, the Formalist textbooks were designed to be used in the teaching of science as a school subject. They were no longer popularisations, but instruments of school-based instruction.

They took their character from a body of ideas and other considerations which are important to keep in mind when examining them. Briefly stated these are:

1. The developing nature of science as a set of professional disciplines. As such it began to exhibit the characteristics of objectivity, quantification, reductionism, and analytical reasoning in a modern form that, in part, form the distinctive disciplines of science. These began to be seen in the textbooks.
2. The elimination of ulterior religious motives. This has already been mentioned in Chapter 1 in relation to the shift of the publication of science books from religious institutions to educational publishers, and in the shift from the writers of textbooks from clergymen and non-scientists to scientists. Given, however, that many 19th century clergymen were scientists or interested in science, this change reflects a willingness to separate their religious views from their purposes of informing readers about science.
3. The increasing demand for the training of scientists and engineers. Science began to assume an instrumentalist role in education.
4. The development of science as a school subject. It became, therefore, increasingly responsive to pressures from teachers and educational administrators. It faced practical methodological problems, the problem of large classroom numbers, and the conflicting views put forth by educationalists and psychologists as to how it should be best taught and learned.
5. The lack of suitably qualified, trained science teachers. This tended to force the textbook into a central position in the

classroom. As well, there was no developed tradition of science education to guide practice and inform teacher training.

6. The influence of external examinations and certification authorities. The examination papers and mode of assessment became an increasingly dominant influence on what was taught and how it was taught. This is most clearly seen in the number of textbook prefaces which claim to match examination demands.

These separate influences combined to produce a type of textbook broadly similar in purpose and style though differing in format.

The extract below is from the Preface to H. Reid's Elements of Astronomy (1842), and shows how some of the factors mentioned above have influenced the author's approach.

...it is extremely desirable that science should be introduced as a regular part of education into all schools, and that for this purpose there should be text-books composed on its various branches to aid the pupil; it being found that the most rapid progress is made when a lesson is given out to be studied by the learner, on which he is afterwards to be examined by his teacher. Of the various sections of Natural Philosophy, no one seems better adapted for the instruction of youth than ASTRONOMY. The phenomena it describes are interesting above all others from their grandeur as well as from their practical application to the uses of human life; while, by the exactness of its laws and the certainty of its demonstrations, it is eminently fitted to improve the mind in precision of thought and accuracy of expression.  
(Reid, 1842)

Several points in this preface are worth highlighting. One is the view of science education as a "means of mental discipline and intellectual improvement." This is repeated later in the emphasis on astronomy as particularly "fitted to improve the mind in precision of thought and accuracy of expression." Such remarks again indicate the presence of a psychological belief in

the reality of 'transfer training'. Secondly, there is a sketchy teaching strategy recommended. And thirdly, the format itself is designed to put the information into "short, aphoristic sentences, which will greatly assist the pupil in forming answers to the various questions that may be put to him by his tutor." (Ibid). An abstract of such 'sentences' is provided below.

441. The mean distance of Saturn from the sun is nine hundred and four millions of miles (904,000,000). His eccentricity is more than 1/20th of his mean distance from the sun.

442. At Saturn, the sun will present a diameter about 1/10th of that seen at the earth. The proportion of the sun's influence which reaches Saturn is about 1/90th of that enjoyed at the earth--as 95 squared to 904 squared.

443. The equatorial diameter of Saturn is about 79,000 miles. The polar diameter of this planet is stated to be about 1/11th less than the equatorial. Having a very rapid rotation on its axis, it is to be expected that Saturn, like Jupiter, will be very much flattened at his poles.

444. Saturn rotates on his axis in 10 hours 16 minutes.

445. Saturn completes his revolution round the sun in 10,759 days, or about 294 years; moving in his orbit at the rate of about 6 miles in a second, or 360 miles in a minute.... (Ibid)

There is no index or collection of questions in this volume. It is unrelieved information. It is impossible to know what a teacher would have done with this text beyond asking for memorizations and assigning homework readings. Nowhere are there appeals to the reader's imagination or religious sentiments so common in the Catechetical or Conversationalist texts. The spirit of science is absent, its role in education and the life of the child, despite the assertions of the Preface, are completely unexplored. The whole notion of science as an exploratory activity is left untouched, not only in that

no accounts are given of how the information was obtained or unfolded over time; but also in that the readers are not asked to explore its meaning for themselves.

Many of these features have persisted over 150 years to influence today's textbooks. But as this particular text is perhaps extreme in its concentration on providing information, it is important to contrast it with something a little closer to the modern textbook. The next extract comes from Galbraith and Haughton's Manual of Hydrostatics, the third edition, 1880. It is one of a series of 12 manuals, all concerned with either mathematics, engineering, or physical science.

#### Specific Gravity of Moist Air

As gases are generally collected over water, they are, when measured, saturated with aqueous vapour, the pressure of which corresponds to the temperature of the water; the weight of dry gas contained in a given volume of wet gas may be calculated as follows:--Let  $p$  and  $t$  be the pressure and the temperature of the mixture of dry gas and vapour, the pressures of which are  $a$  and  $b$  respectively; by equation (25)  $a$  is equal to  $p - b$ , and as the dry gas fills the volume  $V$ , its weight is

$$W = 5.375V(p - b)/460 + t \quad \dots$$

#### EXAMPLES.

1. A volume of hydrogen gas saturated with moisture measures 12.5 cubic inches, the elastic force of the mixture is 29.2 inches, the temperature 52 degrees F., and the force of the vapour 0.388; calculate the weight of dry hydrogen. Ans. 0.26088 grains....(p.70)

#### Equal Transmission of Pressure.--

If a vessel be filled with a gaseous fluid, and if an orifice be fitted with a piston...it is necessary, in order to hold the piston in its place, to exert against it from without inwards a force equal to the elastic force of the gas. Thus, if the elastic force be equal to 15 lbs. on the square inch, and if the area of the piston be 3 square inches, it will be necessary to exert a pressure of 45 lbs. against the piston. If any greater pressure be applied, the piston will enter the vessel until the elasticity of the gas, under a diminished volume, becomes equal to the increased pressure. The additional pressure is thus transmitted equally in all directions to

every point of the vessel. (p.26) (Galbraith and Haughton, 1880)

The format and rhetoric of this textbook is beginning to look familiar; a bit of theory, some description of apparatus, a formula or two, and some problems to work. There is no index, and no statement of intent or purpose given. It reflects the model of science dominant in England at the time and noted as early as 1884 by Justus von Liebig: "What struck me most in England was the perception that only those works that have a practical tendency awake attention and command respect; while the purely scientific, which possesses far greater merit, are almost unknown." (Layton, op. cit.).

The next example perhaps represents the Formalist textbook in its mature form. It comes from J.D. Everett's Textbook of Physics, 1901, which went through at least 11 editions, and was the recommended textbook for Higher School Certificate physics in Tasmanian schools for 12 years.

Acceleration.--Such motion as that of one of the masses in Atwood's machine, or of a body falling freely, is said to be uniformly accelerated. This designation means that the velocity is increased by equal amounts in all equal intervals of time. A body acted on by a constant force in the line in which it is travelling, always moves with uniform acceleration.. This is an obvious inference from the second law of motion, which asserts that the acceleration of a body is inversely as its mass and directly as the force acting on it...(p.34)

The variations of density, pressure and temperature in aqueous vapour--as long as none of it passes into liquid form--are connected by the same laws as those of a gas; that is to say, its pressure is proportional to its density when the temperature is constant, and to the absolute temperature when the density is constant....For example, the weight of a cubic foot of dry air at 10 degrees C., under the pressure of 30 inches of mercury, being 547 grains, and the maximum pressure of vapour at 10 degrees C. being .361 of an inch of mercury, the maximum weight of a cubic foot of vapour at 10 degrees C. is



$$(.622) \times (.361/30) \times (547) = 4.1 \text{ grains...}$$

(Everett, 1901)

The Everett text contains an index, tables of data, end of unit questions, and numerous illustrations. Its Preface states the aim of the textbook to present "the main points of theory...(and) to ground students well in the main lines of scientific theory. The aim must not be so much to teach them many facts, as to teach them rightly to connect a few great facts together. Science must be taught them from a liberal, not a technical standpoint." (Ibid). This seems to be in contrast to the perception of Liebig cited earlier, but in both the texts chosen as examples the main role of science education is the transmission of current understandings. Since well-equipped physics laboratories and teachers trained to use them were rather scarce in 1900 (Layton, op. cit.; Jenkins, op. cit.), these textbooks certainly formed the centre of the classroom activity. The result was formal teaching with a strong emphasis on problem solving through worked examples.

An aspect of the Everett textbook which has become traditional in modern general physics texts is the choice of content, and, in general, its sequence. The topics covered in Everett include Dynamics (classical mechanics--motion, force and energy), Heat, Optics, Hydrostatics (which has not survived as such), Sound, Electricity and Magnetism. Astronomy has tended to disappear from the senior science curriculum, perhaps due to that emphasis on the practical noted by Liebig; it certainly does not hold the assured important place it held in the 19th century. The Preface makes the claim that the content is chosen to include "those portions of Theoretical Physics which are most essential

**Effect of dissolved substances on the freezing point.** When an aqueous solution is cooled, the freezing point is lowered, and the first solid portion to appear is pure ice. The freezing point of a solution is defined as that temperature at which the solution is in equilibrium with the solid solvent. The lowering of the freezing point by the dissolved substance is proportional to the concentration of the solute. This statement is known as Blagden's Law.

It has been shown that the vapour pressure of the solution of a non-volatile substance is lowered according to the formula  $\frac{\delta p}{p} = \frac{n}{N}$ , and thus the "steam line" is lowered to an extent which is proportional to the molecular concentration.

In Fig. 329,  $AX$  is the vapour-pressure curve of the pure liquid solvent,  $YA$  that for the solid solvent, the melting point or freezing point being given by the point of intersection of these two lines. Curves lower than  $XA$  intersect the line  $YA$  at points such as  $P$  and  $Q$ , which correspond to temperatures  $\theta_1$  and  $\theta_2$ , lower than the normal freezing point of the pure solvent,  $\theta$ .

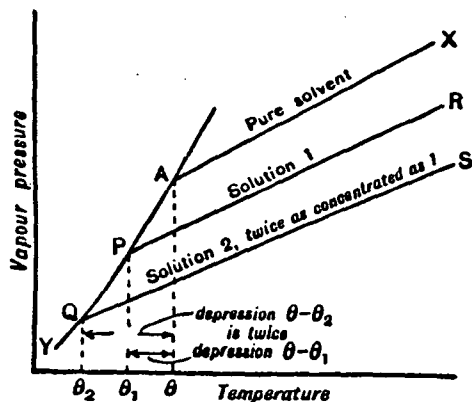


FIG. 329.

Suppose that the molecular concentration of the solute in solution 2 (for which  $SQ$  is the "steam line") is twice that of solution 1 (for which  $RP$  is the corresponding line);  $SQ$  is then twice as far below  $AX$  as is  $RP$ , and if the curves are all approximately straight lines,  $AQ = 2AP$  and  $\theta - \theta_2 = 2(\theta - \theta_1)$ . That is, the depression of the freezing point is proportional to the concentration in moles of solute per mole of solvent. This is the principle of a method used in Physical Chemistry for the determination of molecular weight.

**Equilibrium diagrams for mixtures.** The two curves in Fig. 330 for a solution of common salt in water show how the temperature of equilibrium depends on the concentration. Starting at  $A$  with a weak solution of salt at  $0^\circ \text{C}$ . and cooling it, pure ice separates out, increasing

the concentration of salt in the remainder and lowering its freezing point still further. Pure ice continues to separate out until the point indicated by  $C$  is reached, at a temperature of  $-21^\circ \text{C}$ . and a concentration of about 23 per cent. of salt. Similarly, starting with a strong solution containing about 27 per cent. of salt at  $B$  and cooling it, salt crystallises out leaving behind a weaker solution which on cooling still further deposits more salt, until eventually the point  $C$  is reached. To the left of  $C$  then, the solid deposited on cooling is pure ice; to the right of  $C$ , the solid is pure salt. At  $C$ , both ice and salt are deposited together, or the substance appears to solidify as a whole. Hence, a mixture of which the composition is that for the point  $C$  has a definite freezing point, behaving in this respect like a pure substance. The point  $C$  is called the cryohydric or eutectic point, and the mixture the composition of which corresponds to  $C$  is called a cryohydric mixture, or eutectic mixture.

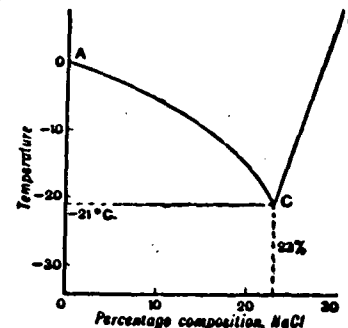


FIG. 330. Equilibrium diagram for salt solution.

**Ice and salt as a freezing mixture.** Two simple points which require some careful thought for their explanation are (a) how it is possible to obtain a low temperature by the use of a mixture of ice and salt, and (b) why salt placed on an icy pavement will melt the ice. Both depend on the same effects. When salt dissolves in water heat is absorbed; and the resulting solution has a lower freezing point than the pure water. In the freezing mixture, then, progressive solution of the salt, with resulting lowering of temperature, takes place until the proportions of the mixture are those of the eutectic mixture, and the temperature is that of the eutectic point. When salt is used to "thaw" an icy pavement the same thing happens; the resulting mixture will remain liquid if the temperature is above the eutectic temperature, as is the case except in extremely cold climates.

**Alloys.** Results very similar to those for a solution of salt in water are obtained with alloys of two or more metals. The simple case of the alloys of lead and tin, which is of great practical importance, will be considered in some detail.

The melting point of lead is  $327^\circ \text{C}$ ., and that of tin is  $232^\circ \text{C}$ . Molten alloys containing known proportions of each constituent can be made by melting a known mass of lead in a crucible, and dissolving the required amount of tin in the liquid lead. Using a  $360^\circ$  mercury thermometer, or a suitable thermocouple, cooling curves for the pure metals and for alloys of different known compositions can be obtained.

Pure lead and pure tin give cooling curves with a single horizontal portion, like the curve for naphthalene, denoting a definite melting point. Alloys of lead and tin, except those with compositions of about 60 per cent. tin and about 40 per cent. lead, give curves with two "halt"

as a foundation for subsequent advances, while at the same time most fitted for exercising the learner in logical and consecutive thought." (Ibid). Most two-year senior physics courses today follow the same path, though without mentioning the second of Everett's justifications--a belief in the transfer of learning.

Another characteristic of the Formalist textbooks which has persisted to the present day is its rhetorical style, which is itself generally referred to as 'formal', in contrast to, for example, the Conversational style. Some very general characteristics, which will be given precise definitions in Chapter 5, will be mentioned. There are no superfluous phrases; it is highly structured; it is descriptive rather than prescriptive; and it avoids the vivid, figurative use of words. Any competent reading of these passages demands operation on a high level of abstraction and logical analysis, plus the ability to follow reasoned argument from a difficult, remote context. As a means of expression, it is closed, offering no invitations to the reader to speculate or question. It never invites the reader to reach above or outside the textbook; it lacks the spirit of enquiry. It is written in the "rhetoric of conclusions". (Schwab, op. cit.). Rather than assist learning, the textbook itself becomes the object of study.

The gap between the language of the Everett textbook and that of the modern physics text is not a large one--it is certainly not fundamental. The Formalist textbooks, in their language of presentation, have reflected changes only in publishing innovations related to format; eg., colour photographs instead of woodcuts. To make this point more specifically, consider the

following extract, from Fundamentals of Senior Physics, 1973.

A plumb bob experiences a gravitational force at any point in this field because of its mass, and the value of this force is the weight of the bob. However, at the same point in the field, different masses have different weight. Thus to describe the strength of the field, we need to consider some quantity which is independent of the mass of the test object used to detect the field and which is a property only of the point at which the mass is placed. The force per unit mass is taken as a measure of the gravitational field strength. The gravitational field strength  $g$  is defined as the force  $F$  per unit mass at a point.

$$g = F/m$$

The measurement of force can be made with a spring balance... (Mayfield et al., 1973)

There are many points of similarity between this text and the Everett one cited above; there is the straightforward stating of information, the use of formula, logical argument and definition, and didactic tone. The technical language of both early and modern Formalist textbooks creates problems for readers, but can be defended on several grounds. First, perhaps there is no other language at all suitable for the purpose of dealing with advanced concepts in science education. However, the historical overview so far considered has suggested alternatives that, although they were matched to different purposes, could be considered as possible rhetorical models for dealing with mature science. There currently exists a wide range of popularizations in science that can inform, and that use a more informal style; books such as Russell's The ABC of Atoms (1924), Toulmin and Goodfield's The Architecture of Matter (1962), and Thomas' The Medusa and the Snail (1979). Secondly, perhaps the formal language is necessary for purposes of objectivity and truth; perhaps it guarantees precision and eliminates ambiguity. These were certainly the feelings of the

Royal Society, which wished to develop a discourse free of ambiguous language. (cf. Sprat, 1667, quoted in Adolph, 1968). Such language, as the language of science, may be our only access to the discipline of science. From this point of view, science education is seen as having the role of introducing learners to a form of knowledge complete in itself, and therefore not allowing science to serve any other purpose, as it once did. Lastly, there is the argument that the science student has to start using this language of science sometime, and can not be shielded from it indefinitely. After all, in crisp, precise manner, here is how the world works--logically, lawfully and quantitatively. But to serve the purpose of being used in schools to initiate learners into science by the act of reading, textbooks must confront the question of how readers might use the text to develop within themselves such a view of science.

#### SUMMARY

All four types of textbook represent clear efforts to produce written forms suitable for their varying purposes--some for autodidactic readers, others for school students. The four different solutions to the problem represent extremes in underlying philosophy. The writers of the Experimentalist textbooks placed a very heavy emphasis on what today would be termed experiential learning--experience of the phenomena in question being the key issue. All the other three types place a much heavier emphasis on language. The Catechetical writers preferred a simple definitive response to key questions with no attempt being made to test depth of understanding or meaning.

This has not survived as a textbook technique except for the occasional modern day 'crammer' which tends to be frowned on by modern educationalists, and in teacher/pupil dialogue. The Conversationalist textbooks almost certainly stem from the Pestalozzian influence of the object lesson on teaching, and from the early spellers and readers. Today, the object lesson as a teaching style is considered out of fashion, but it represents an attempt to make a linguistic bridge between the scientist's world view and the child's--something which continues to be a major teaching problem. These Conversational texts have waned in popularity. By comparison, the Formalist textbook makes little concession to the reader's world view or perspective. The reader is presented with a simplified version of the scientist's world view, and yet it is clear that even these texts contain a level of abstract reasoning and structure of argument which is often much too demanding. As well, the modern science textbook would appear to have combined the purposes of the experimentalists and formalists, producing a book which is often a large unwieldy compendium which in sheer size may be daunting to the average student. And finally, it must be noted that the importance of language in science teaching seems to be much more clearly exploited in the early textbooks, usually with definite and distinctly different rationales and views of the value of reading for learning.

### CHAPTER 3: PURPOSES FOUND IN THE TEXTBOOK PREFACES

#### INTRODUCTION

The preceding two chapters examined the relations between purpose and textbook language. They traced the influence of science education on the textbook, and showed that four major subdivisions of textbooks, based on rhetorical style, can be identified. The purposes of textbooks were shown to be linked to prevailing notions of science education, and that these notions in turn determined the rhetorical style.

This chapter has two main objectives. Firstly, to provide further evidence that textbook authors were and are writing with clear purposes in mind. The words of the authors themselves are examined as set forth in their textbook prefaces. Secondly, the authors' purposes have only been seen to this point in broad outline, and therefore this chapter details those purposes more closely. To do so it is necessary to identify purposes within the textbooks themselves. An immediately obvious way to do so is through an examination of the Prefaces, Introductions, Forewords, etc., written by the author or authors. For convenience, the word preface is used for all those pre-textual statements which can be identified as written by the author or authors. The examination of these prefaces again follows chronological lines. This chapter also provides justification for earlier claims that authors were responsive to prevailing ideas of science education, and that the authors' rhetorical

style was, in turn, shaped by those responses.

Before such an analysis can take place, a number of assumptions must be made clear. Firstly, it is assumed that the authors of these prefaces are not writing with the intent to deceive the purchaser of the textbook in order to make their text more marketable. Three arguments can be used in support of this assumption. In the first place, the writers of many of the texts considered were, and in some cases still are, men and women of sufficient reputation to make such deception unlikely--Huxley, Hooker, and the eminent scientists of the 19th and early 20th centuries, and the clergymen before them; the well-known educators and contributing psychologists since. Secondly, it can be reasonably argued that few authors would risk the loss of confidence and reputation that would follow from the obvious distortion of the aims of the preface and the reality of the text. A third factor working against deception is the tendency for many textbooks to be written by more than one author, or by a committee. Thus, while most authors would be anxious to put their textbook in the best possible light, and may make claims for their work in excess of what is finally achieved, the prefaces are not likely to contain gross distortions of the writer's or writers' true intentions.

What is not assumed in this study is that the authors have always met all the purposes expressed in their prefaces. What an author believes about the nature of science and of science education is not always matched by the talent to expound such views in words, and under the constraints of textbook characteristics. This chapter is only concerned with expressed purposes, however. Later chapters will determine how closely



reality matched promise. Nor does this thesis assume that the authors carefully set out a series of aims or purposes and then wrote a textbook to match. It is clearly impossible in many cases to determine if the prefaces were written before or after the textbook itself. What is assumed is that the preface contains, from the writer's and reader's point of view, an accurate reflection of the authors' purposes. Again, only careful reading and analysis of the textbook can determine if the reality matches these purpose. And finally, it is assumed that the author or authors did in fact write the preface which is followed by his or her name.

As well as the above assumptions, there are two additional points of methodology that should be mentioned before considering the prefaces themselves. Firstly, the intentions of an author of fiction are often unclear, and determining them provides many hours of labour for critics and teachers of English. By contrast, textbook writers have often felt the need to explain and justify their purposes to the public, to teachers, and occasionally to pupils. The preface, however, is the only place in the text where the author speaks explicitly to the reader. After that, no further reference is made to the purposes of the author within the body of the text. Therefore, the presence of the prefaces means this thesis is not reliant on the techniques of literary criticism to determine authorial purpose.

Secondly, 19th century and early 20th century textbook writers can be expected to be defensive about the role of reading in science education, as powerful arguments against textbooks were raised by such eminent educationalists as H.E. Armstrong and the

advocates of the experimentalist methods, as shown in Chapter 1. This may explain why they felt it necessary to include a preface outlining and, occasionally, defending their purposes, as the several examples given in previous chapters show (e.g., Edgeworth, Bert). Yet all the writers of every period assume a secure place for the textbook in the classroom; none are pleading for survival. There is clearly a strong, established view in science education disciplines that there must be a textbook, that children learn by reading, and teachers feel more confident when they have a textbook to lean on. (Mann, 1981; Newton, op. cit.). The Nuffield Science experience, as outlined in Chapter 1, has shown that it is very difficult for modern science education to do without books, but that the role of the book within the classroom, and the quality of the books, can still be debated.

### Method of Analysis

This analysis asks four main questions which the textbook authors could reasonably be expected to address if they attempt to outline their purposes. They are also questions which relate to the concern of this thesis with the language of the textbooks. These are then used as framework questions for the analysis of the prefaces.

1. What is the role of the textbook in science education? This is asking for the author's view of the relationship between textbook, laboratory, field study and so on; in other words, how central a role should the textbook play in the classroom. This question can reveal something of the author's view of science education, and it can also indicate if there have been changes

in views on the importance of the text in learning about science.

2. What is the place of science education in the curriculum? Authors may feel the need to justify the place of science in the total education of the child. This question can reveal something of the author's view of science education in both the life of the child and in society, and is related to the purposes of science education (e.g., to develop powers of observation and analysis, or to meet certain manpower demands).

3. What is the nature of science as a human activity--what is its role in the life of the student and society? This question seeks direct statements of the author's views of the nature of science, a central concern of this thesis.

4. What is the appropriate language for writing about science in a textbook? Answers to this question would include claims made about the nature of reading as well as writing, vocabulary, style, level of difficulty, and language usage; i.e., formal versus informal usages. This question seeks to know whether the authors have been aware of any necessary or important connections between their language style and their views on science and science education.

Using these four questions it is possible to examine the prefaces of the textbooks for authorial purposes, and then to match those purposes to the rhetorical styles classification developed in Chapter 2. The results presented here come from a close reading of all the prefaces contained both in the collection and from other sources; representative examples of the most frequently expressed purposes are presented.

### THE CATECHETICAL PREFACES

There are two methodological factors that must be mentioned when examining the Catechetical textbooks. Only a relatively small number of these early question and answer texts contained prefaces, perhaps because the tradition had not yet become established. It is, however, possible to present broad generalizations from the few prefaces available. Furthermore, in looking at these texts through the framework of the four questions outlined above, it is clear that the first two--dealing with textbooks within science education--are inappropriate. Science education scarcely existed at the time they were written. If they were used in schools at all, it was as readers and spellers as pointed out in Chapter 2. Yet they still function as textbooks because they were taken up by teachers for instructional purposes in schools.

There is evidence that the authors were concerned with the third of the framework questions, that of science as a human activity. Science was seen as an activity that revealed a view of the universe controlled by God and therefore worthy of admiration. The following extract is from the preface to the pamphlet on Botany by Pinnock.

This little Introductory Work..is written with the sole view of rendering more easy the study of a science which, at the present day, is cultivated by all those who have any pretensions to a polite education; and, if it be considered in a moral point of view, this study is well calculated to furnish us with instruction, and conduct us, by gentle steps, to the knowledge of that Great Being, who has condescended to form plants with so much delicacy, and grace them with such a variety of beauties. (Pinnock, 1828, op. cit.)

In his introductory chapter, Turner (1832) discusses the various divisions of science and art, and then makes the following

statement about the "eighth division of knowledge".

Q. What is the eighth division?

A. The Knowledge of GOD the Creator.

Q. How many sciences does that include?

A. It includes only one,--Natural Theology; or the knowledge which we derive of Nature's God, from the study of nature. Before it can be very correct, there must be a very considerable knowledge of nature. (Turner, 1832)

The main other purpose claimed for the Catechetical textbooks was to respond to the need for autodidactic (or self-teaching) textbooks dealing with secular material. Again, there is support for this view in the prefaces.

No science is more generally interesting, than that which explains the common phenomena of life...The Author has spared neither labour nor expense to render his (text) instructive and amusing to the young, as well as to those of maturer life. (Brewer, 1855)

In a commercial country, like Great Britain, an acquaintance with Chemistry possesses the highest advantages; for whatever station in life our children be destined to fill...whatever avocation, in short, they may be called on to pursue, the rudiments of Chemical Science must prove materially useful to them; while the ramifications are so various, that they present to the inquisitive mind an endless source of amusement and delight. (Pinnock, Chemistry, 1828)

The intention has been to make the work an introductory catalogue to all the sciences, arranged as nearly as possible in the way in which they may be studied most succesfully, and acquired with the least labour. A glance over the table of contents will show what the arrangement is; and the Editor flatters himself that the work will be equally useful in public schools and for private learners. (Turner, op. cit.)

The final selection from Turner comes from the 20th edition, 1832, after the text had begun to be taken up into schools. All these selections are revealing of three main points concerning these early textbooks; their concern with religion, their concern with the educational advancement of their readers, and

their concern to make the content both 'instructive' and 'amusing', which can be taken to mean pleasurable to read, which may suggest some notion of learning theory.

The fourth framework question referred to the authors' concerns with the language of the textbook, and what statements, if any, were made by the writers themselves about their efforts to make that language appropriate. In general, the Catechetical prefaces made only passing comments on language. The most substantial remarks come from Brewer.

The object of the present book is to explain above 2000 of these questions...in language so simple that a child may understand it, yet not so childish as to offend the scientific. (Brewer, op. cit.)

Far more common, and related to the question of language, are comments that the authors have taken into account their likely readers.

The object of this little work is to lead the youthful mind, by easy and progressive stages, to a general and intelligent acquaintance with the system on which Natural History is based. (Owen, 1856)

Many years have elapsed since the first appearance of this popular school-book--a book which, by bringing something like an arrangement of the more important branches of human knowledge within the reach of young students, merited, there is no doubt, the extensive and prolonged patronage of the public which it has received. (Turner, op. cit.)

Though Natural History has so long been regarded as a study more beneficial to mankind than any other, yet few attempts have been made to facilitate the progress of a child in this valuable and interesting science. However deficient, therefore, this Catechism may be in explaining the wonders or developing the mysteries of Nature, it is hoped that an acquaintance with the leading features may be gained by an attentive perusal; particularly as it is produced in that form to which the instructors of youth, in the present enlightened age, have given so decided a

preference. (Pinnock, Catechism of Natural History, 1821)

There is clearly evidence for at least four purposes in the Catechetical prefaces. Firstly, a concern to show the presence and power of God in nature. Secondly, for the purpose of assisting in the education of young, autodidactic readers as well as those under instruction. Thirdly, they were written with due regard for scientific accuracy, and the belief that scientific knowledge was important in the total education of youth. And finally, there is some indication that the writers chose the Catechetical style to be in harmony with current teaching practice (e.g., Pinnock above), and in the belief that such a style would lead to the easy acquisition of knowledge.

#### THE CONVERSATIONALIST PREFACES

As with the Catechetical texts, these Conversational texts were not originally written with school children in mind, but for autodidactic readers. Therefore, the first two framework questions are again inappropriate. However, there is evidence that these authors saw a role for books in teaching science, even if not within the classroom. The authors of these fictional story-book form texts are united in their desire to add to the secular knowledge of their readers, even when concerns with moral or intellectual development are present. The following extracts reveal this purpose, and provide answers to the third framework question--what is the nature of science as a human activity.

Botany is in itself a very comprehensive science, and one which it will require much time and study to understand; but this little book will shew you the first step towards acquiring some knowledge of

it. (Parley, Tales About Plants, 1839)

The Author trusts that the whole work will be found a complete compendium of natural and experimental philosophy, not only adapted to the understandings of young people, but well calculated also to convey that kind of familiar instruction which is absolutely necessary, before a person can attend public lectures in those branches of science with advantage. (Joyce, 1846)

The acquisition of knowledge, however, though in this case a secondary, is by no means an unimportant object; and the discussion of the several topics proceeds accordingly... (Rollo, op. cit.)

It was argued in Chapter 2 that the Conversationalist textbooks developed out of the school spellers and readers (cf. Maria Edgeworth in support of this view; also Jenkins, op. cit.). Recall that the preface to the Rollo Series book on Air mentions that "teachers have, in some cases, done the author the honor to introduce some of the preceding works of this class into their schools, as reading books..." (Rollo, op. cit.). Such views help to answer the fourth framework question, concerning the most appropriate language for writing about science. For not only the Edgeworth and Rollo textbooks, but the also very popular Scientific Dialogues of the Rev. Joyce mention the importance of reading as a method of learning.

The Author conceives, at least, he shall be justified in asserting, that no introduction to natural and experimental philosophy has been attempted in a method so familiar and easy as that which he now offers to the public--none which appears to him so properly adapted to the capacities of young people... (Joyce, op. cit.)

Conversation, with the habit of explaining the meaning of words, and the structure of common domestic implements to children, is the sure and effectual method of preparing the mind for the acquirement of science. (Quoted from Edgeworth's Practical Education, on the frontispiece of Joyce, 1821)



The Conversationalist writers, then, are seen to express two main purposes. The first is a purposeful use of this style based on a belief in the method of conversational story-telling for learning. The second is a commitment to the value of secular knowledge in the life of the child. Reference to religious purposes was generally absent from these texts' prefaces.

What is still not present in the preface statements are any comments on the nature of science, or the place of a text in science education. 'Young people' and 'children' are felt to need an introduction to scientific information, but science is not seen as a discipline of study. A final quotation from the Rollo preface, in a passage preceding the one cited above, emphasises this point.

The main design in view, in the discussions which are offered to the juvenile world, under the title of The Rollo Philosophy, relates rather to their effect upon the little reader's habits of thinking, reasoning, and observation, than to the additions they may make to his stock of knowledge. The benefit which the author intends that the reader shall derive from them, is an influence on the cast of his intellectual character... (Rollo, op. cit.)

The prefaces to both the Catechetical and Conversationalist texts were generally very brief statements. They contained no reference to school science, the laboratory or the connections between science and experiment.

#### THE PREFACES TO THE EXPERIMENTALIST TEXTBOOKS

It was the Experimentalist writers who laid the greatest emphasis on science as a method, convinced that it was this methodology which gave science its uniqueness as a discipline of

study, and constituted its greatest contribution to the life of the student. Therefore it is their answers to the third framework question, the nature of science as an activity, that dominates their prefaces. While it is true that some scientists divided the sciences into the Observational (such as Botany) and the Experimental (such as Chemistry), the shared conviction of the Experimentalist writers was that science was best seen as a collection of techniques guided by a commitment to a unique form of enquiry.

This is not to say that these writers were uninterested in teaching the readers the fundamental principles of the various sciences. On the contrary, it is important to realise that the Experimentalist writers were convinced that their approach would positively aid the learning of fact, principle and theory relevant to the science being dealt with in the textbook.

In publishing the Science Primers on Physics and Chemistry, the object of the Authors has been to state the fundamental principles of their respective sciences in a manner suited to pupils of an early age. They feel that the thing to be aimed at is not so much to give information, as to endeavour to discipline the mind in a way which has not hitherto been customary, by bringing it into immediate contact with Nature herself. For this purpose a series of simple experiments has been devised, leading up to the chief truths of each science. (Balfour Stewart, 1884)

The above quotation comes from Balfour Stewart's Physics. The exact wording is also included in another of the Macmillan Science Primers, Roscoe's Chemistry. It is clear that while the "fundamental principles" of the sciences are not to be neglected, it is disciplining the mind to a particular way of operating on the world that is crucial to learning those principles. Nature must be directly consulted by the learner,

and Nature does not respond to any sort of questioning. Only when those questions are couched in the form of "experiments" does Nature reveal her answers.

The prefaces do show, however, that this shared conviction did not always lead to shared views on teaching or pupil activity. Consider the following two extracts, the first from the preface to H.E. Roscoe's Chemistry, first published in 1872 and reprinted 32 times up to 1913.

These experiments must be performed by the teacher in regular order before the class, or better by one pupil, or two pupils jointly, under his superintendence. The power of observation in the pupils will thus be awakened and strengthened...

The second extract is from Hooker's Botany (op. cit.)

In using this Primer the plants indicated are, whenever possible, to be put into each pupil's hand...

There are still traces, then, of a felt difference in the value of actually having students perform the activities. Exposure to the method was perhaps assumed to be enough. Another piece of evidence from the prefaces re-emphasises the feeling among the physics and chemistry writers that experiments were preferably to be done by the teacher as demonstrator.

The whole of the apparatus needed for all the experiments...will be supplied by Messrs. J.J. Griffin and Sons, 22 Garrick Street, Covent Garden, London, W.C., for L19 3s. 8d. exclusive of packing. (Balfour Stewart, op. cit.)

Included in the back of these physical science Primers was a statement concerning the proper method of demonstration of each experiment, including this quotation from Roscoe.

Faraday, our great master in experimental lectures, always devoted many hours to the preparation of the experiments for each lecture. No point, however trifling, bearing upon the success of the experiment was considered

unimportant; he used to try the stoppers of all the bottles he had to use to see that they had not become fixed, and thus would cause delay by requiring forcible opening. (Roscoe, op. cit.)

This emphasis is very likely due to the relative scarcity of well-equipped physical science laboratories, and teachers trained in experimental methods, a point detailed in Chapter 1. The role of the textbook--the first framework question--was not explicitly discussed in these prefaces. Given the Experimentalists' insistence on the primacy of the experimental method, it is perhaps surprising that many of them still issued textbooks. The best known of these were published as ten Science Primers published by Macmillans: T.H. Huxley's Introductory, Roscoe's Chemistry, Balfour Stewart's Physics, Geikie's Physical Geography and his Geology, Foster's Physiology, Lockyer's Astronomy, Hooker's Botany, Jevon's Logic, and his Political Economy. All were published under the joint editorship of Huxley, Roscoe and Stewart. The long publishing lifetimes of these textbooks, to which reference has already been made, plus the reputations and commitment to science education of the authors, argue for their considerable influence. But it was not to last for very long. By 1914 Macmillan was publishing textbooks reflective of the new demands made on education by compulsory secondary schooling, demands which seemed to place greater emphasis on the body of knowledge of each scientific discipline rather than on the methods. A textbook which may capture this transition, and which does mention, very briefly, the role of the textbook, is Gregory and Simmons' Introductory Chemistry, published by Macmillan in 1914.

A course of work in elementary science must include not only practical exercises to be performed by each pupil, but also sufficient consideration of principles to enable the purpose of the experiments to be understood and the results to be coordinated. Lectures and descriptive text bring together the separate facts collected in the laboratory, and without them much of the practical work tends to become mechanical and meaningless.

In the present book an endeavour has been made to provide a course of work in which practical exercises and the principles they exemplify both receive attention. (Gregory and Simmons, 1914)

The key to the change about to become dominantly conveyed through the Formalist textbooks can be seen in two phrases from the preface quoted above: "a course of work", reflective of emerging concerns with courses, syllabi and examinations; and "practical exercises", reflective of the view of the laboratory lesson as illustrative of physical science practice and results, rather than the key to "disciplining the mind in a way which has not been hitherto customary..." as expressed in the Experimentalist prefaces.

Another Experimentalist text to discuss the role of the textbook in science education was Perkin and Leans's An Introduction to Chemistry and Physics. They mention the controversy over the role of the textbook in education, most likely in response to the criticisms of Armstrong mentioned in Chapter 2.

It has been the fashion lately among some to decry any use of text-books. It is very noteworthy that young boys (aet. 12) learn very little from a chapter in a text-book, while it is equally remarkable how an older class (aet. 16) may realise, with fidelity of detail, experiments they have never seen, and make rapid progress with comparatively little help from a master....

We know that many teachers have found our book more useful to themselves than to their classes; an able boy can perhaps do without a text-book entirely, but his duller comrade often needs a helping hand in the revision of his work. It need scarcely be pointed out that there are experiments

for which detailed and frequent instructions are necessary, and in such cases the necessary information may be obtained by a boy directly from a text-book, and its use will remove a burden from the teacher. And further, it is a great convenience to have mathematical examples in type...But enough of detail; every teacher must work in his own way to do his best work. (Perkin and Lean, 1906)

From this passage it can be seen that some Experimentalist authors did not see the text as having an important role to play in teaching or instruction, but only in informing and providing numerical problems. Indeed, among brighter pupils it could be dispensed with altogether. This conservative view of the importance of the textbook in science education is partly due to the emphasis that the Experimentalists wanted to place on enquiry, and on disciplining the mind, rather than on accumulating facts. It is also partly due to an expressed conviction that teachers have a degree of autonomy that must be respected. This latter conviction has survived into the Formalist textbooks, as will be shown, but the former view can be seen in current general science texts which emphasise enquiry, but have changed their content to 'activities' to further that enquiry, in contrast to the Experimentalists whose texts supported an enquiry into a specific discipline.

It can be seen that the main interest of the Experimentalist writers was with the third of the framework questions--what is the nature of science as a human activity. There are no discussions of the appropriate language for science education (the fourth question), or of the place of science education in the curriculum (the second). The latter may be due to the fact that just such a debate was taking place outside the schools on a political level, as outlined in Chapter 1.

## THE PREFACE TO THE FORMALIST TEXTBOOKS

A set of purposes common to the Formalist textbooks is more difficult to specify, because they are written with a varied set of audiences in mind. With the establishment of science as a school subject towards the end of the 19th century, and the accompanying proliferation of courses for students with different abilities and/or interests, the purposes of the authors become varied. It is possible, however, to see some common concerns expressed in the prefaces.

The first of the framework questions used to analyse these texts is: what is the role of the textbook in science education. Several characteristic responses to this question can be found in the Formalist prefaces.

### 1. Links with examinations

From the earliest days of the Formalist school textbook in the mid 19th century up through today, one central purpose has tended to dominate: they are, almost without exception, written to match syllabus or examination demands.

The work is designed primarily to cover the Intermediate Pass Course in Science, Engineering, and Medicine of the University of London, but it is also suitable for Intermediate Honours Candidates and for University Scholarships. Further, it meets the requirements of the Civil Service Commissioners in connection with Junior Appointment, the Post Office (Engineers), and the Army Entrance Examination. (Allen and Moore, 1918)

The above quotation is one of the more excessive. But it is echoed in the majority of all Formalist textbooks.

This small volume is intended as an introduction for beginners, and primarily for those who are reading for the South Kensington Elementary Examination in Magnetism and Electricity.

(Poyser, 1894)

This book is intended primarily to meet the requirements of the Oxford and Cambridge School Certificate Examinations. (Bailey and Bausor, 1914)

In this book an endeavour has been made to cover the syllabuses required in Physics for the Intermediate, the Higher School Certificate, and Scholarship Examinations of the various Universities. (Smith, 1944)

The inclusion of this extra material has enabled a complete course in Inorganic Chemistry to be provided for several examinations which are intermediate in standard between the ordinary and advanced levels of the General Certificate. (Cavell, 1946)

This book provides a suitable course of study for the Leaving Certificate Examination in Physics, as prescribed by the University of Melbourne. (Stump and Rowlands, 1950)

The course provided in this single volume is designed as an introduction to physics and has been written with the needs of the CSE student especially in mind. (Chaplin and Keighley, 1977)

The works cited cover a span of 83 years, starting roughly at the time of compulsory secondary education in the Commonwealth. Examination requirements are not a concern for the autodidactic textbooks, and the prefaces to the Experimentalist text tend to emphasise other concerns.

It may be argued that this over-riding purpose of the Formalist textbooks reflects a convenient way for the writers to select content. What a textbook can accomplish, however, must surely be a function of what it contains. By making the textbook subject to the demands of outside influences, the text serves a purpose that may be in conflict with purposes which can be better served by such written material. More specifically, a clear danger is that the need to 'cover the ground' will force a style of rhetoric, or instructional methodology, inconsistent



with wider educational aims, such as those found in the earlier Catechetical and Conversationalist texts. Armstrong (1903) was particularly scathing of this characteristic of Formalist textbooks.

I notice that it is customary in University Extension courses to preface the syllabus--itself an invention of the enemy--with a list of text-books...Don't look at a textbook; avoid most of them as you would poison. Their methods are as a rule detestable and destructive of all honest effort toward development of powers of self-helpfulness; the worst offenders usually being such as are written by those who have 'felt a want' in connection with some particular examination. (Armstrong, 1903)

An important point emerges clearly from this concern of the Formalist textbooks with examination demands. The language of the textbook is concerned with correct descriptions or representations of matters of fact or knowledge. To this is added the strong constraint to present information in such a form that it can be easily translated into examination answers. Recalling that the Formalist textbooks were mainly written by teachers familiar with the pressures and format of external examinations, it is only to be expected that the language of the textbook would come to adopt characteristics suited to the ultimate goal of getting students successfully through such examinations. The specific nature of those characteristics needs detailing, therefore, and such detail will be the subject of Section C of this thesis.

## 2. The textbook as a collection of knowledge

A view often expressed in these prefaces is to see the text as a compilation of the important or unifying principles of science in a convenient form. The following selections are typical.

...it is hoped that a study of the following pages

will furnish the student with a comprehensive knowledge of the essential principles of Elementary Physics... (Smith, 1944)

In writing this book, the aim has been to provide a complete course in elementary theoretical and practical chemistry. (Cavell, 1946)

The book is intended to meet the syllabus adequately without being excessive, and the systematic and compact presentation employed should simplify the task of the student to grasp the essentials of the subject with true understanding. (Barrell, 1958)

An essential characteristic of this purpose is succinctly summed up in the preface to the Everett Text-Book of Physics (1901). Everett states the aim of his textbook as "not so much to teach them many facts, as to teach them rightly to connect a few great facts together." (op. cit.). The distinction between "facts" and the knowledge needed to "connect them together" is a crucial one. The prefaces clearly express the view of science as a collection of facts bound into a coherent whole by a set of principles. Everett implies that his text has the purpose of teaching those connecting principles, rather than training or disciplining the mind of the readers in such a way as to develop the ability to make such connections themselves. However, as the number of 'great facts' increased, the authors had to select from an ever-growing collection of material. One result of this can be seen in the fifth edition, 1970, of G.R. Noakes' New Intermediate Physics, which reached 965 pages. In his preface, Noakes claims that the book "ranged less widely" than the four separate volumes that preceded it; and that "although the book is subdivided in the usual way, it really represents the subject as a coherent whole, by emphasising that the same basic principles apply throughout." (Noakes, 1970).

The majority of Formalist writers, however, were more pre-occupied with finding criteria by which to select content from the vast range available, and having made the selection, attempting to demonstrate their essential unity.

This expansion of the science (of electromagnetism) and of its practical applications has rendered more difficult than before the task of presenting with sufficient clearness, yet with necessary brevity, an elementary exposition of the leading phenomena, and of their relations to one another. (Thompson, 1901)

To bring the subject within the compass...described, an account is given only of phenomena which are of special importance, or which appear to throw light on other branches of Physics, and the mathematical methods adopted are very elementary. (Poynting and Thomson, 1925)

...as to subject matter they (the authors) have included in this book only such subjects as touch closely the everyday life of the average pupil. In a word, they have endeavored to make it represent the everyday physics which the average person needs to help him to adjust himself to his surroundings, and to interpret his own experiences correctly. (Millikan and Gale, 1927)

When arranging a course of instruction for intermediate students...one is met with the difficulty that the range of subjects which may be dealt with is so large....The result..is that the teacher has either to attempt to cover all the ground..or he has to limit the number of subjects which he will consider. The author believes that this latter alternative is the better one... (Watson, 1932)

The selection criteria may differ, then, but the aim is to present a course of study within the bounds of the selection that reflects the main principles of the subject.

### 3. The textbook as link between scientist and learner.

The extract cited above from Millikan and Gale serves to introduce another common theme of science textbooks: to point

out the applications of scientific principles to ordinary life, or, conversely, to use every-day experiences to build up increasingly complex scientific concepts. Either way, the intention is to link the scientists' world view with the students'. There are two different justifications for this view expressed in the prefaces. The first is an educational, or pedagogic one.

It appeared to me to be plainly dictated by common sense, that the teacher, who wishes to lead his pupil to form a clear mental picture of the order which pervades the multiform and endlessly shifting phenomena of nature, should commence with the familiar facts of the scholar's daily experience; and that, from the firm ground of such experience, he should lead the beginner, step by step, to remoter objects and to the less readily comprehensible relations of things. (Huxley, 1891)

And almost 60 years later another Huxley was to continue the argument.

We have wished to present science not as a 'school subject', but as a living body of knowledge which is interwoven into everything around us, whether machines or manufactured articles or the play of natural forces, whether the life of the fields or the mysteries of the laboratory. (Andrade and Huxley, 1934)

This view is directly related to the child-centred pedagogical beliefs that had entered Britain mainly through the work of Pestalozzi. In this sense the textbook of Huxley (*Physiography*, 1891) and others with this view can be seen as responsive to models of child development and learning. But by far the most common justification is to provide the scientific content with the necessary relevance, not explicitly linked to learning, but to convince the student that what is learned can be applied. Examples of prefaces stressing the applications of scientific

knowledge to every-day life are so common that only two, very typical statements will be cited in evidence.

...care has been taken to stress the many illustrations and applications of physical principles in everyday life. (Smith and Smith, 1949)

The treatment follows the course of discovery by experiment, and proceeds to the consideration of practical and technical applications. (Kearsey, 1971)

The distinction that these textbooks make is a curious and subtle one. Either the experiences of daily life are used to illustrate and illuminate the concepts of science (the pedagogical view) or the concepts of science are used to illustrate and inform daily experience (the relevance view). In the former, the author is searching for concepts and understandings from the readers' world that will help make the scientific ones more familiar and, therefore, more easily learned. If this was consistently applied throughout the text, it may be argued that the author was influenced by ideas from learning psychology. In the latter, the author is attempting to show that science can add to and illuminate experiences in the readers' world; science, therefore, is relevant and applicable to everyday concerns.

#### 4. Textbook sequence

There is another way in which the content of the Formalist textbooks is seen to be similar, and that is in the sequence of the topics included.

The great majority of general physics textbooks order their content from classical mechanics through optics, heat, hydrostatics, to electricity and magnetism (Newton, op. cit.). Chemistry too shows such an ordering, though not quite as

rigidly as physics. Chemistry texts tend to deal first with classifications: elements, mixtures and compounds; physical and chemical changes; solutions and colloids; acids, bases and salts. This is either immediately preceded or followed by discussion of the atomic theory and symbols. This classification section is then followed by detailed treatments of substances: air, water and metals; halogens; or separate chemicals.

This sequence can be argued to result from one or more of three influences. Firstly, it can be responsive to learning psychology, in that the sequence of topics is reflective of an attempt to take the reader from the basic underlying principles to the more complex. In this view, an analogy can be constructed with the child's intellectual development.

Secondly, in both physics and chemistry, these orderings of content are rarely argued to be an historical sequence, but rather reflects the logical ordering of the material. The American PSSC textbook makes this point explicitly.

The topics in the PSSC course are selected and ordered to progress from the simple and familiar to the more subtle ideas of modern atomic physics. (PSSC, 1960)

It is important to note that the PSSC textbook is one of the very few to use a different order of content; they start with motion, but develop an atomic model before investigating optics and waves, leaving the treatment of mechanics to the third section of the textbook. (Chaplin and Keighley, 1977, is another exception, starting their textbook with light).

And thirdly, there is the possibility that the sequence reflects the power of tradition. In the great majority of textbooks

there is no justification given for the choice of sequence; the unspoken assumption is that this is the order in which the science must be learned. Nor do Formalist textbooks often argue that the teacher should feel free to use the chapters in any order. This can be contrasted with preface statements from modern general science textbooks. Writers of general science texts are apparently quite aware that they are writing for readers of mixed ability. They have responded to this in two ways, the first of which is illustrated by the two examples that follow.

It is assumed that teachers will respond to the excess of material in the text by selecting from it to suit the level of ability, interests and academic requirements of those in their charge. (Criddle, Izett and Ryan, 1975)

Book 1 introduces students to Enquiry Science in their first year of secondary schooling. The book is divided into thirteen independent modules, each module consisting of a variety of experimental 'Activities' where consideration has been given to Piaget's "concrete stage" of conceptual development. However, the number of 'Activities' completed by any group will largely depend on the ability of the students in that group. (Comino and Ryan, 1978)

These writers distinguish between difficult concepts and, presumably, simpler concepts. But there is generally no distinguishable pattern in the ordering of their content; as the Comino and Ryan text makes clear, the separate units are 'independent'. This independence would imply that sequence is not an important part of any learning theory. Other general science authors, however, are concerned with sequence.

...although the Guide is written apparently in sequence with an organized development of concepts and vocabulary, it is not intended that the sequence should be followed rigidly. Nevertheless, departures from this sequence will need careful thought to deal with possible

omissions and conceptual difficulties. (Nuffield Combined Science, 1970)

Jardine's Physics is Fun, though not a general science text, makes the same claim: "...this book is designed to be worked through chapter by chapter...I believe this is one of the sacrifices that must be made if a usable teaching book is to be produced." (Jardine, 1969). Writers such as those responsible for the Nuffield text above are more concerned with the logical development of the subjects under consideration, rather than with the psychological development of the learner. In this, they closely resemble the Formalist authors.

Finally, most textbook writers express a rather conservative view of their role in the classroom; authors have been reluctant to tell teachers how to use their texts. Writing as they must for large classes of mixed abilities, and for use in classrooms of very different methodologies, this may not be surprising. And, unlike the Catechetical and Conversationalist authors, the Formalist writers do not generally express the purpose of positively influencing the readers' attitudes towards science. One of the most popular and long-lasting textbooks, Gregory and Hadley's (three editions and 22 reprints between 1909 and 1941) states in its preface that it is "designed not so much to inspire as to instruct." (op. cit.). No modern textbook makes any greater claim.

The second framework question used in analysing these texts is: What view of science is held by the authors?

#### Science as method or results.

American, British and Australian Formalist authors of all



periods generally hold one of two views of science, as expressed in their prefaces; it is either seen as an ordered collection of knowledge held together by law and theory, or it is seen as the sum of its techniques; i.e., a method. Science is presented to the reader as either Pure or Applied; Theoretical or Practical. The distinction was clear at the beginning of the Formalist textbook dominance in schools.

#### Knowledge

This book is primarily intended as a text-book for elementary classes of Physics. It aims at presenting, in brief space, those portions of Theoretical Physics which are most essential as a foundation for subsequent advances, while at the same time most fitted for exercising the learner in logical and consecutive thought. (Everett, op. cit.)

#### Method

Not merely, or even mainly, to impart information, but to set before the student a large and compact body of truth obtained by a method which shall remain for him, throughout life, a pattern and norm of clear and correct thinking. (Crew, 1910)

The Formalist textbook prefaces, however, despite the presence of statements as emphatic as Crew's, are not concerned to give precedence to the elaboration of the Method, nor to developing scientific concepts through using the experimentalist approach. Nor does this elaboration appear within the body of the text. The Formalist textbook authors divide rather neatly into those who are writing textbooks of 'practical physics' or 'experimental chemistry', and those who pay lip-service to experimentation within theoretical considerations. Typical of the former are these preface statements.

The author believes that the experiments chosen throughout the book are presented in a newer and simpler form perhaps than heretofore...contriving details of laboratory method which will help beginners to obtain with certainty accurate

results even in difficult experiments such as finding the Coefficient of Expansion of a Gas and the Latent Heat of Vaporization of Steam. (Brown, 1945)

Chemistry, as a science, is based on experiment; laws and principles are grounded on fact. Pupils must realize this, and not theorize 'in the air'. Because true facts are obtained only by carefully observing relevant phenomena the need for the cultivation of the art of accurate observation has early been emphasised. (Taylor, 1933)

In this work for beginners an attempt is made to present the subject from a purely experimental standpoint. Statics is a study which affords excellent scope for practical treatment, and it is therefore very valuable as a means of training boys to systematic thought and deduction. Such training is always best achieved when based on the boy's own experience and achievement, and it is hoped that the performance of the thirty experiments outlined in this book, and the discussion of their results and consequences, will provide ample material for this purpose. (Hart, 1915)

The following pages are intended to serve as a book of reference to the student working in a physical laboratory...The aim of the book is to draw attention to those points which require care, and to indicate the sources of error which are common to all the instruments which are likely to be employed. (Watson, 1930)

To give an impression of these practical textbooks, a sample of the table of contents in the Watson text will be helpful. Chapter IV deals with Density, and includes the following: "29.Density. 30.The measurement of density--corrections for temperature of water and buoyancy of air. 31.Measurement of the density of a solid heavier than water by the method of Archimedes. 32.Measurement of the density of a solid lighter than water. 33.Measurement of the density of a solid in the form of small pieces--the pyknometer. 34.Measurement of the density of a liquid with a sinker. 35.Measurement of the density of a liquid with specific gravity bottle. Pages 79 -

92".

The concern with manipulation of equipment and measurement is very strong in these textbooks, emphasising the work in the laboratory at the expense of theory. Sometimes the techniques and skills are seen as directed towards the accumulation of data which can be used to illustrate a law of nature. For example, an experiment is described that enables the student to measure angles of incidence and refraction for a ray of light in air and glass. This is taken as confirmation of a law of refraction--such laws were themselves somehow 'derived' from numerous experiments and calculations of this sort.

The essential purpose of these practical textbooks is summed up in a single sentence from the preface to Allen and Moore's A Text-Book of Practical Physics, 1918: "...the development of men and women capable of doing good work under adverse or unfamiliar circumstances." It can best be thought of as 'training' rather than 'educating', and the language of these textbooks is strictly confined to the precise giving of instructions for successful laboratory practice. This is far removed from the Experimentalist approach which was to develop general powers of observation, inquiry, and so forth.

The theoretically orientated Formalist textbooks give laboratory practice a minor role to play, concerned as they are with the results obtained. Enough has been said about this approach already, and therefore only one example will be given.

As no textbook can take the place of experimentally illustrated lectures and of practical work in the laboratory, no attempt has been made to describe experimental illustrations of the various phenomena. (Watson, op. cit.)

This example comes from the small number of books which claim to

pay attention to the important role of the laboratory. Many Formalist textbook prefaces do not even mention the school laboratory at all. In chemistry texts, this minor role of the laboratory is more likely to be expressed through removing the experiments from the main body of the text itself.

The experiments described in the sections headed "Practical Illustrations" at the conclusion of the chapters can in most cases be performed with very simple apparatus, and as many as possible should be done by the student. The majority of them are also well adapted for lecture experiments. (Senter, 1919)

Full practical details for a large number of simple experiments have also been included at the ends of the appropriate chapters, and care has been taken to give the quantities of materials for these experiments, since their omission is a common cause of failure in elementary work. (Cavell, op. cit.)

Examples of the nature of this practical work attached to the end of the chapter show that they, like the physics ones, are interested only in verifying theoretical results or determining values of physical constants.

Experiment 43. To verify the Law of Constant Proportions by Making Magnesium Oxide by two Methods.

Experiment 45. To verify the Law of Multiple Proportions with the Oxides of Lead.

Experiment 46. To Determine the Density of Oxygen.

Experiment 75. To Determine the Weight of Carbon Dioxide given off when 100 gm. of Calcium Carbonate are treated with Dilute Hydrochloric Acid. (Mee, 1938)

Often associated with either view above is the insistence on plenty of numerical problem solving--from the working of such problems, comprehension grows. Many of them are taken from past Examination papers. It is not often suggested that such numerical problems are an integral part of science either as a method or as a collection of results. Rather, it is argued that

they are necessary to make the readers familiar with theoretical principles.

The third framework question used to analyse these textbooks was: What is the authors' view of the place of science in society and the life of the child?

Formalist textbooks are seldom concerned with this issue. In general, the American writers have been more concerned to place education in a social context--their prefaces are often long, carefully considering a wide range of educational issues. The following extract is from Bower and Robinson's Dynamic Physics, 1942.

One purpose of this book is to provide an understanding of the principles of physics necessary to cope with the present mechanized environment...Another purpose..is to help young people lay a foundation for successful careers in the field of science...A third purpose..is to stimulate critical thinking as a basis for intelligent action in a democracy. We are forever concerned with the preservation of our American way of life....In organizing and shaping the contents of this book, the authors have been guided by the Report of the American Policies Commission..in the direction of the four worthy aims laid down as a general pattern for education in a democracy... (Bower and Robinson, 1942)

None of the British or Australian Formalist textbooks are this explicit. The American text at least pays some attention to the placing of science in a socio-political context. They often contain the idea that all educational studies can serve wider, if not higher, purposes. It is tempting to assume that the American approach reflects their pragmatic view of science as a tool of 'better living'. Science serves the people in support of a positivistic faith in the progress of discovery in science and consequent increased material well-being. This latter

statement has been a characteristic of science textbooks regardless of country of origin.

The school text draws no clear distinction between science and technology; technological advance and scientific advance are taken as almost synonymous. Thus, school science, in stressing simultaneously technological advance and scientific method clearly embraces this positivistic ideal. (Smolicz and Nunan, 1975)

A recent textbook to make statements about what science is, and its relations to the life of the student, is the Australian Academy of Science's Elements of Chemistry, 1983. In the section entitled "To the Student", the authors state:

Chemistry has an important role in our lives--too important for any of us to be ignorant of it. This book provides the opportunity for you to become acquainted with chemistry as it affects you everywhere and all of the time. The intent of the book is to provide a blend of the facts of chemistry and the patterns, generalizations and theories of chemistry with applications of chemistry in our world. As you study chemistry, you are urged to ask continually 'How is this important to me in my everyday life?' (Bucat, 1983)

This is not of course as explicit as Bower's American textbook cited above, and it may be reflective of a concern for relevance rather than expressive of a view of the role of science in society or the life of the child. However it is intended, such a purpose does allow the possibility of the language of the textbook to refer outside of the body of knowledge which is distinctive to chemistry, to the world of the reader.

The fourth framework question asked: What is the appropriate language for writing about science in a textbook?

Few authors of Formalist textbooks make more than very brief statements about writing style or language usage, and their

relations to learning. As early as 1901 Thompson, in his Elementary Lessons in Electricity and Magnetism was stating his intent to present his material with "sufficient clearness, yet with necessary brevity." Gregory and Hadley (1941, op. cit.) stated that "A textbook should be concise in description and precise in instruction..." Barrell (1958, op. cit.) wanted to be "systematic and compact." Stump and Rowlands (1950, op. cit.) desired to be "clear and concise." Chaplin and Keighley (1977, op. cit.) believed that the use of colour and photographs would somehow make their text "easily readable." More attention, in fact, was paid to layout than language.

There were several over-riding beliefs concerning the 'proper' language for a textbook revealed by the examination of the Formalist prefaces. Firstly, the writing should be brief, or concise. The writers were anxious to remove unnecessary words and repetitions. In contrast to the Catechetical and Conversationalist texts, the Formalist texts were clearly not designed to match classroom dialogue or discussion. Secondly, the writing was to be precise; it had to say exactly what was meant, and express exactly what was the case. Thirdly, it was to possess great clarity. Exactly what is meant by this term is unclear (though the assumed meaning is close to 'explicit' and 'context-independent'), but it seems to have been a function of the first two characteristics, rather than a concern to match the language to the reader's abilities. It is of importance, however, that a concern to make textbooks concise, precise and clear will impose enormous constraints on the rhetorical style available to the author, who may, for example, decide as a result that the Conversational style is inappropriate. It may

also place enormous demands on the reader if it is too unfamiliar a style, or makes very little concession to the students' world view.

As the position of the textbook in science education became more assured, writers gave less and less space to a preface at all. The authors' comments have become limited to pointing out such changes to the textbook as 'the switch to S.I. units', or 'the more extensive use of graphs and photographs', or 'the inclusion of certain examination questions', or 'the inclusion of new topics in line with syllabus changes', or that they are 'responsive to teacher feedback'; i.e., "These comments have guided much of the revision incorporated in this edition."

#### SUMMARY

This chapter had the aim of identifying the important and characteristic purposes of the authors of physical science textbooks as revealed by the prefaces contained within those texts. The prefaces were examined against a background of four questions: the role of the textbook in science education, the view of science as an activity, the place of science education in the life of the student, and the language of the textbook. Each defined rhetorical type of textbook was seen to have its characteristic purposes. The Catechetical were shown to reflect ideological purposes in the inclusion of religious content within textbooks for autodidactic readers. The Conversationalists were guided by the purposes of teaching secular material through a dialogue format, felt by the authors to be highly valuable for learning. The Experimentalists wished to emphasise the values of the 'scientific' approach to



acquiring knowledge of Nature through experiment. While the principles of each discipline were important, the Experimentalists felt that the best approach to those principles was direct acquaintance of the learner with phenomena through the experimental method. And finally, the Formalist tended to emphasise the structured body of knowledge discovered by the various disciplines, further shaped by the matching of the textbook content and sequence to examination demands. The role of the laboratory was shown to be often supportive of theory work. Two additional characteristics of the Formalist texts were the emphasis on the application of learned knowledge outside the classroom through concerns for relevance, and the scant attention paid to the appropriate language (concise, precise and clear) for meeting those demands through a written textbook.

## SECTION B

This is the second layer of the analysis, with three main concerns.

Firstly, it uses aspects of genre-theory to begin the literary analysis of textbook language, an analysis that characterises texts by both structure and purpose. Those purposes were identified in Section A.

Secondly, it uses aspects of stylistics to further refine the classification of textbooks as works of prose.

Thirdly, it presents a second order classification of textbooks based on rhetorical and stylistic criteria.

CHAPTER 4: TEXTBOOKS AND GENRE THEORY:  
TOWARDS A MORE FUNDAMENTAL CLASSIFICATION OF TEXTBOOKS

INTRODUCTION: THE TEXTBOOK AS LITERATURE

A great deal of textbook (especially science textbook) criticism takes place under the assumption that a textbook is non-literary. The textbook, by being placed firmly in the non-fiction category, is seen to be a different kind of written production from the novel or the poem. And so it is, but the ways in which it is different are deserving of closer attention.

In many ways, fiction and non-fiction writings are very similar. In the process of writing both fiction and non-fiction, authorial meanings must be conveyed by words which are subject to the constraints of language. In both cases, too, it can safely be assumed that authors have purposes and intentions, the achievement of which depends on their skills as writers and not on their authority. Thus clumsy works which fail to engage the reader are failures in either domain. From the point of view of the reader, all written material demands interaction with presented meanings. It may be argued, of course, that in a non-fictional work the 'meanings' are intended to be less open to debate, less subjective. Nevertheless, the reader has a task to perform--to extract meaning from a text. Ronald Wardhaugh, in an article Reading Technical Prose, put it this way:

I would argue that reading is active, productive, and cognitive. It involves an active search for information and interaction with the text; it

requires the constant constructive involvement of the reader in what he is doing; and it demands the use of higher order mental abilities. (Wardhaugh, 1976)

This comment helps to make the point that any discussion or criticism of textual language, whether fiction or non-fiction, must take place against the consideration of what is to be understood by reading. This is also a view currently emphasised by research into literary style, a point developed in the next chapter.

Given these basic similarities, it is more difficult to see why textbooks have been disregarded by literary critics for so long. There is certainly a tradition of critical comment on style by reviewers of non-fiction. But this commentary has seldom attempted to use any well-established criteria for stylistic analysis. One consequence of artificially separating fiction and non-fiction has been the resulting loss of serious attempts to judge the writing of non-fiction by such literary criteria. Notions of quality and style, for example, have created a set of criteria of standards which critics have consistently applied to literary works. Of course, which works are valued by any one critic on any given scale will vary widely over time and culture. But agreement is not the issue here. What is important is that there is a very old tradition of literary criticism which has not only provided a theoretical background for the discussion of written works, providing insights and valuable referential knowledge; it has also provided a critical context which can act as a positive impulse to an author's self-criticism, resulting in works of higher quality. In a cultural setting in which quality of craft is being constantly

discussed, there is at least the opportunity to respond to actively debated ideas of good and bad writing. By being removed from such a setting, the writing of non-fiction is forced into arbitrary and ill-defined criteria of standards, or even lack of standards. For example, recall the lack of attention given to quality of prose in the prefaces of the textbooks considered in the previous chapter. These authors were not responding to a well-argued tradition of craftsmanship in textbook writing. This is not to say that the writers of all types of non-fiction are uniformly indifferent to their prose quality. As Peter Medawar put it:

No one who has anything original or important to say will willingly run the risk of being misunderstood; people who write obscurely are either unskilled in writing or up to mischief.  
(Medawar, 1974)

But without a background setting of criteria for and discussion of quality, it is difficult to see how writers can become skilled communicators in any medium.

#### METHODOLOGY

This chapter uses one area of literary criticism, genre-theory, not only to show how it may be applied to non-fiction, but also to develop useful terminology and classifications for textual analysis.

The decision to use genre-theory was not an arbitrary one. It was chosen after careful consideration of the possibilities for analysing textbook language offered by sociolinguistics, particularly the work of Bernstein (1971) and Halliday (1973, 1978). Sociolinguistics studies language in a social context. Three key ideas for characterising this context are referred to

as field, tenor and mode.

The environment, or social context, of language is structured as a field of significant social action, a tenor of role relationships, and a mode of symbolic organization. Taken together these constitute the situation, or 'context of situation', of a text. (Halliday, 1978)

Halliday associates the concept of genre with the idea of the 'mode'. Mode refers to the medium (written or spoken), but also to the range of functions that the language is serving.

The rhetorical concepts of expository, didactic, persuasive, descriptive and the like are examples of such semiotic functions....The various genres of discourse, including literary genres, are the specific semiotic functions of text that have social value in the culture. (Ibid)

Genre-theory, then, is seen by sociolinguistics as being concerned with the functions of language in a social context. To fully analyse how language functions in such contexts, all three of Halliday's concepts (field, tenor and mode) would be necessary. But the difficulty with adopting such an approach, given the purposes of this thesis, lies in determining the 'functions' of a textbook. Before that can be determined, it is necessary to examine the underlying structure and purpose of the textbook. In other words, before anything can be said about the functions of the textbook in a social setting, something must be known about the characteristics of that text, characteristics that determine how it is read, what is learned, and how it is learned. None of these characteristics have yet been determined for textbooks. Genre-theory can help to establish those characteristics, and in this sense is prior to any sociolinguistic analysis.

Section A has outlined the social context that influenced the authors' purposes; the historical context of science education.

It also provided a first order classification and characterisation of textbook types; Catechetical, Conversationalist, Experimentalist and Formalist. This Section places the textbook in a different context; the textbook as literature. Using the concepts of classifying and characterising literary works that arises out of genre-theory, it is possible to examine the relationship between the language of the textbook and the authors' views of science and science education even more finely than in Section A, because now the analysis shifts away from the context, and first order approximations, to the language itself.

#### GENRE THEORY

Genre-theory is an attempt first of all to classify written works.

Genre should be conceived, we think, as a grouping of literary works based, theoretically, upon both outer form (specific metre or structure) and also upon inner form (attitude, tone, purpose--more crudely, subject and audience). (Wellek and Warren, 1972)

Two key considerations come immediately from this definition; that of structure and that of purpose.

##### 1. Structures in Textbook Language

If classification were the sole value of genre theory, it would still be of use to this thesis. But it cuts deeper than that.

Theory of genres is a principle of order: it classifies literary history not by time or space (period or national language) but by specifically literary types of organization or structure. Any critical or evaluative--as distinct from historical--study involves, in some form, the appeal to such structures. (Ibid)

Genre-theory thus argues that we cannot evaluate a textbook

without examining the structures which textbooks embody and share. This makes the demand that an attempt is made to determine the distinguishing structures of textbooks. Structure can refer to a whole range of criteria, from the fixed grammatical structure of the work, to the lyric structure (e.g., iambic pentameter and dipodic) and on to whole complete units of prose, such as drama or short story. Identifying the important structures, and then using them for comparing like texts still may seem to be nothing but an identification and sorting process--though this alone would be valuable for textbooks, as there has been no serious attempts to develop a classification scheme by which they may be handled.

It is important to point out the close relationship between structure, rhetoric and genre-theory at this point. Traditionally, rhetoric has distinguished between types of prose by identifying varying purposes; e.g., expository, didactic, persuasive, and descriptive. (Croll, 1966). Rhetorical studies attempt to assign to each of these purposes the appropriate style; i.e., it was originally meant to be prescriptive. However, in reality each of these purposes may be couched in many forms. For example, expository purposes may be expressed through a philosophical treatise, a sermon, a poem such as Lucretius' On the Nature of Things, or an essay. Each of these will have a different outward form, but the same inner purpose. Genre-theory attempts to order prose works by reference to both these characteristics. Modern textbook do not differ markedly in terms of structure. There is no question of examining differences in such things as metre, or narrative versus epic. Nor is anything to be gained by looking for such characteristics



as illustrated by the phrase "Enforced abundance is the distinctive characteristic of the sonnet--pregnant expression of strong feeling with reflective profundity." (Hirsch, 1967). However, there has been a change in structure between the Catechetical, the Conversationalist, the Experimentalist and the Formalist texts. These differences would allow the placing of these texts into different genera if structure was to be the only criteria. The Catechetical would be placed in the traditional genre of Catechism, the Conversationalist in that of Childrens' Stories, and the modern textbook in that of Expository Text (Pearson, 1940). Before that should be done, however, the other criteria of purpose must be considered, especially as purpose is prior to text.

## 2. Purposes of Textbooks

It is in considering purpose that genre-theory touches directly on the topic of language in textbooks. In Section A a variety of authorial purposes were identified as characteristic of the four textbook types. From these various purposes it is possible to identify two distinct over-riding ones, expressed both in the prefaces and in the contemporary views of science education. Those two are the purpose to instruct and the purpose to inform. Regardless of subject matter, or the structures of the text, authors wrote their textbooks with one or both of those purposes in mind. These two purposes can be used to categorise two distinct genera. In an instructional genre, the main intention of the writer is to adopt those usages of language that will best move the reader from one position or level of understanding to another. Informational genera, by contrast, emphasise usages

intending correct descriptions or representations or matters of fact or knowledge. Examples of the language characteristic of each of these genera is given below.

Genre of Instruction: Examples

"I didn't know that the grass would burn so before," said Rollo.

"It will not," said his father, "unless it is both hot and windy. This is an illustration of what I explained to you the other day. When grass is heated above a certain point, it takes fire. Now, when one blade of grass is burning, it does not usually produce heat enough to raise the next one to such a degree of heat that it will take fire; but this afternoon it will; for now the heat of one little tuft burning is enough to heat the next one sufficiently to cause it to take fire, because it is already partly heated by the sun."

"And the wind helps," said Rollo (Rollo, 1855)

The earth, too, hangs in space as you sometimes see a balloon. Now is it at rest? or does it move? Perhaps you will say that it does not move, because your school-house is where it always was; that the houses or trees near to it are no further away or nearer than they were.

But this does not help us: let us take a large ball of worsted, or an orange, to represent the earth, and stick into it one pin to represent the school-house, and other pins to picture to you the trees and the homes around it.

You will see at once that whether the worsted ball or orange is at rest or in motion, the positions of the pins with regard to each other will not change.

How, then, are we to settle the question? (Lockyer, 1904)

Genre of Information: Example

When the temperature of a solid body is raised, in general the distance between any two points in the body increases, that is, the body expands. Thus a cylindrical rod of iron when the temperature rises increases not only in length but also in diameter. If we consider only the increase in length, we are said to deal with the linear expansion of the body. If, however, the change in volume is considered, we are said to deal with the cubical expansion of the body.

If a bar of solid is heated from 0 degrees C. to 1 degrees C., the ratio of the increase in length to the original length is called the coefficient of linear expansion. (Watson, 1932)

To place the passages from Rollo and Watson in separate genera

is clearly reasonable, as they differ in both outward form and inner purpose. To do the same for the passages from Lockyer and Watson may seem slightly arbitrary; they are certainly not as different as, say, epic poetry and Elizabethan drama. Nevertheless, they do show structural variations critical for distinguishing genera. Their structures may be more subtly distinct than the Rollo/Watson texts, but they show very distinct "inner forms" or purposes. All three texts, of course, share a common history within science education. But with the fundamental disagreement between authors as to whether science should be seen, and taught, as a method or as a body of knowledge came the division of the textbook into the two genera. This allows texts such as Rollo's and Lockyer's to be placed in the same genre of instruction despite their differences in structure, and texts such as Watson's to be placed in a genre of information. This distinction is a crucial one, and throughout this analysis, reference will be made to these two genera--instructional and informational.

As a result of the above analysis, the textbook classification developed in Section A can be seen to fit into traditional genre-theory classification in the following ways.

The Catechetical texts can be assigned to the genre of information. Their question and answer format, along with their purpose of presenting secular information to autodidactic readers without offering instruction, their view of science as a collected body of knowledge, and their concern to use that knowledge to reflect on religious and moral themes, provide characteristics appropriate for placing them in that genre.

The Conversationalist texts can be assigned to the genre of

instruction. Their purpose was not simply to present knowledge, but to use the story form to teach, considering it the most appropriate for learning. As shown by the passages in Section A, the story format emphasised finding out as well as information. The Experimentalist text are also placed in the genre of instruction. Their prefaces reveal a concern for the purpose of teaching science as a method, and the passages show a concern to lead readers along a trail of enquiry to reach conclusions. The Formalist texts are placed in the genre of information. Their purposes are revealed by the prefaces to be more concerned with science as a body of knowledge rather than as a method, and the quoted passages reveal an emphasis on stated results rather than on enquiry.

#### THE IMPORTANCE OF GENRE-THEORY TO LANGUAGE CHOICE

It is important to ask whether genre-theory is prescriptive of language use, or heuristically valuable only as an aid to classification.

Genre theorists argue a more important role for generic conceptions than classification and characterisation by structure and purpose. They bluntly argue that genre is necessary for communication.

Since a type (e.g., epic poetry) can be represented by more than one instance (e.g., The Iliad), it is a bridge between instances, and only such a bridge can unite the particularity of meaning with the sociality of interpretation. Certainly a communicable meaning can have aspects which are unique--indeed, every meaning does. But it must also belong to a recognizable type in order to be communicable.

...quite aside from the speaker's choice of words, and, even more remarkably, quite aside from the context in which the utterance occurs, the details of meaning that an interpreter understands are

powerfully determined and constituted by his meaning expectations. And these expectations arise from the interpreter's conception of the type of meaning that is being expressed. (Hirsch, 1967)

A writer has a meaning to convey--it might be about why metal bars expand upon heating, or the way jealousy can lead to murder. That meaning, Hirsch would argue, can only be communicated if writer and reader share a context of ways of saying. A unique meaning is unintelligible unless it is linked to the traditions of the genre. More specifically, if a reader is confronted with a passage that is known to be from a textbook, a set of 'meaning expectations' (Hirsch's term) are established--"In this type of utterance, we expect these types of traits." These expectations, fixed by experience with the genre, determine the details of meaning the passage contains. Again quoting Hirsch: "All understanding of verbal meaning is necessarily genre-bound." (Ibid)

For a writer of textbooks, a narrowed choice of language, structure and communicable meanings is already determined by choice of genre. A writer diverging too far from the genre takes risks of being misunderstood. For example, readers familiar with the genre of science fiction are not concerned to attach literal truth to the scientific or technological facts presented by the author. To cast a science textbook into that genre risks evoking similar responses from the reader. Genre theory suggests, therefore, that if an author intends a meaning to be, say, the laws of conservation of energy as foundations of physical theory, then by placing the discussion in a textbook, it can be assumed that the reader is already expecting a certain kind of meaning that helps with the actual meaning of the

particular instance. This can be very helpful, and taken advantage of.

More specifically, when authors start with a certain purpose in mind--for example, to inform readers of the underlying principles of physics--they presumably choose the rhetorical type they feel to be most appropriate for meeting that purpose. Traditionally, this has been expository. Secondly, as the stated purpose is to inform readers, they adopt the genre of information for their textbook. What they choose to say about those underlying principles will depend on their views of the nature of science and science education. Genre-theory argues that these choices will determine to a great extent what the author can say about the topic without risking uncertain meanings.

For readers, on the other hand, there is no substitute for carefully guided experience with the genre of textbooks. Readers familiar with the structures characteristic of that genre come to textbooks with a set of expectations about the kinds of meaning to be found there. It is crucial that the writer be aware of this.

Even when the meaning which the speaker wants to convey is unusual...he knows that in order to convey his meaning he must take into account his interpreter's probable understanding. If his interpreter's system of expectations and associations is to correspond to his own, he must adopt usages which fulfill not only his own expectations but also those of his interpreter.  
(Ibid)

Writers must be aware of the restricted 'usages' available to them if they wish to build on the shared past experiences of writer and reader.

## SUMMARY

The significance of genre-theory, and that of literary criticism in general, can be indicated quite simply.

Firstly, both this thesis and genre-theory are centrally concerned with notions of purpose. Genre-theory links purpose with usage, structure and meaning--all components of the language of textbooks, and all reflective of the authors' views of science and science education. It thus lends greater weight to the value of determining what the purposes of the textbook are, which was the subject of Section A. These purposes determined the placement of the texts in the genre of information (Catechetical and Formalist) or instruction (Conversationalist and Experimentalist). This connection between the first order classification of textbooks from Section A and generic classifications provides a basis for the second order classification argued for in the Introduction to the thesis.

Secondly, a further essential component of that classification is structure, another term used by genre-theory to characterise literary types. Section C examines the textbooks for structures which can then be interpreted in the light of genre-theory. Attention to prose structures designed to offer explanations or to instruct would then reveal a great deal about the usage, structures and meanings the textbook relies on. From the point of view of learning from reading, such an analysis would also indicate what shared expectations, associations and experiences the writer thought essential to bring to the text.

Finally, literary theory and criticism, in the guise of genre-theory, can throw a great deal of light on a consideration

of textbook language. This is possible, initially, by classification based on structure and purpose. This is then extended by pointing out the relation of both of those to authors' views on science and science education, as well as to reader expectations, and the matching of author/reader expectations through 'shared past experiences' with that form. There is a further factor in the determining role of genre in selecting communicable meanings--"all meaning is necessarily genre-bound". This in turn raises the question of the constraints genre places on usage and structure. All of these points suggest it is important to attach a greater significance to the textbook as a conveyor of genre-bound meanings, and on its language as a function of that meaning. They help provide a focus for a consideration of how the textbook functions educationally, where presumably well-determined meanings are being presented to readers.



## CHAPTER 5: STYLE AS A LITERARY CONSTRUCT FOR CLASSIFYING TEXTBOOKS

### INTRODUCTION

Up to this point in the analysis of textbook language, the term 'textbook style' has been used without clarification and specification. Connections have been made between the first order classification of texts in Section A and the 'style' of the four types of texts. Further connections have been implied between rhetorical types and the appropriate 'style' for each in the previous chapter. And genre-theory argues that 'style' is a component of generic classification because choice of genre determines language usage and, hence, style. But can the consideration of textbook style reveal anything about the relationships between textbook language and views of science and science education? Style, or more particularly stylistics, does have an important role to play in this analysis for the following reasons.

Firstly, one of the main concerns of this analysis, as outlined in the Introduction, was to develop a vocabulary through which to discuss the language of a textbook. Style is an attribute of language which, as will be shown, has been very loosely used and even more poorly defined. By spending some time attempting to give greater precision to the meaning of style, the discussion of textbook language will be advanced. Secondly, style is an important consequence of authorial decisions about purpose. The purpose to express a view of science education as using the methods of science will force stylistic patterns on the

resulting prose consistent with that purpose. Thirdly, style is sometimes a powerful determinant of textbook content and structure. For example, if concern for style is greater than concern for scientific accuracy, then the Conversationalist approach to textbooks is valid; style was often seen by both Catechetical and Conversationalist authors to be of greater importance than content. And such a decision will mean clear constraints on what can be said, how it can be said, and how other purposes can be fulfilled. And fourthly, style may have influences essential to the process of learning that cannot be realized without it--motivation, interest, retention, attention and recall are all factors that may be strongly influenced by the style of the writing. Style may be the rhetorical factor that not only gives access to the purposes and views of the author, therefore, but also gives the readers access to the information contained in the text.

#### METHODOLOGY

This chapter approaches these questions in the following way. First there is a discussion of what is meant by the terms 'style' and 'stylistics', the study of style. This is followed by a look at the historical development of modern expository prose style, of which textbooks form a subset. An analysis of the stylistic character of Catechetical and Conversationalist texts is given. This will necessarily be brief because of the restricted nature of these two types. The Catechetical texts are very tightly constrained by the question and answer format, and this allows few stylistic possibilities. The Conversationalist texts (being stories) are more suited to

analysis based on criteria from literary criticism. Finally a specific analysis of Experimentalist and Formalist prose style is undertaken. This approach is intended to be descriptive rather than theoretical--no new theories of stylistics or linguistics are being proposed. It is rather an extension of current thinking on questions of style to science textbooks that is being undertaken.

### STYLE AS A LITERARY CONSTRUCT

Any discussion of what is meant by style quickly runs up against the wide range of opinions as to what style is. Enkvist (1973) in an examination of style in literature, lists seven commonly used definitions.

...a higher, active principle of composition by which the writer penetrates and reveals the inner form of his subject...

...style as a shell surrounding a pre-existing core of thought or expression...

...as the choice between alternative expressions...

...as a set of individual characteristics...

...as deviations from a norm...

...as a set of collective characteristics...

...those relations among linguistic entities that are statable in terms of wider spans of text than the sentence...(Enkvist, 1973)

Comments on textbook style usually interpret style to mean either a set of individual or collective characteristics, to use Enkvist's distinctions. Below are some examples of these comments from research literature.

We raise the question 'How inconsiderate are children's textbooks?' because we suspect that many are very much so. Considerate text is clear and straightforward, enabling the reader to gather information efficiently, with minimal cognitive effort. A text that violates one or more of these maxims is inconsiderate. (Kantor et al., 1983)

"...highly formal..." "...unreal and remote..."  
 "...impersonal..." (Rosen, 1972)

"...verbose, obtuse and dull." (Mann, 1981)

The most common rhetorical style chosen by writers...is one sometimes referred to as 'textbookese'. It is an objective, unelaborated, straightforward style with an anonymous authoritative 'author' reporting a body of facts in one proposition after another. (Crismore, 1984)

It is not possible in all the cases above to judge if the writers were being critical or approving. What is evident is that certain key words are used in attempting to classify or describe textbook language--formal, objective, straightforward are the most value-free ones commonly used, with verbose/unelaborated as contrasts of opinion, and obtuse, dull, unreal and remote indicative of the subjective terms used. Whatever is actually intended by these terms is unclear. For example, what is meant by the term 'formal' when used to describe a literary style? Rosen (1972), using Halliday's above mentioned ideas of 'field', 'tenor' and 'mode' (Halliday, op. cit.) discusses textbook language by reference to 'register' analysis. In discussing the tenor of discourse (i.e., "how formal is the utterance?") of textbooks, Rosen uses the idea of a "relationship" between the writer and the reader. Relationships can be either formal (and impersonal) or, supposedly, informal (or personable). With respect to textbooks, Rosen says: "This writer-reader relationship is the more sophisticated by virtue of its tenuousness. How unreal and remote this is for the ordinary pupil." (Rosen, op. cit.). Thus 'formal' is taken in the sense of a formal relationship with someone. The defining characteristics of such a

relationship, even assuming this is the appropriate metaphor, are not made clear, except through such phrases as 'tenuousness, unreal and remote'. They are certainly not exclusive to textbook language, as exactly those words can be used to describe works of fictional literature.

The authors of textbooks have not done much better themselves, except that their descriptions of their language have been intended to be positive. The following terms are to be found in the textbooks themselves: concise, precise, systematic, compact, clear, and simple. Objectivity is a characteristic that seems to have been taken for granted. Comparing the two sets of terms, those of the researchers and those of the authors, there is not a great deal of overlap, unless one is to argue that 'formal' and 'straightforward' means 'concise' and 'precise'. As well, critics of textbook prose such as Kantor et al. (op. cit.) would deny that the authors have indeed been 'clear' and 'simple' even if they have met their other criteria. Even so, the authors of textbooks have been equally remiss in their neglect of providing meaningful definitions of the terms they use to characterize their writing. For example, what is meant by the term 'precise' in textbook language? Presumably it is close to the dictionary definition of 'accurately expressed'. But of course this is only a claim that the expressions are free from error, or convey the correct meaning. The former claim is simply the reasonable expectation that any textbook be accurate in matters of fact. The latter begins to encroach on the area of pedagogy by consideration of meanings. It is also a claim that can apply to fictional writing and literary criticism that is concerned with meaning. It is also unclear why the writers

of the textbook believe that such language is most appropriate for their purposes, or why teachers and readers should value such characteristics.

The question arises as to whether it is possible to speak more precisely about the stylistic characteristics of a given piece of prose. Stylistics attempts to develop an objective account of what appears on the surface to be a highly subjective literary phenomenon. Rival theories of style have developed, particularly over the last 50 years, but all were given an initial impetus with the work of Charles Bally. His early works (Bally, 1909) developed the linguistic model previously formulated by Saussure, extending it to include those non-conceptual components of language, of which style is one.

Thought has two aspects: the conceptual and the non-conceptual. The former is a result of convention while the latter has its source in personal expression and emotion. That is, thought is a product both of objective, conventionally determined concepts and of subjective and private feelings, attitudes, motives, perspectives, etc. (Bally, in Taylor, 1980)

This dual nature of thought, and its expression in language, creates for Bally a dialectic, a struggle between the desire to express individual, private feelings, and the necessity to use conventional, determined concepts to ensure being understood at all. This is closely related to similar claims within genre-theory concerning meaning being 'genre-bound'. Stylistics became the study of those language 'elements' which express the emotions. A particular style will be determined by the ways in which those emotions are successfully communicated.

Such a view of style is clearly psychologically based, and later stylists have been concerned to be far more analytical than

Bally, if not more objective. The stylistician Riffaterre changed Bally's emphasis from the subjectivity of the message to the role of the receiver of that message.

...the object of the analysis of style is the illusion that the text creates in the mind of the reader. (Riffaterre, 1971)

The stylistic context is a linguistic pattern suddenly broken by an element which was unpredictable, and the contrast resulting from this interference is the stylistic stimulus. (Riffaterre, 1959)

The reader becomes aware of the style of a particular passage when he or she finds unexpected (unexpected as determined by context) linguistic elements within the passage that act to call attention to the unique viewpoint of the writer. Stylistic analysis is then the task of identifying these unexpected elements. As Taylor points out, "In this way the reader's perception plays a large role in the determination of stylistic structure." (Taylor, op. cit). This emphasis on the role of the reader was later extended by Dillon as stylistics began to use the ideas of Chomsky and information processing.

The way a writer chooses to frame sentences and place their elements does affect the reader's cognitive processes in predictable ways which analysis can explicate, but via the strategies of processing: a particular construction or preference of a writer is important insofar as it affects processing of the text. In this way, stylistics becomes concerned...with the way texts and readers act on each other. (Dillon, 1978)

Transformational grammar was apparently successful in answering many questions about how differences in style could be produced from the underlying deep structures of the grammar, but the difficulty still remained about how these stylistic differences can affect the reader; i.e., how do the transformations determine the communicational effectiveness of the writing?

As a result of the work of Dillon, stylisticians recognised the need for a model of reading to complement earlier work. Again, this has close parallels with genre-theory, which also demanded some account of what it means to read works in different genre. Modern stylisticians since Dillon have been using information-processing models to answer this need.

Enough has been said to suggest that 'style', whatever it is, cannot be defined simply by referring to characteristics of the written message alone, but is a complex relationship that exists between the text and the reader.

...if terms like 'loose' or 'terse' or 'emphatic' (to take examples from the traditional vocabulary of stylistics) have any significance as descriptions of style--and surely they do--it must be because, like the description 'complex', they relate to certain identifiable structural properties...What the impressionistic terms of stylistics are impressions of are types of grammatical structures. (Thorne, 1970)

What remains to be explained of course is the fact that different styles, different characters of surface structure, different foregroundings, have profoundly distinct consequences in the readers experience...To be more exact what do transformations (of grammar) do to us? (Fowler, 1972)

Stylistics is stating that access to precise statements about style can only come from careful application of the rules of transformational grammar; all our other notions are simply impressionistic and intuitive. In order to capture a complete picture of style, a model of reading is also required. This means judgement of a textbook in isolation from its readers is inadequate. What is also required is a way of discussing the impressionistic and intuitive notions that are evident, and which do capture some of the essential differences between such obviously different types of writing as, say, the



Conversationalist and the Formalist.

There is at least a long history of debate over what styles are being used at any given time within a society, and which styles are 'best' or most appropriate for given communicative purposes. These studies are grouped under the discipline of Rhetoric. A fuller discussion of the history of that debate allows this analysis to not only examine some possibly rigorous meanings for different prose styles, but also to place the language of textbooks within an historical framework of ideas about style.

#### RHETORIC AND PROSE STYLE

Studies of rhetoric traditionally start with Aristotle, and for the purposes of this analysis the seminal work of Morris Croll will provide the framework for discussion. His essay, "'Attic Prose' in the Seventeenth Century" traces the rise of a prose style suited for the purposes of philosophical discussion from the days of the Greek philosophers to the seventeenth century. At the time of Cicero there were three recognized prose styles.

In the time of Cicero it had become customary to define the character of the three genera more fully by a reference to the effect of each upon the audience. The genus humile is best adapted to teaching or telling its hearers something; the genus medium delights them or gives them pleasure; the genus grande rouses them and excites them to action. (Croll, 1966)

There are interesting parallels between the ideas of stylistics concerning the role of the reader, and the classification of rhetorical types based upon intended effects on the audience. The main concern of this section is with the genus humile, or common style, which in the 17th century was known as the Attic

style. Aristotle gave three essential characteristics of this style--clearness, brevity, and appropriateness. It is important to examine each of these in turn.

1. Clearness. Though expressed in varying and often ambiguous ways, clearness was often defined by contrasting it with its opposite, deliberate darkness. It referred to the attempt to "depict the effort of the athletic and disciplined mind in its progress toward the unattainable goal of ultimate knowledge." (Ibid). In science textbooks, clearness is regarded as a virtue.

Clearness is evidently the first merit of an exposition of objective reality, as in the statement of the facts and laws of natural science; Aristotle occasionally had such exposition in his mind, and, partly on his authority, there have been in modern times several attempts to erect the theory of style on the foundation of mere scientific clearness. (Ibid)

This concern for clearness, as has been shown, is still present in textbook prefaces.

2. Brevity. Croll has given a slightly more descriptive idea of what is contained in the idea of brevity.

It is a quality that is almost necessarily involved in the attempt to portray exactly the immediate motions of the mind. In the history of all the epochs and schools of writing it is found that those which have aimed at the expression of individual experience have tended to break up the long musical periods of public discourse into short, incisive members, connected with each other by only the slightest of ligatures, each one carrying a stronger emphasis, conveying a sharper meaning than it would have if it were more strictly subordinated to the general effect of the whole period. (Ibid)

Here is a meaning of brevity that is perhaps not identical to what is meant by the term when used by textbook authors, for whom brevity means to say a lot in only a few words. For

Aristotle, brevity means a structural change, letting smaller units carry more immediate meaning. What is to be shed are all features felt to be superfluous to the intended meaning. There is no mention of the need to condense thought into a smaller package, the main result of which is increased abstraction rather than clarity or ease of understandability. As well, brevity was seen as more suited to private, personal communication as opposed to public discourse. But as has been claimed for 'textbookese', one of its characteristics is an anonymous author giving the reader access to public information.

3. Appropriateness. The third characteristic is appropriateness, which is also a chief focus of this study.

Aristotle does not clearly define what he means by it, but it is evident that he thinks chiefly of appropriateness to the character of the audience addressed and the nature of the occasion: a style should adopt itself to the social requirements of the discourse, and not be, for instance, either too lofty or too mean for the kind of audience contemplated. (Ibid)

This idea of appropriateness is closely allied to the linguistic notion of 'register', the combination of field, tenor and mode already referred to. Croll goes on to argue that this meaning of appropriateness was not suited to the views of the Stoics who followed Aristotle, and who subsequently modified it. The nature of this modification is crucial to the understanding of textbook language. For the Stoics, appropriateness had two aspects, appropriateness to thing and to person.

If (as Lipsius defines it) "everything is said for the sake of the argument" (or subject), and "the vesture of sentence and phrase exactly fits the body of the thing described", thought and discourse are exactly identical, and there is only one science of both, which we may call logic or

dialectic, or what-not. The proper outcome of "appropriateness of the thing" is such a mathematical style as was contemplated by Bayle and some seventeenth-century Cartesians, a style admirable of course for scientific exposition, but limited to uses in which art has no opportunity. (Ibid)

An extremely important distinction has now been drawn. Rhetoric can either be appropriate to the subject (e.g., science) or it can be appropriate to the audience (e.g., learners). In this distinction there is the possible origins of the distinct genera of information and instruction respectively. There is also the justification for the claims of a unique 'language of science' which, as will shortly be shown, found voice in the Royal Society. But first it is necessary to understand what the Stoics meant by appropriateness to person. This aspect of the 'argument' is meant to "...render one's own experience in the encounter with reality as exactly, as vividly, as possible."

A style appropriate to the mind of the speaker, therefore, is one that portrays the process of acquiring the truth rather than the secure possession of it, and expressed ideas not only with clearness and brevity, but also with the ardor in which they were first conceived. It is no more a bare, unadorned, unimaginative style than the oratorical style is... (Ibid)

The characteristics of this style are "the figures of wit"; antithesis, or the contrast of ideas by expressing them as parallels of strongly contrasting words; 'point', or turns of wit; and metaphor, "the greatest of the figures by which literature may interpret the exact realities of experience..."

(Croll, op. cit.)

So for the Stoics the combination of appropriateness to thing and to person meant the expression of the means of acquiring truth about the thing, using not only clearness and brevity but

figures of "wit". A criticism of modern textbook language may then be based on the view that textbooks pay attention only to appropriateness to thing, and lack attention to such figures of wit. This would imply that such language cannot portray the "ardor" with which the process of acquiring the truth was conceived; only the secure possession of truth is communicated. A transition must now be made from the work of Croll to the beginnings of organized science as represented by the Royal Society. For the members of the Royal Society (established in 1663) were deeply concerned to establish a prose style suited to their purposes. Many early textbook writers, as has been shown, were members of the Royal Society, and may be expected to have reflected the Society's views on prose style. It has been argued by some researchers that these views reflected the Utilitarian philosophy of the members of the Society; that language must serve the end of practical results. (Adolph, 1968). There is no doubt that the Society was determined to enforce a prose style suited to utility. In his well-known preface to the history of the Society, Sprat (1666) first argues against prevailing rhetorical styles, and then delivers the official view of the Society.

They (the members of the Society) have therefore been most rigorous in putting in execution, the only Remedy, that can be found for this extravagance: and that has been, a constant resolution, to reject all the amplifications, digressions, and swellings of style: to return back to the native purity, and shortness, when men delivered so many things, almost in an equal number of words. They have exacted from their members, a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the Mathematicall plainness, as they can: and preferring the language of Artizans, Countrymen, and Merchants, before that of Wits, or Scholars.

(Sprat, in Adolph, op. cit.)

Adolph goes on to argue that Sprat "...intended the style practiced by the Society to serve as a model of what all prose which advanced useful knowledge should be..." (Ibid).

There are still difficulties with the exact meaning to be attached to such terms as "close", "naked", and "natural", but the intent is quite clear: to strip the language of all unnecessary words and phrases; to aspire, in fact, to that purity of the genus humile which aimed at brevity, clearness, and appropriateness to thing. By avoiding the language of "Wits and Scholars" the Society clearly hoped to allow Truth to come from fact rather than persuasion.

What is being shown here is the beginning of the tradition of Formalist textbook language. The genus humile or plain style did not originate with the Royal Society. But as the Society gained in influence, its ideas of expression increasingly became the only acceptable ones in the fields of science and, though not immediately, in science education. The separation between appropriateness to thing and to person became fixed in the language of textbooks; corresponding, as has been said, to the separation of the two genres of information and instruction. There can be little doubt that the genus humile, or Attic style, has been and continues to be appropriate to the needs of science. Without the accompanying characteristic of appropriateness to person, there arises the possibility of it being unsuited to the needs of learners.

Given this background to questions of style, the textbook types can be examined for their stylistic characteristics.

## STYLE IN THE CATECHETICAL TEXTBOOKS

The Catechetical texts, in their bare simplicity of question and answer form, might be taken as the epitome of the genus humile applied to instruction. Stripped of all superfluous phrasing (except the occasional reference to well-known English poets or the Bible), these texts represent as "naked" a style as is possible without the abstractions of mathematical symbolisms. They satisfy the criteria of brevity, and offer descriptions and definitions that are intended to be precise and clear. Their lack of vivid, figurative language, establishes them as committed to the idea of 'appropriateness to thing'.

The Catechetical texts, whether in science or other areas of secular knowledge, can be characterised more formally in the following manner.

First order classification:

1. Catechetical, based on the whole-text characteristic of the Question and Answer format.
2. Purpose: to inform autodidactic readers, often under the belief that this format was modelling the best method of instruction found in schools.

Second order classification:

1. Rhetorically. type: expository; style: genus humile (appropriate to thing).
2. Generically. genre of instruction.
3. Stylistically. seeks to be precise, concise, brief and unadorned; attempts to avoid figurative language, formal author/reader relations.

## STYLE IN THE CONVERSATIONALIST TEXTBOOKS

Any discussion of style in the Conversationalist textbooks must quickly move to the field of literary criticism, for these books were written in a fictional format, allowing the individuality of the author to be expressed. Thus they are far more open to a stylistic analysis that uses the traditional terms of literary studies--tone, mood, distance, introspection, terseness, and so forth. These authors, writing for children, had a great sense of audience, and their texts can be said therefore to conform more strongly to the idea of appropriateness to person than to thing. The authors still wanted to be accurate with their science, but they were willing to forego brevity and "mathematicall plainness" to achieve their other purposes.

### First order classification:

1. Conversational, based on the characteristic of dialogue between characters, and also reflective of the presence of the traditional elements of story--plot, characters, setting.
2. Purpose: to use fictional story formats to teach secular material to autodidactic readers, often under the belief that this was the best way to learn.

### Second order classification:

1. Rhetorically. type: literary/descriptive; style: genus medium.
2. Generically. genre of instruction.
3. Stylistically. seeks to use language in such a way as to be vivid, personal, true to matters of fact, and to suggest emotional as well as intellectual attitudes to information.



Comprehension more important than information. Use of figurative language common, along with a wide range of individual authorial language.

### STYLE IN THE EXPERIMENTALIST TEXTBOOKS

This section extends the discussion of style to include three areas of interrelationship between style, learning, and notions of science.

1. The authors' views of the roles of reader and writer. This view will determine the kinds of discourse permissible, and therefore strongly influence the style.
2. The text's presentation of the inter-relationship between the activities of science and learning.
3. The emphasis the authors place on knowing and learning. This relates to the distinction between the genera of information and instruction, and examines the way in which information is presented to the reader.

In carrying out this analysis, reference will frequently be made to the following prose passage from an Experimentalist textbook, Roscoe's Chemistry.

Let us see if we can get anything else from water than steam, by treating it in different ways.  
 Experiment 12.--Instead of sending heat into the water, by which I only get it to boil, I will send a stream of electricity through the water (to which I will add a few drops of acid to allow the electricity to pass more easily). I use four cells of a Grove's battery, and the electricity will pass into the acidulated water by the two platinum wires passing through the cork at the bottom of the glass funnel, when I join these with the copper wires from the battery.  
 What do we notice the instant we join the wires? The water near the wires seems to boil, or effervesce, owing to small bubbles of gas being

given off. These bubbles cannot be steam, because steam, if formed near the wire, would at once be condensed by the water near it, and these bubbles rise up through the cold water. Let us try to collect these gases; and we will see whether the bubbles from the one wire are the same as those from the other. For this purpose we will put a small test-tube filled with water over each wire, so that the bubbles as they rise round the wire must be caught by the tubes, which are both of the same size. What do we notice as the gases collect? Why, that in one tube we are getting just twice as much gas as in the other. (Roscoe, op. cit.)

This passage shows the characteristics of the Experimentalist textbooks identified earlier in this study. Science is seen as based on method, and it is written in the manner of what Schwab referred to as the "narrative of enquiry" (Schwab, op. cit.). However, the writers of the Experimentalist textbooks were prominent members of the Royal Society, and should therefore be expected to show the stylistic preferences called for by Sprat. Consider the first question raised by this section--the authors' view of the role of writer and reader. Since modern ideas on style are concerned with relations between text and reader, then this question of role is an important one. Recall that this role relationship is referred to in linguistic studies as tenor of discourse.

The language we use varies according to the level of formality, of technicality, and so on. What is the variable underlying this type of distinction? Essentially, it is the role relationships in the situation in question: who the participants in the communication group are, and in what relationship they stand to one another. This is what...we called the 'tenor of discourse'. Examples of role relationships, that would be reflected in the language used, are teacher/pupil, parent/child/, child/child in peer group....It is the role relationships, including the indirect relationship between an author and his audience, that determine such things as the level of technicality and degree of formality. (Halliday, op. cit.)

This notion of tenor suggests that a key determinant of textbook style will be the role the author adopts with respect to the readers--eg., teacher, guide, parent, dogmatist, questioner, informant, responder, doubter, contradictor .

The Experimentalist authors' view of their role was discussed in the historical sections of this study. As scientists and science educators of high reputation, they were concerned to see their view of science as a methodology adopted in schools. For them, science education was a training in the acquisition of the skills and knowledge associated with that methodology. Their position was, therefore, not simply teacher, but advocate of a belief. They were anxious to act as demonstrators of the correctness of that belief in schools. To do this, as the passage indicates, they chose a prose style appropriate to the role of practicing scientific enquirer. The word 'practicing' is important here. That role allows the textbook to show characteristics sharply different from any of the other types. An obvious, immediate difference is the authorial voice, more that of master to apprentice than distant authority. There is greater use of personal pronouns--I, we, you--and of the active, present tense rather than the passive, past tense. Because the emphasis is on the role of practicing enquirer, the passage contains a greater number of sentences which give direction, refer to observations, and indicate manipulations. Another Experimentalist passage, this time from Balfour Stewart's Physics, also shows these characteristics.

#### PROPERTIES OF LIQUIDS.

18. They keep their Size.--In a liquid such as water, we can move the particles about very easily, but we cannot by any means force a quantity of water into a smaller size, or make a

quart content itself with a pint bottle.

Experiment 11.--Let us, however, try to do so, and see what result we get, because we ought always to make an experiment when we can. Let us take a quantity of water shut in at one end, while at the other there is a water-tight piston or plug. Now let us try to drive this piston down in order to force the water into a smaller volume, and to do so let us put a large weight upon the piston; but notwithstanding all this we cannot compress the water.

21. Liquids find their level.--The next property of liquids is that they always place themselves so as to have a level surface.

Experiment 16.--Even when the liquid is contained in bent tubes, that in the left-hand tube will always be at the same level as that in the right, and this will take place whatever be the shape of the tubes. Indeed, I have only to fill some of these curiously shaped tubes with water in order to convince you that this is the case. You see the water is at the same level in all the tubes. (Balfour Stewart, op. cit.)

Besides the effect of the authors' view of the relationship between writer and reader, these passages illustrate the second main point of this section. Style will be influenced by the individual author's perception of the inter-relationship between the activities of science and the learning of science. The author of a pedagogical text may (and perhaps should) be concerned to ask two questions related to the subject written about and the learner of that subject. Firstly, are some areas of the subject more easily learned than others? This question is not necessarily related to style, but concerns the sequencing of material, and matching content to the readers' anticipated level of cognitive development. The second question is of greater importance here. It asks if there are characteristics of the subject or discipline itself that can make that discipline more easily learnable. The Experimentalist writers may have been arguing that, by using the activities of science (i.e., observing, experimenting; in short, doing), the nature of

science and its results are best learned. By contrast, the Conversationalist writers, for example, were arguing that dialogue between children was the best way for them to learn anything. If any such a choice is made by an author, then the style will reflect that choice. It is very likely that arguments such as these are inextricably bound up with the authors view of the nature of science, and the purposes of science education. But it is, strictly speaking, an educational question. For it does not necessarily, logically follow that if, say, science is conceived of as an activity, then the best way to learn science is by doing those activities. Authors, however, do make such assumptions; e.g., some Formalist writers advocated lots of numerical problem solving as the best way to learn. The Experimentalist writers clearly believed that the best way to learn was by doing--or at least being shown--experiments. This pedagogical choice is reflected in the style. Observation and manipulation are stressed. There is a correspondingly higher frequency of occurrence of terms related to these activities than in the other textbook types. Phrases such as "Let us see...", "What do we notice...", "Let us try...", and "I take the tube...I bring it...." characterise this style.

The third question of this section asks where the authors place the greatest emphasis, knowing or learning. The earlier discussions of genre suggest that a textbook which places its emphasis on knowing (e.g., knowing the rules, formulae and laws) will fall into the genre of information. A text emphasising learning, the acquisition of knowledge, will be placed in the genre of instruction. This distinction will certainly lead to

stylistic differences. For example, the manner in which information is presented to the reader will reflect this emphasis. Lists of formulae, tables of data, and worked sample problems all emphasise knowing rather than learning. The problems at the ends of the chapters are strong indicators of the concern placed on knowing the answer rather than learning the methods. These stylistic features are difficult to see in small prose passages; they are characteristics of the whole text. It is interesting to note, however, that Roscoe's Chemistry contains no tables of data and no questions at the end of sections. Nor does Balfour Stewart's Physics. What counted as knowing in these Experimentalist textbooks was not the rote learning of information. Knowing was more closely attuned to the idea of skilfully applying a procedure to a task. Since style is regarded as part of writer/reader interaction, the reader as learner will encounter the writer as an initiator into those procedures. The process of reading becomes, not the search for information, but the following of a 'master craftsman' at work.

For the Experimentalist texts, then, the following classification is possible.

First order classification:

1. Experimentalist, based on the central role of experimentation in both science as a discipline, and in science education as the chief focus of study.
2. Purpose: to instruct the reader in the processes of enquiry which are uniquely scientific.

Second order classification:

1. Rhetorically. type: didactic/expository; style: genus humile

(appropriate to person).

2. Generically. genre of instruction.

3. Stylistically. The authors role is that of guide, or teacher, thus allowing a more personal, informal style. The prose emphasises words and sentences that correspond to enquiry; eg., questions, directions and demonstrations.

#### STYLE IN THE FORMALIST TEXTBOOKS

The opportunity presents itself with the Formalist textbooks to try and make some more specific comments on what might be meant by the commonly used terms of textbook language criticism. For example, the terms 'formal', 'concise' and so on have been mentioned as needing more careful consideration than is usually afforded them in discussions of textbooks. This section analyzes them by referring to specific textbook passages and determining if these critical and descriptive terms can be usefully applied to textbook language.

The analysis bases itself around characteristic examples of Formalist textbook prose, chiefly from Mayfield et al.'s Fundamentals of Senior Physics (1979). A detailed examination of specific passages serves the analysis better than generalizations over a wide range of textbooks because the focus is so much narrower that potentially misleading generalizations are avoided. It allows the close examination of the structure of the prose, the word choices, and the literary style.

The following passage comes from the section in Mayfield et al. that deals with the concept of energy.

...it would seem that the law of conservation of

momentum does predict the actual outcome of an interaction, but it does not preclude other possibilities which never occur in practice. There must be another law (or laws) which accounts for one outcome and precludes the rest. The conservation of momentum has been so successful that we look for another quantity which might be conserved.

The problem was solved by the Dutchman Christiaan Huygens when he correctly suggested that the scalar quantity mass times velocity squared was conserved as well as the vector quantity momentum...The quantity  $\frac{1}{2}$  mass times velocity squared is called the kinetic energy of the particle. (Mayfield et al., op. cit.)

This style of writing has often been referred to as formal (e.g., Rosen, Mann, and Siegel, op. cit.). As this term is never given specific meanings by these writers, it is necessary to attempt to understand its meaning by examining the word itself. Assuming non-idiosyncratic uses, formal can be taken in two ways; (1) valid by virtue of its form, explicitly and definitely, in accordance with recognized rules or forms; (2) required by convention, perfunctory, observant of rules. (O.E.D., 1982). The former usage is demonstrated by considering the difference between the idea of formal versus informal proofs in geometry, the latter by the idea of formal versus informal attire at social functions. Both usages are characterised by considering their usual synonyms--precise, regular, stiff and methodical.

The above passage is formal in both senses of the term. It takes advantage of the belief (valid or not) that this type of discourse is required by objective truth. The very style itself is felt to convey a sense of validity. This formality has resulted, as shown earlier, from a long tradition of Attic prose that was developed in the 17th century for scientific purposes. It is now codified in the genre of information, corresponding to



the first use of formal above. The second usage implies that there are rules that, if followed, give writing authority and objective validity in its own sphere, and that these rules shape formal prose. Some of those rules need outlining.

One such rule is concerned with authorial voice. In the case of formal prose, the author as an individual must be distant from the prose written; his or her personal beliefs, attitudes, idiosyncracies and personal speaking voice must be absent, and ideally it will be written in the third person passive. The passage quoted above does use the first person plural term "we", as if speaking directly to the reader, but of course there is no possibility of learning anything about the character behind this "we" based on the passage alone; in that sense it is anonymous.

A second rule demands that the writer be as precise--that is, unambiguous--as possible. Each term is defined, its context limited, its relations to other terms within the discourse made explicit. In the opening paragraph to the chapter on energy, preceding the passage just considered, the Mayfield textbook makes this point explicitly. Other textbooks have been slightly more flexible with precision of definitions, but the results have often been vague and unsatisfactory because the writers have not devoted any time to discussion of the nature of definition and the need for precision according to certain pragmatic rules. An example from the PSSC textbook will make this point clearer.

Although energy may be hard to define precisely, it is familiar to all of us. In everyday language, we often speak of energy in the following way: we say we are "full of energy" if we get up in the morning eager and ready and tackle a job or take on a challenge. But when we have been active for some time, we get tired and

say we have "lost our energy."...For the moment we shall say that energy is the essential thing involved in jobs--not the creation of energy but its transfer from one form to another.

The work  $W = Fx$  done accelerating the mass  $m$  from rest is equal to the quantity  $mv^2/2$ , or in other words,  $mv^2/2$  is equal to the energy transferred to the body in setting it in motion. We call it  $E_k$ , the kinetic energy of the body: that is,  
 $E_k = mv^2/2$ . (PSSC, op. cit.)

The textbook writers seem to have felt the need to familiarise the reader with the meaning of certain terms within the discipline, and precision is an obvious virtue. But the writers confuse the precision of the mathematical formulation with precision of definition. To say that  $E = M \times (V \times V)$  is not to say what energy is, but only how it is related to other quantities. It is easy to understand the attraction of such mathematical formalisms when faced with the imprecision of definitions such as "Energy is the essential thing involved in jobs..." or the more familiar "Energy is the ability to do work." Energy is seen then as an ability rather than as an entity (like an atom) or a process (like acceleration). If the student was not carefully guided in his or her interpretation of the word "ability", it might become confused with cleverness, talent, or mental power. Such an approach, while it may overcome some of the difficulties mentioned with respect to the imprecision of verbal statements, leaves the reader with an understanding of precision in scientific writing as meaning something akin to the "tailored to fit within specified tolerances" dictionary notion. A fuller, more open discussion of the specific role that energy has to play within physics could gradually unfold the meaning of the term. Literal definition itself is no guarantee of unambiguous meaning.

Indeed, it has been argued that figurative language (e.g., metaphor, analogy and simile), can be as precise as literal phrasing. (Ortony, 1975; Petrie, 1974; Croll, op. cit.)

The argument thus far suggests that the rule of formal prose that calls for precision in expression is taken by the writers to mean mathematical formalism. There are, of course, certain things (like laboratory equipment) and certain processes (like filtration) which the textbook writer can precisely label through naming. Such naming is not peculiar to science education, and the textbook has a real role to play in such precise pointing out. But there are many concepts which cannot be so named (energy, force, field, inertia, matter are examples), and for which notions of precision, and the proper stylistic devices for assuring that precision, need more careful attention by textbook writers.

A further rule guiding formal language calls for the discourse to take place within a narrow, specified context. This demand is obviously closely related to that of precision, because it is only within a specified context of applicability that concepts can become precise. This rule does, however, raise questions of the influence of style in making connections between the context of the reader's world and that of the science under consideration. A familiar, non-stylistic way of forging such links is the use of "real-life" situations in the problems and examples given in the text. But the recent concern over 'alternative frameworks' (Driver, 1983) suggests that many learners are either not making connections between their own personal constructs and those of science for the explanations of phenomena, or they carry around incompatible views--one learned

formally and the other experientially. Attention is now beginning to be paid to the question of meaningfully joining together (and in some cases supplanting) these world views. (Warren, 1979; McCloskey et al., 1980; Watts, 1983). Again, some research has suggested that figurative language, particularly metaphor, may have an important role to play here.

I have argued that metaphors are essential for learning in a number of ways. They may provide the most memorable ways of learning and thus be our most effective and efficient tools. But further, they are epistemologically necessary in that they seem to provide a basic way of passing from the well-known to the unknown. However, such a formulation is somewhat misleading, for the crucial use of metaphor is in moving from one conceptual scheme with its associated way of knowing to another conceptual scheme with its associated way of knowing. Finally...it seems that the activity phase of understanding metaphors has much in common with exemplars--concrete problem solutions-- in providing an alternative to immediate observation as one of the crucial legs for triangulating our theories and observations on the world. (Petrie, 1979)

Metaphor is seen as an important linguistic device for throwing into sharp contrast a comparison between two quite unrelated terms. The metaphor functions to throw new light on both in ways that are strongly contextual. If metaphor has this power, perhaps it is one stylistic device that textbook writers could use to overcome reduced context difficulties. (Ortony, 1975).

A further difficulty arises when the writer's intent is not only to have the student realize the context of applicability of the concepts as defined by the text, but also to generalise to wider contexts. To illustrate this it is necessary to return to the Mayfield text. As quoted, the writers are careful to narrow the context of discussion to allow their treatment of energy to be more precise. But they do not then return with their precise

definition and present it, in context, against the other meanings and understandings about energy that they mention in their introductory paragraph. It may not, of course, be the intention of the Mayfield text to encourage comparison and generalization. The significant point for this argument is that the style of the language does not permit it.

A further rule of formal prose style is that of limited syntax. Syntax refers to sentence construction, and the rule suggests that only a limited range of sentence types will predominate in a given type of textbook. An analysis of this rule would first demand a classification of sentence types, and an exhaustive content analysis to determine patterns of usage, if such existed. The argument of limited syntax is not crucial to the analysis presented here, but it is of interest to see how such an analysis would deal with a brief textbook passage. Consider the following piece of prose from the same Mayfield textbook.

What do we know of the nature of charge? From observations of interactions between charged objects...we find that there are two kinds of electric charge, which are arbitrarily called positive and negative. Objects with like charges repel each other and objects with unlike charges attract each other.

The charge ultimately arises from the fundamental particles of matter itself. The atoms of which matter is composed contain positively charged protons and negatively charged electrons. The charge of one proton is of the same magnitude as the charge of one electron. An 'uncharged' body contains equal numbers of protons and electrons so that the object as a whole is electrically neutral. When two neutral objects such as the comb and dry hair are placed in contact, charge in the form of electrons may be transferred from one object to another. When separated, one object has an excess of electrons and is charged negatively and the other object has an equal deficiency of electrons and is charged positively. (Rubbing the two materials together increases the area of contact and assists the transfer of charge). (Mayfield, op. cit.)

The passage consists of ten sentences, nine of which are statements, with one question. The average sentence length is 18.6 words. The second paragraph, containing seven sentences, consists of four 'simple' sentences--that is, they have the simplest noun-phrase followed by a verb-phrase order. These are the first four sentences of that paragraph, and their average length is 15.5 words. The last three sentences of that paragraph are 'embedded' sentences--they have a clause beginning with "when" which is embedded in, respectively, a simple sentence and a compound sentence (which consists of two simple sentences joined by "and"). Their average length is 28.5 words. The last sentence of each paragraph is a compound sentence, but the final sentence has the unusual gerund "rubbing" for its noun-phrase. The second sentence of the first paragraph is another embedded sentence, but it is multi-embedded, containing four clauses and 27 words.

If the opening question is disregarded for a moment, the result is: four simple sentences which are statements of fact (all in the second paragraph), and the remaining five sentences are complex embedded and/or compound sentences with an average length of 23 words. Several points can be made about such a syntactical structure. The first relates to the memorability of complex sentences. Psycholinguistic research (Slobin, 1971; Miller and Isard, 1964) suggests that syntactically complex sentences are harder to recall. The role of context cannot be disregarded of course, and there are studies which suggest that context can remove some barriers to recall of difficult sentences. Notice, however, which sentences would seem to be easiest to recall. They are the opening question (though

questions can raise problems of their own: Slobin, op. cit.) and the four simple sentences of fact. This is an advantage for learning information. But the other sentences provide the explanations and reasonings on which those facts are based, or are given relevance. The second point is concerned with the way the explanations are offered syntactically. Consider the sentence "When two neutral objects such as the comb and dry hair are placed in contact, charge in the form of electrons may be transferred from one object to another." This statement is designed to provide the beginnings of an explanation for observed phenomena. Yet in fact, an observable event (the placing of a comb and dry hair in contact) is being linked with an unobservable event (the transfer of charges). The syntactical linking of these two by the complex sentence creates the possibility of the reader assuming that either the contact causes the transfer of charge (if the sentence is read in the form 'when X happens, Y results) or that there is some as yet unclear association between the two events.

This tendency to use syntactically simple sentences for matters of fact, and syntactically complex sentences for explanations, is not unusual in formalist textbooks. Here is another example, this time from Ingram.

In physics, we need to define a quantity that tells us how much of the electric property a body possesses. We call this quantity electric charge. The analogous property in gravitational theory is mass. The principle difference between the electric and gravitational properties is that all bodies have mass, while most bodies in their normal state have no perceptible charge. The reason for this is that there are two opposite kinds of charge, called positive and negative. A body having equal quantities of each has no long-range electric property. On the other hand, there is no negative mass. (Ingram, op. cit.)

The pattern is the same; short, syntactically simple sentences for the facts and definition--"We call this quantity electric charge"--and longer, more syntactically complex sentences for the explanations--"The principle..."

Up to this point, four rules of formalist writing have been considered; authorial voice, precision, reduced context, and limited syntax. Of these, precision and reduced context may be considered to be part of a necessary complex of stylistic characteristics demanded by the nature of the textbook--they are required to be precise and of limited context. Syntax and authorial voice, on the other hand, are elements of the writer's style not necessarily imposed by the material or the purpose of the textbook. There is no discipline-bound need for science textbook writing to be either impersonal or syntactically complex.

A further stylistic component of textbook writing is referred to as the rhetorical model of the text. Although not one of the rules of formal writing as just investigated, formal writing can be seen to be characterized by its own rhetorical model. Rhetoric is concerned with the art of persuasive or impressive speaking and writing. The rhetorical model is a description of the way in which the writing moves through the material from which it is arguing. It asks if the presentation of material and argument to the reader is a straight-forward linear one, whether it is circular, or branching. A linear model moves from one point to another in a continuous chain, much like a formal mathematical proof. A branching model takes sides-tracks, refers back to itself or other material, and makes connections



between related but separate elements within the discourse. An analysis of rhetorical model can take place at any level within the writing, from the over-all plan of the entire work down to individual arguments.

There are two stylistic concerns of rhetorical model analysis of interest to this thesis, operating at different levels within Formalist textbooks. The first of these relates to the writer's view of science as a discipline, and the effect of that view on the rhetorical style of the textbook. It can be argued, from the earlier examination of the history of modern scientific prose style, that the style of science textbooks is derivative from the model of 'correct' scientific writing. In particular, the type of reasoning or argument allowed is determined by the established methods that give validity within science as a discipline. Since, as has been shown, textbook writers appeal to a model of science that emphasises logical, inductive and deductive formal reasoning, the textbooks argue in the same way. This imposes a strictly linear rhetorical model on the textbook. The presentation to the reader follows the pattern: experiment leads to observation, followed by discussion with theory, stating a definition and finally a mathematical formalism. This is the classical model of the scientific method; observe, deduce, generalise, quantify. There is no longer, however, a consensus view that this is in fact the way science does operate, especially since the work of Kuhn. Nevertheless, even if it is the way science does work, it is not necessarily the best way for science education to proceed. That argument would need to appeal to learning theory and relevant educational research.

The second point of interest concerns the linear rhetorical model as it appears in the textbook at a much higher level, that of the order of presentation of material to the reader. The entire textbook is arranged, of course, by topics. But the ordering of these topics is not arbitrary. Again, the evidence from the prefaces alone, as detailed in Chapter 3, indicates that the content is often ordered to represent either the logical ordering of the subject, or the progression from simplest to most complex. Both of these rationales dictate a linear model. The most common ordering in general physics textbooks has, for the whole history of the Formalist text, been from dynamics to electro-magnetism, with optics, thermodynamics, and, until its demise, hydrostatics, somewhere in between. Within each larger heading, the topics are usually covered in the same order. The contents of the section on Light in Everett's Textbook of Physics (1901) ran in this ordering: reflection, refraction, formation of images, lenses, magnification, chromatic dispersion, spectra, colour, the eye, photometry, velocity of light, polarized light. The 1960 edition of PSSC Physics's chapter Optics and Waves is strikingly similar: how light behaves, reflection and images, refraction, lenses and optical instruments, the particle model of light, introduction to waves, waves and light, interference, light waves. This arrangement is important, for it is not just expressive of a progression towards complexity ("The topics in the PSSC course are selected and ordered to run from the simple and familiar to the more subtle ideas of modern atomic physics." PSSC, op. cit.), but towards a conclusion. The whole progression through the section is one long argument leading to

the current views of the topic under consideration. A closer examination of the PSSC text will make this point clearer. The phenomena to be studied are dealt with first by a series of observations about reflection and refraction, treating light as if it were a beam or ray; that is, its behaviour and not its substance is being studied. From its behaviours, a set of laws of reflection and Snell's Law of refraction are generated, before it is known what is in fact being reflected and refracted. These laws are next used to examine the behaviour of lenses, and converging and diverging light rays. A few laws of optical behaviour and magnification are developed. It is only after long examination of the the behaviour of light that a consideration of the nature of light (as particle or wave) begins. The linear rhetorical model presents this sequencing as inevitable, and the conclusion is drawn that behaviours of entities must be studied prior to examinations of substances. This way of arguing is not justified by the demands of science, nor has it been seen as necessary by the writers of earlier textbooks. The Catechetical authors, for example, also used a linear model, but started from the definition of light, and then used that definition to account for certain phenomena.

This linear model can be seen even more clearly when contrasted with the rhetorical model employed by the Conversationalist textbooks. Their model, based on dialogue, consisted of questions posed by characters, statements of fact, religious and social asides, social conversation, moral injunctions, and descriptions of scene and action. Much of the dialogue may seem irrelevant to the aims of science education today, but it did provide an alternative, multi-branching rhetoric around which to

organize content. The digressions away from the linear flow of scientific information allowed 'stopovers' for review, reflection, the drawing of implications, the discussion of parallel developments (historical, or from other disciplines) and the placing of learned material in familiar contexts. These branching patterns resemble at times the verbal discourse of the teacher when attempting to explain and discuss scientific phenomena. Human conversation is flexible and responsive in a way that the linear model does not permit.

The Formalist textbooks can then be classified as follows.

First order classification:

1. Formalist, based on their characteristically formal language structure.
2. Purpose: to inform readers of the results and structure of scientific disciplines.

Second order classification:

1. Rhetorically. type: expository; style: genus humile (appropriate to thing).
2. Generically. genre of information.
3. Stylistically. distant authorial voice, linear rhetorical model, reduced context, limited syntax, and the concern for precision, conciseness and impersonal expression.

### SUMMARY

The idea of Style in textbooks has been investigated from four viewpoints.

Firstly, a discussion of the literary meaning of the word style. It investigated the changing understanding of style as a characteristic of language, and ended with the current view of

style as determined by the interaction of text and reader.

Secondly, a look at the history of prose style from the analysis by Aristotle to the recommendations of the Royal Society. It was claimed that the desire of the Royal Society for a prose suited to the purposes of science led to the establishment of a tradition of such writing. This tradition has not only affected science but also science education. A crucial aspect of this section was the recognition of a dichotomy between the appropriateness of the writing to subject and to audience.

Thirdly, an attempt to give some meaning to the criticism of formal textbook language by examining the rules that characterise such language. Those rules--distant authorial voice, concern for precision, limited context, and limited syntax--were dealt with against the background of selected Formalist textbook passages. A further characteristic of such language--rhetorical model--was also examined.

Fourthly, a discussion of selected Experimentalist textbook passages was used to point out three further determinants of textbook prose style. Those three were the writers' view of the role relationship between author and reader; the writers' perception of the interactions between the subject being written about and the learning of that subject; and the emphasis placed by the authors on knowing or learning.

Using these four viewpoints, a second order classification of textbooks was generated. The concepts of genera (of instruction and of information) were found to be of use in the previous chapter for classifying texts; this was added to in this chapter by a stylistic analysis which used the concepts of rhetoric to develop further the classification system. At the same time,

further relations between the language of the text and the authors' views of science and science education were highlighted.

## SECTION C

This is the third layer of the analysis, with three main concerns.

Firstly, it examines the textbooks for evidence of two important purposes identified in Section A--explanation and instruction. Those purposes are revealed in the texts as prose structures, which are essential generic characteristics identified in Section B.

Secondly, it uses content analysis to provide verification of the results of the thesis presented in Sections A and B.

Thirdly, it presents a third level of classification, based on the results of all three Sections.

## CHAPTER 6: EXPLANATORY STRUCTURES IN SCIENCE TEXTBOOKS

### PART A: OUTLINE OF TYPES OF EXPLANATIONS OFFERED

#### INTRODUCTION

In the Introduction to this thesis it was claimed that an important structural feature of textbook language was explanation. In particular, reference was made to explanation as a characteristic type of argument expected to be found in science textbooks. It was also claimed that the types of explanations could reveal the authors' view of the nature of science, and that the level of explanation could reveal their view of science education.

In general terms an explanation can be seen as a type of argument, which in turn consists of a series of statements designed with one of two possibilities in mind. One is to persuade the reader to a particular point of view, the second is to put forward a carefully prepared structure, or line of reasoning, in order to demonstrate the validity of a particular principle or generalisation. The former is more typical perhaps of political and theological uses of argument, the latter of mathematics and science. This distinction is made clearer by relating it to the discussion in Section B of the nature of rhetoric. Recall that classical ideas of rhetoric attempted to match a style of speaking or writing with a particular purpose; e.g., to persuade, to teach, to entertain. Persuasion (or



argument) was to be done by and through a particular rhetoric. The Royal Society attempted to replace rhetoric as a tool of persuasion with empirical enquiry, and in doing so called for the adoption by scientists of Sprat's 'naked Prose'. The distinction, then, is between rhetoric as argument and empirical enquiry as argument. However, this distinction calls for yet another between arguments in mathematics and science as well.

(Indeed) it is just because the propositions (whether singular or general) investigated by the empirical sciences can be denied without logical absurdity that observational evidence is required to support them. Accordingly, justification of claims as to the necessity of propositions, as well as the explanation of why propositions are necessary, are the business of formal disciplines like logic and mathematics, and not of empirical inquiry. (Nagel, 1979)

Science, therefore, must establish the truth of its propositions by appeals to empirical evidence, while mathematics deals in necessary truths. For this reason, it is possible to describe the arguments of science as empiric as distinct from the analytic arguments of mathematics and logic. An analysis of explanation in texts provides the opportunity to see if such distinctions are demonstrated in the writing.

The classic form of argument is the syllogism. From two given or assumed propositions called the premisses, and having a common or middle term, a third is deduced called the conclusion, from which the middle term is absent. Syllogistic argument is commonly found in all types of textbooks, but does not itself show the distinction between empiric and analytic arguments pointed out above; nor does it give any indication of the variety of explanations that may be based on its form.

Given such distinctions (persuasive/demonstrative;

empiric/analytic), textbook authors can be seen to present a variety of types of arguments within the same book. Some wish to use persuasive arguments in support of a particular view of science, say experimental or theoretical, or for the educational value of numerical problem solving, or for the place of science in society. These kinds of arguments typically occur in the prefaces to the texts and, clearly, they are generated from the purposes of the authors. If authors are concerned to re-enforce their purposes within the text itself, they must include, in some fashion, prose material in support of the premisses of their arguments. For example, an argument for a particular view of the place of science in society may be supported in the text by occasional discussion of the use of science in both alleviating hardship and creating new social conditions. On the other hand, the authors may not, of course, wish to argue for a purpose, but will simply take the premisses as guiding principles for textual structure and content. For example, rather than argue for numerical problem solving, the author may simply include many such problems.

Authors may also include in their texts empiric arguments, which attempt to argue for a specific scientific conclusion. For example, the author may wish to argue for the general validity of the law of conservation of energy. Or another may wish to argue for a more specific explanation, that of the causes of the tides. In these cases, the conclusions must be explicitly presented, but must also conform to accepted ideas of proof and evidence within science. Again, the authors may wish only to present these conclusions without arguing for them, expecting readers to take them on trust. In the latter situation, the

authors' purpose cannot be for the reader to learn the processes of experiment and reasoning which led to the establishment of the presented explanation.

It is clearly necessary, therefore, to distinguish between argued and un-argued purposes. The distinction is an important one, because purposes which are explicitly argued for by the author become part of what is to be learned by the reader. Continuing an example from above, if an author argues in the text for the value of numerical problem solving, then that is a clearly signalled intention that the reader should come to understand if not accept that point of view, and learn to see problem solving in the same way as the author (as well as learn to solve such problems). If the author does not argue for such a view of problem solving in the text, such signalling is missing. The reader cannot then be expected to come to share the author's point of view. Of course, the reader may come to such a view independently.

Authorial purposes which are explicitly argued for, then, will be represented in the text as arguments--a series of statements designed to persuade or demonstrate. Such a use of the word argument is consistent with its usual definition of 'reason(s) advanced for or against a proposition.' (Oxford English Dictionary). How do arguments determine textbook language? Firstly, as just discussed, by their link with purpose. Secondly, an argument, to be seen as such, must have a clearly recognisable premise, it must have justifications to support that premise, and ideally it must connect premise and justifications in ways that are coherent, well-ordered, and also comprehensible to the reader. These demands impose a

structure and limitations on the textbook's language.

It is also particularly important to be clear what is meant by a language structure as used here. A language structure consists of an distinct, identifiable unit of prose that is concerned with one purpose only. For example, if an author wishes to argue for the importance of science for understanding modern society, the textbook language will be under certain constraints in so doing; i.e., justifications should only be drawn from relevant areas, and they must be arranged and ordered in such a way as to convince the reader of their validity and value as reasons for accepting the author's view. The author then places these statements together, organising them to read logically and coherently. Or, to give another example, if the concern is with a specific scientific conclusion, then the authors details the experimental method, the underlying theory, the type of reasoning used, the relevant assumption, the data, and the conclusion itself. In either case, the prose unit that contains such arguments is referred to as a 'language structure'.

#### EXPLANATION

It is possible to use the same syllogistic form to argue for very different views, of course. Given the variety of arguments, and the consequent language structures, that are present in textbooks, it is necessary to choose one for detailed study. Explanation is a suitable choice, for reasons that will be detailed below.

Firstly, an explanation in science can be regarded as an answer to a why-question. (Hempel, 1965). Examples of such questions would be: why do the planets move in elliptical orbits with the

sun at one focus?, why do metal bars expand on heating? Clearly, a major purpose of textbook authors would be to provide explanations as answers to these why-questions in science, even if they do not offer explanations of such things as the place of science in society.

Secondly, it has just been noted that the syllogistic form allows the writer to argue for very different purposes; argument, therefore, is too general a term to be helpful. Explanation, however, is discipline bound; that is, different areas of knowledge may have different ideas as to what counts as an explanation. This simply means that what will be allowable as an explanation in one field, say religion, may not be allowable in another, say science. An example of this discipline-dependent nature of explanation is readily seen in the controversy between Creationism and Evolution as rival explanations for the same phenomena--the current diversity and (apparent) inter-relatedness of life. Put crudely, miracles (creationism) are not allowable as explanatory structures in modern science, and natural laws (evolutionary theory) are not a sufficient explanatory structure in modern religion. The actual arguments, however, as opposed to the explanations, may still be conducted by both sides using similar language structures; e.g., logic, appeals to evidence, or construction of valid, fruitful analogies.

Thirdly, there are still a range of possibilities within textbooks as to what is in need of explanation; the method of gaining information, or the completed results, or the applications of those results. Which of these factors is emphasised will reflect the authors' views of the nature of

science, and what it is about science that it is important to communicate to readers. And each of these factors in turn demands a different type of explanation, which in turn will influence the language of the textbook. Again, if the second order classification is reasonable, then different rhetorical types of texts should contain different types of explanations. Fourthly, explanation, as a type of argument, is linked to rhetorical classifications such as expository (persuasive and informative arguments) and didactic (arguments designed to demonstrate). It therefore allows the classification of texts already begun to be taken a step further, to see whether there are differences in the textbooks' language structures which reflects the rhetorical distinctions made in Section B between the four textbook types.

It can be seen from the above that an explanation, when it is an answer to a why-question within the discipline of science, will be present in the textbook as a prose structure. If the specific nature of scientific explanations is considered, then it can also be stated that the explanations (the statements and their connections) can be written and displayed independently of any person providing the explanation; i.e., it is an empiric or analytic argument.

#### TYPES OF EXPLANATION IN SCIENCE: AN OVERVIEW

What does count as an explanation in modern science? Four different answers will be presented here. Each of the four will subsequently be used a framework against which to examine textbook explanations, which will take place in Part B. The

following section is intended to outline the four main types of explanations found in textbooks, not to argue for them.

### 1. Aristotle's Four Causes.

One of the earliest discussions of scientific explanation comes from Aristotle. A complete account of any natural process must, it is claimed, take a range of factors into account, such as the material make up of the object(s) involved, the range and types of forces at work, and the nature of the measuring devices. As well, there are different ways in which the question 'Why?' can be asked in science, calling for different types of explanation in response. An early recognition of all these factors is found in Aristotle's 'four causes'. (Toulmin and Goodfield, 1962). An example will make this clearer. Suppose the textbook author is concerned to provide an explanation to the question "Why does a metal rod expand when heated?" According to Aristotle's four causes, four different types of explanatory structures are possible.

(1) Aristotle's first cause is referred to as the 'From what' cause. Explanations are based on the material constitution of the objects concerned; here, the fact that the bar is made of iron.

(2) The second cause is referred to as the 'What was it' cause. Explanations are based on the form or essence of the object; here, the fact that it is an iron bar.

(3) The third cause is referred to as the 'By what' cause. Explanations are based on causal agents acting on the object; here, heat could be taken to be acting on the iron bar in such a way as to bring about expansion, perhaps by 'pushing' the molecules apart.

(4) The fourth cause is referred to as the 'In aid of what' cause. Explanations are based on identifying the purposes or ends of the phenomenon; here, an example could be that iron rods expand because such expansion is useful to man.

These four kinds of explanation are not necessarily in conflict with one another, though they do not all have equal standing as

scientific explanations today. For example, Aristotle's fourth cause--'In aid of what'--raises the problem of teleological explanation in science. Textbook authors may select from these four types the one(s) they feel to be most suitable for explanation of the phenomena that they have to deal with, and the readers they envisage using their books.

## 2. Cause and Effect Explanations.

Explanations that are based on finding causes for phenomena are clearly identifiable with the third of Aristotle's causes, the 'By what' cause. A clear statement of the nature of this type of explanation is given by T.H. Huxley in his Introductory.

Anything is said to be explained as soon as we have discovered its cause, or the reason why it exists; the explanation is fuller, if we can find out the cause of that cause; and the further we can trace the chain of causes and effects, the more satisfactory is the explanation. (Huxley, 1902)

Huxley's text does not suggest that there is any real difficulty in establishing that one event or condition is indeed the cause of another. If it is recalled that Huxley associated science with common-sense, this is perhaps not surprising. Science would then assume causal relations in the same way as everyday experience does; the water causes the fire to go out, the wind causes the tree to fall over. Yet causality has come under close scrutiny by philosophers of science, and it appears that common-sense views may not be adequate for all areas of science.

The view that the (causality) principle is an empirical generalization...is difficult to maintain. For when the principle is formulated in a fully general way, without mention of which factors determine the occurrences of things and processes, the principle excludes nothing whatever from the logically possible orders of events in



the world; and in effect the principle collapses into an implicit definition of what it is to be a causal or determining factor in natural processes. On the other hand, if the principle is formulated in a more limiting manner, so that it does mention which traits of things are the causally determining ones in natural processes, the principle turns out not to be universally true, and can therefore be asserted as sound only for certain special subject matters. (Nagel, op. cit.)

Nagel also points out that there is considerable diversity in the use and understanding of the term 'causality' in science. It is variously interpreted as a principle of wider scope than any particular causal law; a trait affirming something pervasive throughout nature; a principle asserting something about laws and theories rather than the subject matter of laws and theories; a regulative principle for enquiry; an inductive generalization; or as a priori and necessary. (Ibid). It therefore will be necessary to distinguish between these meanings when examining the textbook authors' use of the term.

### 3. Empiricism.

A common way of interpreting causality is to assume that causes can be determined empirically, and many textbook authors adopt some or all of the principles of empiricism. Causal relations are to be identified and described by reference to laboratory operations. In the strictest form of empiricism, termed operationalism, a theory must contain only observables, and the more primitive the observables, the better (Bunge, 1967). Operational definitions are common in Formalist textbooks. There are two points that must be mentioned in reference to operationalism. Firstly, there are philosophical difficulties with operationalism (sometimes referred to as logical positivism) which will not be detailed here beyond noting that

some philosophers of science such as Bunge deny that such definitions are meaningful (Bunge, op. cit.). Secondly, there is confusion over what is to count as an 'observable' in this kind of definition.

A second, milder form of empiricism relies on what is sometimes referred to as the Double-Vocabulary View: every theory contains both observational terms (e.g., 'hot') and non-observational terms which are not reducible to sense experience (e.g., 'temperature'). Correspondence rules or postulates confer meaning on the theoretical terms by relating them to the observables. An example of this is given below.

Temperature. Thermometers.--The qualitative meaning of the term temperature is familiar to every one; thus a body which feels hot to the touch is said to have a higher temperature than a body which feels cold. Our senses, however, do not allow of our making any but the very roughest estimate of the amount by which the temperature of one body is higher than that of another. Hence in order to measure temperature we are obliged to make use of the change in some physical property of some kind of matter which takes place as the temperature changes. The physical property which is most usually employed for this purpose is the volume of a liquid or of a gas, both of which depend on the temperature. (Watson, 1932)

The difficulties associated with empiricism are important enough to examine a little more fully, especially as they touch on the very real problem of the role of the laboratory in science education. Piaget explored some facets of the nature of empiricism in an article titled The Gaps in Empiricism.

This brings us...to the central argument of empiricism: that all knowledge should be related as closely as possible to observable facts. In reality, in every field--from physics to psychology, sociology or linguistics--the essence of scientific knowledge consists in going beyond what is observable in order to relate it to subjacent structures...(in) physics we might be justified in regarding as observable features the

repeatable relations which functional analysis strives to translate into "laws", but on examination of the actual work of scientists--and not the philosophical statements to which they so often limit themselves--we have to recognize that their systematic and unceasing need to discover why things happened forces them to break through the barriers of the observable... (Piaget and Inhelder, 1976)

What is often termed 'empiricism', then, actually goes beyond the observable. Even at a very elementary level, explanation quickly makes this jump, which accounts for the presence of bridging structures such as models, systems, and other abstract organising principles in explanatory structures.

#### 4. Inductivist and Deductivist Accounts of Explanation.

There are two important types of explanatory structures which come under this heading--the covering-law model and axiomatics.

##### A. Covering-Law Model

An early clear statement of inductivist explanations was given by Carl Hempel in 1965 in his Aspects of Scientific Explanation, using a 'covering-law' model. This model has been widely taken up, expanded, and criticised. The following is an outline of the model.

##### Explanation in Science: Four Criteria

- (a) The presence of a law or generalization about the phenomena under scrutiny.
  - (b) Empirical statements about observable conditions with regard to the phenomena.
  - (c) Internal consistency in the chain of reasoning between premisses and logical conclusions.
  - (d) Empirical truth in the sense that conditions do, in fact, prevail and that the generalization is, to the best of our knowledge, well founded.
- (Hempel, op. cit.)

What the model briefly states, then, is that to give an explanation of a particular phenomena--say the expansion of a metal bar on heating--it must be shown to be an instance of, or

"covered by", a known law, or laws, of nature. This model is clearly distinctive of science, even if it also taken as a model for other disciplines, such as sociology.

There is no need to elaborate the recent philosophical difficulties associated with every step of Hempel's criteria given above. However, it is still the accepted view of most contemporary philosophers of science--Passmore, Braithwaite and Popper are examples--that natural laws exist and that the aim of scientific explanation is to interpret natural law.

Unless science education is seen to have the express purpose of introducing learners to the natural philosophic roots of science, there is no compelling reason to elaborate on the difficulties of the inductivist/deductivist approach. In fact, as seen in Chapter 3 on textbook prefaces, the authors were rarely concerned to make such notions explicit, though passing reference to such ideas appeared in some 19th century texts. This presents an obvious difficulty in providing explanations for readers, for, as we have seen, there are four (at least) types of explanatory structures possible. The presence of a well-defined model of explanation would seem to provide a useful entry point for examining the arguments of a science textbook, for initiating the reader into a distinctive model of explanation in science, and for purposeful use in providing explanations of phenomena. An explanation would thus be seen as an argument to persuade the reader to accept the phenomena as correctly explained within a framework of scientific explanation.

#### B. Axiomatic Systems.

Physical axiomatics refers to the view of physics as being built

solely on a set of abstract, self-evident axioms. (Bunge, op. cit.). It is important to spend some time looking more closely at the nature of the axiomatic system in physical sciences, because the consequences of such a view of science have a profound influence on the structure and language of textbook explanation.

The physical sciences are not the only field of study to attempt to use axiomatics as the basis of their organisation; Spinoza's philosophical treatise on Ethics, for example, begins in the Euclidean manner with eight definitions (or meanings assigned by the author) and seven axioms (or statements about how the world is). From these are derived or deduced principles for human conduct. Axiomatics is principally a deductive system.

Axiomatics, at least in its simplest expression, has three important aims. First, it attempts to organize the operating theories on a logical structure, a deductive one in most cases. This involves elaborating a formalism. Euclidean geometry, of course, is the supreme example of a mathematical formalism--from a set of axioms the Pythagorean theorem, for example, can be deduced. This aim of axiomatics is to reduce what are referred to as the self-evident, or primitive concepts (e.g., mass) of a field of study to a set of mathematical symbolisms which can then be manipulated by the rules of mathematics, and from which the entire range of relevant phenomena can be deduced. Maxwell's equations of electromagnetism are such a formalism, and it seems clear that Newton, in the Principia, considered his laws and their attendant definitions to also form such a formalism; he referred to them both as laws and axioms.

The fact that the notion of a deductive system was

introduced into European thought in a mathematical context--Euclid's Elements...has had the effect that the first explicitly deductive systems, including the greatest of them, Newton's Principia...professed to prove their later propositions--those which were confirmed by confrontation with experience--by deducing them from original first principles. (Braithwaite, 1953)

Of course, a strict formalism allows no physical or, from the readers' point of view, 'everyday' meaning to be attached to the symbols in the equations. Force simply is mass times acceleration, or electric current is voltage divided by resistance--and physics becomes a branch of mathematics. Most teachers would probably not be too unhappy with such an abstract view, and some physicists have come close to such a position. Formalist textbooks are anxious to develop a mathematical formalism as soon as possible, and it is common for the student to be asked to derive certain equations (e.g., for kinetic energy) from more basic algebraic expressions in the true axiomatic manner. Such a strict formalism gives an impression of science as unconcerned with explanation in any but a deductive sense. Axiomatic science might then be treated as an abstract activity, trying to remove its concepts from any contact with the readers' world.

The second aim of axiomatics is related to the notion of assigning physical meaning to the terms in the science being considered. Axiomatics attempts to assign unambiguous meanings to the primitive concepts of a law or theory, removing intuitive or anthropological misconceptions. There are two facets to this problem. Firstly there is the relationship between axiomatic meaning and the role of a formal prose style in scientific writing, which is seen to be connected to rhetorical discussions

from Section B. Conceiving of science as a deductive system would seem to imply the language characteristics of the genre of information and its associated stylistic features. Secondly, axiomatic meanings are seen to relate to a series of concerns with the formulation of Newton's formalism expressed by scientists.

Mach (1960): With regard to the concept of 'mass', it is to be observed that the formulation of Newton...is unfortunate. Newton felt distinctly that in every body there was inherent a property whereby the amount of its motion was determined and perceived that this must be different from weight. He called it, as we still do, mass; but he did not succeed in correctly stating this perception.

Poincare (1952): But how are we to measure force and mass? We do not even know what they are. What is mass? Newton replies: 'The product of the volume and the density.' 'It were better to say', answer Thomson and Tait, 'that density is the quotient of the mass by the volume.' What is force? 'It is', replies Lagrange, 'that which moves or tends to move a body.' 'It is', according to Kirchhoff, 'the product of the mass and the acceleration.' Then why not say that mass is the quotient of the force by the acceleration? These difficulties are insurmountable.

Eddington (1929): His formulation of the first law reads: "Every body continues in a state of rest or of uniform motion in a right line except insofar as it doesn't."

The textbook writer who takes notice of statements such as the above would have two concerns. The first is to take great care in the formulation and expression of the axiomatic terms used in the textbook, as they seem to be open to a great deal of critical appraisal by eminent scientists in the field. The second is to clearly establish for the student the nature of the deductive method that is being used. Other researchers have commented on the axiomatic characteristics of science textbooks.

The subject of dynamics is presented in most general physics textbooks in much the same form as...by Newton...more than two and a half centuries ago. Important quantities are not explicitly defined. Unnecessary reliance is placed on intuition and anthropomorphism. In brief, the theory is deficient in rigor and lacking in clarity. (O'Leary, 1947)

#### EXPLANATION AND TEXTBOOK LANGUAGE

An important reason for focussing on explanation in textbooks concerns the significant effects it has on textbook language. If appeals can only be made to discipline-dependent explanatory structures, then textbooks must incorporate them into the text, where they will be available for analysis. This is clearly seen in the passage below, which comes from Introduction to the Sciences, 1856. It was one of over 100 textbooks published by W. and R. Chambers as the Chambers Educational Course. They were widely used and well known to teachers and the general public.

Matter, in all its forms, is subject to various fixed rules or laws, which have been established by the Creator for very important ends. By one of these, it is ordered that every particle or mass of matter possesses a power of attracting other particles or masses. (Chambers, 1856)

In the history of science there was a period when, to some authors of scientific material, Divine Law was superior to natural law. Textbook language contained appeals to, and arguments based on, such a belief. Thus the type of explanation felt to be allowable influenced the language used.

Explanation is also seen to be related to the central question of using textbook language to examine the authors' views of the nature of science and science education. This is because explanations are chiefly concerned with providing meaning. Not



only are they a part of what is to be learned, but without them the content of the textbook remains unconnected, unverified, and without scientific significance. The content would remain merely encyclopedic. For example, explanations provide the framework within which facts and principles are given meaning, and they place observations within the structure that is called science, from which meanings are derived. Meaning in this sense is identical to the uses of the word in such sentences as: "What does the word 'potential' mean in physics?" or "This metal rod expands upon heating. By that we mean that...." or "In chemistry we claim to be able to explain why certain gases are inert. By the term 'inert' we mean that..." It is clear that if it is the methods of science that allows unique and specifiable meanings to be given in each of these cases, then the language authors choose to provide those meanings will reflect their views of those methods.

### SUMMARY

Part A has made the distinctions between arguments that are designed to persuade (rhetorical arguments), and those which are designed to present a carefully prepared structure to establish the truth of a proposition (analytical or empiric arguments). Within the latter explanation was selected as a type of argument useful to this analysis because of its importance in science generally and because it is a feature of textbooks that is related to questions of rhetoric that were developed in Section B. Four types of explanatory structures were outlined, based on Aristotle's Four Causes, Cause and Effect relationships, Empirical accounts, and Inductivist/Deductivist accounts. These

four will be used as frameworks against which to examine textbook authors' explanations in Part B.

## PART B: EXPLANATION IN SCIENCE TEXTBOOKS

The purpose of Part B is not confined to identifying what explanatory structures are to be found in the four textbook types. Attention is also paid to the links between those structures and the textbooks' language, and the level of explanation offered to the reader. Two fundamental questions are also considered.

1. Has the nature of scientific explanation been elaborated in the body of the text?
2. Do the kinds of explanations given differ depending on the phenomenon being considered?

It is necessary to point out that textbook authors do not make any direct comment on the nature of explanation in science in their prefaces, with the exception of T.H. Huxley's Introductory (op. cit.). Therefore the type of explanations given must be extracted from the body of the text alone.

### EXPLANATION IN THE CATECHETICAL TEXTBOOKS

The Catechetical textbook authors did not explicitly detail or even refer to the nature of explanation in science. But they occasionally carefully distinguish between scientific and other types of knowledge or methodology.

Q. Can you tell me the meaning of the word Science?

A. It is the same as knowledge, the Latin name for which is scientia, formed from the verb scire, to know.

Q. What is the distinction?

A. Merely to know that a thing exists, or that an event has taken place, without any reference to

its relations to other things or events, is simple knowledge of the thing or the event; and when the knowledge of the relations is added to the simple knowledge, the sum becomes scientific knowledge, or science. (page 1)

Q. And cannot scientific knowledge be obtained without any effort?

A. It cannot. Whatever number of individual things a person may know, he has no science if he does not know the relations that they have to each other or to other things; and that is found by comparing the one with the other, which is an operation of the mind, an effort or exercise of thought... (page 2)

Q. Do they (art and science) proceed by the same means, then?

A. They do not: science proceeds by discovery; art proceeds by invention (page 16)

Q. Is any particular name given to sciences of that kind?

A. They are called experimental sciences; the applications of art by which it is sought to discover the truths, being only trials (experiments), and not certain applications, as is the case where art is founded upon science. (page 17)

A. ...for after considerable progress has been made in science and in art, there are certain general laws found out, which, though not absolutely certain in a new case, are very useful in pointing out what is likely to be discovered, and what not. (page 18) (Turner, 1832)

Science is pictured in this passage as the knowledge of things, events, and their relations. It proceeds by discovery, and moves towards truth. In progressing, general laws are discovered, acting here as guides to likely future discoveries; their role in explanation is not mentioned.

#### (1) Explanation Using Aristotle's Four Causes

In dealing with the textbooks of this type, this section also introduces some of the important language considerations involved in the analysis of explanation. The first of these is the notion of levels of explanation. There are two ways this needs to be considered; how far the textbook will pursue notions

of ultimate explanation, and what level of explanation is appropriate to the reader. The first of these will be considered immediately. Where does the final explanation lie--in the laws, in the origin of those laws by God, in the particular psychology of man? At the highest level, these Catechetical textbook authors provided explanations that were teleological. Reference is made to phenomena occurring in response to some ultimate purpose, or because they were designed that way. The following quotation is from Introduction to the Arts and Sciences by the Reverend R. Turner, 1832, the 20th edition.

Q. What is the grand foundation of Natural Theology?

A. To our comprehension, the universe is infinite; that is, we cannot assign boundaries to it, neither can we fix a time for its beginning or end; all its varied powers and principles work as if it were one; and therefore unbounded extent and interminable duration must be, to the Maker of it, not more than momentary thought is to man.

Q. And is the existence of knowledge and power equally conspicuous throughout all the works of nature?

A. It is, only we do not heed it in those things with which we are familiar: that one's foot is firm on land, and sinks down in water, or in empty space, is just as strong a proof of the Almighty wisdom and power as the revolution of systems,--the resistance in the one case, and the yielding in the other, are portions of the same general law that sustains suns and planets. (Turner, op. cit.)

But such teleological explanations (Aristotle's fourth cause) are not commonly resorted to in the normal explanations given to common phenomena in the textbook. Rather, they were usually reserved for separate passages within the textbook dealing with God's relationship with the natural world. Actual teleological explanations of specific phenomena are rare; in most cases the 'laws' or 'principles' of science will serve. The origins of

these laws in God's design is mentioned but not usually otherwise elaborated. While it is true that some of these textbooks mention God frequently, it is usually only in reference to 'the splendour and majesty of his works'.

These teleological explanations are the only one of Aristotle's four causes commonly used in the Catechetical textbooks.

## (2) Cause and Effect Accounts of Explanation

These are by far the most common of the explanatory structures offered in these texts. Whenever 'principles' or 'agents' are referred to, they are regarded as causal principles or agents.

An appeal to the Turner textbook will make this point above clear. In what follows, a "principle" of caloric is used to provide an explanation of several phenomena--changes of state, and expansion.

Q. How would you define caloric in a chemical sense?

A. It is the principle by which the cohesion of the atoms of bodies is loosened, or the atoms themselves separated from each other.

Q. Does heat always expand the volume of bodies?

A. It does so at very various rates; but it may generally be said to do so when there is no change of state of the body and no chemical action.

Q. If there is a change of state?

A. When the change is from gas to liquid, or from liquid to solid, a quantity of heat becomes sensible, in the generality of cases; and when the change is the other way, a quantity disappears.

Q. What other general function, besides loosening the connexion of bodies, may be supposed to be performed by heat or caloric?

A. Their change of state; and we may say that it is owing to its relation to caloric that any body happens to be a solid, a liquid, or a gas; and that a different relation to caloric would place it in another of those states. (Turner, op. cit.)

Here there is definite reference to a cause or principle; empirical data in the sense of perceived changes of state; a

chain of logic between cause and effect, although that chain is very thin--in this instance, the whole explanation can be seen to founder on the undefined meaning of the phrase "...relation to caloric...", for this relation is necessary to the proof.

Dr. Brewer's Guide to Science provides further examples of explanation in these early textbooks, and a contrast to Turner. Brewer makes no reference to laws of nature at all.

Q. What are the principal effects of heat?

A. 1.-- Expansion. 2.--Liquefaction.  
3.--Vaporization, and 4.--Ignition.

Q. Show that heat expands air.

A. If a bladder (partially filled with air) be tied up at the neck, and laid before a fire, the air will expand until the bladder bursts.

Q. Why will the air swell, if the bladder be laid before a fire?

A. Because the heat of the fire will drive the particles of air apart from each other, and cause them to occupy more room than they did before.  
(Brewer, op. cit.)

This example is important for the point concerning levels of explanation, mentioned earlier. Once the reader has been told that heat causes objects to expand by driving their particles apart, the rest of the questions in the section ask about specific instances of that general principle; i.e., "Why does a glass crack when hot water is poured into it?" It is thus an example of using deductive argument. But a full, or deeper explanation, requires some understanding of why heat 'forces particles apart'. This is particularly true in this case, when heat was defined in the very first question of the Brewer textbook as "That which produces the sensation of warmth." The fuller explanation is not given in Brewer, perhaps because of the age and educational background of his likely readers, rather than concerns over ultimate explanations. This is seen to be the case not only because of the intent of the textbook, as

stated in the preface, to explain common phenomena "...in language so simple that a child may understand it, yet not so childish as to offend the scientific." It is also indicated by the lack of concern given to the nature of explanation in the sense of ultimate or 'first cause' explanation. Brewer's task becomes to correctly determine the level of explanation appropriate to the reader.

### (3) Empirical Accounts of Explanation

The Catechetical writers made no reference to the laboratory at all, and therefore operationalism or a double-vocabulary view have no place in explanation in these texts. Yet there are numerous examples of observations, or immediate sensory experience, both of which are the foundations of empiricism. The pattern is usually for some phenomenon to be pointed out, and then this is generally followed by the question 'why?' This question is in turn followed by a causal explanation. If "...the central argument of empiricism (is) that all knowledge should be related as closely as possible to observable facts" as Piaget (op. cit.) claimed, then these Catechetical texts clearly start in the right way. But as the above example of caloric shows, these writers were not to be confined to using only sensory impressions to build up scientific explanations.

### (4) Inductivist/Deductivist Accounts of Explanation

The Catechetical textbook authors were likely to see God as the ultimate explanation, but they were not concerned to make such a view a principle concern of their texts. No clear, definitive and explicit model of explanation is presented. A better clue



as to the general level of explanation given in these textbooks comes from an examination of inductivist/deductivist explanations offered. It is necessary to remember, when reading these passages, that there was a great deal of confusion between simply stating what has been found to be the case, and providing explanations.

Q. What are the principles that maintain a body in a state of rest?

A. Pressures which exactly oppose each other, and the body is on that account said to be in equilibrio, or equally balanced.

Q. How many forces or pressures are necessary for keeping a body in equilibrio?

A. Two, which are equal and exactly opposed to each other.

Q. If they are opposed, but not equal?

A. The body will have a tendency to move equal to their difference. (Brewer, op. cit.)

This passage can be fairly called an explanation of equilibrium, or, at a more concrete level, of why objects remain at rest. "Pressure, or forces" is given a definition later in the section quoted as "Anything which tends to produce motion is a power or force, in a mechanical sense." It is easily seen that this passage meets some of the criteria of Hempel for explanation. There is mention of a general law or 'principle' (today called the law of inertia), and there is at least a hint or reference to empirical evidence in the notion of 'equal' and 'opposed' if it is assumed they were derived from observation. But the logical connections between principles and results are not elaborated.

The passage does emphasise three important points concerning explanation in these early textbooks. Firstly, a rejection of explanation by deference to authority, or, more specifically, human authority, as it has been shown that divine authority

could still be evoked when required. This is seen in the move away from early Greek ideas that objects have an inherent tendency by their natures to be at rest, or to move to their place. Secondly, there is a strong desire to emphasise physical or objective causes as explanations for events. The emphasis in the Catechetical textbooks was on phenomena, not on essences or forms. This is a central reason why the first two of Aristotle's 'four causes' were seldom used. This is also shown by the reference in the textbooks to a "body" or "object". This abstraction away from a particular object does not allow explanation to rest on the composition or form of the object. And thirdly, there is clear use of logic in making inferences and, therefore, providing explanations. This is clearly related to the last point above. General rules are given, for abstract objects, from which deductions can be drawn about particular objects. Logic is also the key means by which the "relations" were to be established. There are further uses of logic, however.

Q. Explain what you mean.

A. That steam requires force to keep it from separating, and ice requires force to separate it; and if the one can be changed into the other, they must be both capable of some intermediate state, such as that of liquid water, which can be changed into steam or into ice. (Ibid)

This passage is an appeal to a logical argument without empirical proof.

#### (5) Levels of Explanation

The level can be decided upon by the writers in three ways. They can consider the level to be fixed by the amount of knowledge required to move from one level to the next deeper

(e.g., before equilibrium can be treated in greater depth, perhaps the reader needs to know vector arithmetic). Or the writer can consider the level to be determined by the readers' level of intellectual development (e.g., in a Piagetian sense). Finally, the level can be fixed by a definite purpose of the writer's (e.g., to match the levels to those of external examination questions). All three levels may be constraining an author at the same time. In the examples given from the Catechetical textbooks, the authors' views on levels of explanation are not clear, but the passages suggest that the authors deliberately chose a low level of explanation not only to match the intellectual level of the readers, but also to suit their purposes of providing simple explanations of common phenomena for autodidactic readers. This assumes that the authors had a higher level of explanation available to themselves. Considering the reputations of many of these authors, and the references in their prefaces to having the information either supplied or checked by 'leading authorities', this assumption seems fairly certain.

#### (6) Language and Explanations

The above section leads to a consideration of the relationship between the language of these early textbooks and explanation. It was claimed in the Introduction to Part A that argument was a determiner of textbook language. More specifically, explanation was claimed to impose a certain structure on the textbook language, due to the distinctive, if not unique, nature of explanation in science. Structure of course does not imply a necessary prose style. It is then fair to ask if the

Catechetical style of writing is appropriate for providing explanations; does it hinder or promote the purpose of providing explanations to readers? There is no doubt that the desire to provide explanations at some level has structured the language in these texts to some degree. As seen in the passages quoted above, there are patterns of explanation; a principle is stated, deductions are drawn, and examples are given. What is also clear, however, is that these textbook authors were more strongly influenced by purposes other than providing explanations. Those other purposes were to inform their readers about the results of science, and linking the natural world to the divine. Explanation is not a strong determiner of language style in these textbooks because explanation was a minor purpose; and of course, these writers felt free to move out of the constraints of a model such as Hempel's because reference to divine explanation was legitimate. In the case of the Catechetical writers, it is truer to say that explanation had to fit into the question and answer format as best it could, rather than acting as a strong constraint. There is no reason why explanation cannot take place within such a question and answer format, of course--Socratic dialogue can argue to perfectly satisfactory explanations. What may be argued to be missing is the lack of actual empirical data in these dialogues, where all points are logically debated from evidence taken as given and correct.

The discussion and examples indicate that the authors had a view of science as both a collection of information about the structure and function of the material world, and as ordered by law. The pattern of explanation used suggests that it is

appropriate to place these texts in the rhetorical category of expository, and within the genre of information. The explanations express nothing of the methods of science, nor of science as concerned with enquiry. Science education was therefore the use of contemporary catechetical teaching methods to present the information for memorisation.

#### EXPLANATION IN THE CONVERSATIONALIST TEXTBOOKS

The writers of the Conversationalist textbooks were less concerned with science as a school subject or as a discipline, than they were with other ends. These writers used scientific content to teach proper behaviour, improve reading skills, and discipline the mind. It is not surprising, therefore, that they paid little attention to scientific models of explanation. As did the Catechetical authors, they saw science as a method of discovering natural truth, and were equally concerned to present the discoveries and not the methods to the readers. For these authors, presentation was more important than content.

#### EXPLANATION BASED ON ARISTOTLE'S FOUR CAUSES

An interesting example of the use of Aristotle's first cause--"What is it?"--is found in the Rollo textbook on Fire. The following is offered as an explanation for the use of 'spirits of turpentine' as an aid for lighting a lamp.

"But, father, why will the wick light any quicker?"

"Why, different substances take fire at different temperatures. For instance, if you were to put a little heap of sulphur, and another little heap of sawdust, on a shovel together, and put them over a fire, so as to heat them both equally, the sulphur

would take fire very soon, but the sawdust would not until the shovel was very nearly red hot...There is a great difference in different substances, in regard to the temperature at which they inflame." (Rollo, op. cit.)

Here explanation depends, to some extent, on the nature of the substances themselves, along with heat as an accompanying causal agent. There is no attempt to say why different substances "inflame" at different temperatures; again, as in the Catechetical textbooks, the writer's assumption must have been that such a level of explanation was inappropriate to his purposes. In the Rollo textbooks, religious teleology was completely absent.

#### CAUSE AND EFFECT EXPLANATIONS

By far the most common form of explanation in these texts is causal. The following is typical of this approach.

James. Will you explain the causes (of the tides)?

Tutor. I will endeavour to do this in an easy and concise manner, without fatiguing your memory with a great variety of particulars:--

The ebbs of tides, and their mysterious flow,  
We, as art's elements, shall understand. Dryden.

You must bear in mind then, that the tides are occasioned by the attraction of the sun and moon upon the waters of the earth: perhaps a diagram may be of some assistance to you...

Since the force of gravity or attraction diminishes as the squares of the distances increase, the waters on the side A are more attracted by the moon M, than the central parts at C...

Charles. You mean that the waters will rise at A by the immediate attraction of the moon M, and will rise at B by the centre C receding and leaving them more elevated there.

Tutor. That is the explanation. (Joyce, op. cit.)

The passage illustrates many of the points made in the

discussion of the Catechetical texts: causal principles, logical arguments, lack of empirical data, and no clear connections between principles and phenomena at the underlying "why" level of explanation. It is interesting to compare this explanation with a modern one from It's Your World (Ball et al., 1976), an integrated general science textbook published in Australia.

The effect of the gravitational attraction of the Sun and Moon on the Earth produce another natural change--the tides. The side of the Earth nearest to the Sun experiences a gravitational attraction slightly stronger than that of the Earth itself. On the opposite side to the Sun, the attraction is slightly weaker. The water in the oceans moves under these forces. Water is 'pulled' by gravity to pile up on the side nearest to the Sun. On the opposite side of the Earth, the water which has been left behind also piles up. This creates 'solar tides'.

Similarly the Moon causes 'lunar' tides...  
(Ball, 1976)

There has clearly been no change in the explanations given by these authors in terms of either depth or kind. The more modern textbook's version is arguably even more confusing for the reader, with such phrases as "...slightly stronger than that of the Earth itself." and "...also piles up." Nevertheless, both examples are concerned to use a causal agent or principle (attraction) to provide explanations for the phenomenon.

While teleological views are present, they are most strongly expressed in those works published by religious organisations, such as the Society for Promoting Christian Knowledge, or which were written by authors who had religious purposes in mind. An example of such a textbook is Joyce's Scientific Dialogues, 1821 (op. cit.) This was one of the most popular textbooks of its type ever produced. It was re-issued up to 1846, with new editions appearing at frequent intervals. Though there is a

great deal of religious content, there is only one reference to God as the "First Cause". It occurs late in the book in an interesting passage.

Charles. What can be the use of these fixed stars?

Tutor. Your minds indeed are too enlightened to imagine, like children unaccustomed to reflection, that all things were created for the enjoyment of man. The earth on which we live is but one of eleven planets circulating perpetually round the sun as a centre, and with these are connected eighteen secondary planets or moons, all of which are probably teeming with living beings, capable, though in different ways, of enjoying the bounties of the great First Cause. (Joyce, op. cit.)

In the rest of Joyce's textbook, God is presented as the Creator and Sustainer of all the wonders of nature, but not specifically as the cause of phenomena directly. The explanations given by Joyce are similar in level and structure to those of the Catechetical writers.

#### EMPIRICAL AND INDUCTIVIST/DEDUCTIVIST ACCOUNTS OF EXPLANATION.

There is no evidence in these texts of the use of either of these structures. Laboratory experiments are absent, and natural law is not used as an organising principle for explanations.

#### LANGUAGE AND EXPLANATION

Recall that the Conversationalist writers had an expressed commitment to their rhetorical style. They believed that such story-based writing was one of the best ways to learn. Given this commitment, it is unlikely that they would allow the demands of scientific explanation to control that style to any degree. As in the Catechetical texts, explanation takes a minor



role. The Conversationalist story can, however, provide a setting in which the need for an explanation can arise quite naturally in the course of the story, a need which could lead to discussions of explanation offered by other texts or the teacher.

#### EXPLANATION IN THE EXPERIMENTALIST TEXTBOOKS

No mention will be made in this section of Aristotle's Four Causes as they do not occur, and only brief mention will be made of Inductivist/Deductivist accounts. The Experimentalist authors had an over-riding commitment to causality.

#### CAUSE/EFFECT AND EMPIRICAL ACCOUNTS OF EXPLANATION

The Experimentalist textbooks, written as they were by scientists of great reputation and commitment to science as a method, bring scientific explanation to far greater prominence than either of the textbook types considered so far. Indeed, Huxley considers the nature of explanation explicitly in his Introductory. The following is an expansion of a quotation from Part A of this chapter.

Anything is said to be explained as soon as we have discovered its cause, or the reason why it exists; the explanation is fuller, if we can find out the cause of that cause; and the further we can trace the chain of causes and effects, the more satisfactory is the explanation. But no explanation of anything can be complete, because human knowledge, at its best, goes but a very little way back towards the beginning of things. When a thing is found always to cause a particular effect, we call that effect sometimes a property, sometimes a power of the thing. Thus the odour of onions is said to be a property of onions... When we have made out by careful and repeated observation that something is always the cause of

a certain effect, or that certain events always take place in the same order, we speak of the truth thus discovered as a law of nature...But it is desirable to remember that which is very often forgotten, that the laws of nature are not the causes of the order of nature, but only our way of stating as much as we have made out of that order. (Huxley, op. cit.)

These statements show a willingness to address the issues of the nature of science and scientific explanation for the readers. While there is a clear commitment here to causality, the empirical data component of the model is stressed in the subsequent sections of the Introductory. An important feature of this model is the emphasis placed on repeated verifications of causal relations leading to a law of nature. This is clearly opposed to using the laws of nature as explanations for phenomena, as in the Inductivist/Deductivist approach.

Although written after the first of the Macmillan Primers appeared, and in response to difficulties with method and explanation between the separate sciences, the Introductory volume was intended to be read before any of the more specialised Science Primers. As a result, the other textbooks make no direct mention of explanation. As a consequence of the model of explanation outlined by Huxley, however, their explanations tended to be rather long for such small volumes. For not only had causes to be discovered through experiment and observation, they also had to be demonstrated--such was the dual nature of the Experimentalist concern with scientific method. Here is an example from the section on Heat in Balfour Stewart's Physics. First there are some introductory remarks on the nature of heat, and the methods to be used to discover its properties.

Now if heat be something that has entered into the ball we should expect that as it cools it will grow continually lighter. If, however, this experiment be properly made, it will be found that the iron ball does not lose weight as it cools, and therefore whatever heat be, its presence has not made the ball one grain the heavier.

We have strong reasons for thinking that heat is really a kind of vibratory motion, so that when a body is heated each extremely small particle of it is moving about either backwards and forwards or round and round. But these particles are so very small, and their motions so very rapid, that the eye has no means of seeing what really takes place...

You see now how great a likeness there is between a sounding body such as a bell and a hot body such as a white-hot ball. The particles of both bodies are in a state of rapid motion: those of the bell strike the air around the bell, and the air conveys the blows to our ear; the particles of the hot ball also deal a succession of blows to the medium around the ball, and this medium conveys the blows to our eye...

...in the case of heated bodies, we have first of all to study the bodies themselves, and secondly to learn how fast the rays of light and heat which they give out travel through the medium. (Balfour Stewart, op. cit.)

There is a clear picture here of the way explanations will proceed. In order for heat to be used as a cause, it must be clearly defined. Experiments are used to show that heat is not a material substance, and analogies are used to gain a picture of heat as a mode of vibration, like sound. This is followed by a set of experiments describing the effect of heat on various substances, resulting in expansion, change of state, and chemical change.

Expansion of bodies when heated.--When a body is heated, it almost always expands; that is to say, it gets larger in all directions. To prove to you that this is the case let us heat a solid, a liquid, and a gas...

Experiment 37.--Here is a hollow glass bulb which is filled with water; let us now heat this glass bulb, and the water will rise in the fine tube which is attached to the bulb. In this case both the glass bulb and the water expand, but the water expands much more than the glass bulb, and hence

it pushes its way upward in the fine tube...  
(Ibid)

Interestingly, the passage does not make the clear statement that heat is the cause of the expansion, nor does it ever state why heat causes the expansion. Expansion is left as one of the "powers" of heat. This level of explanation is similar to that of the Catechetical and Conversationalist textbooks, but perhaps for slightly different reasons, unconnected with purposes outside science as was the case with the earlier texts. It may be that Balfour Stewart felt that such a causal level of explanation was appropriate to the readers' understanding, as well as being the correct model for science. Nevertheless, no explanation for the actual effects of heat on objects when they expand, change state, or undergo chemical change is given.

One more example of explanation will be given to indicate that the example from Balfour Stewart is not atypical. Roscoe's Chemistry is interesting from the point of view of explanation because it shows clearly that Roscoe was not so concerned with using laws to provide explanations for phenomena, as he was for using laboratory techniques to uncover the "properties" of substances. Thus, the Roscoe textbook is more descriptive than interpretive, and explanation of phenomena is clearly based on method.

What is Water made up of?

Let us see if we can get anything else from water than steam, by treating it in different ways.

Experiment 12.--Instead of sending heat into the water, by which I only get it to boil, I will send a stream of electricity through the water...I use four cells of a Grove's battery...and the electricity will pass into the acidified water by the two platinum wires passing through the cork at the bottom of the glass funnel, when I join these with the copper wires from the battery.

What do we notice the instant we join the wires?

The water near the wires seems to boil, or effervesce, owing to small bubbles of gas given off...

If we repeat this experiment with the water, we shall always get the same result, and by no other treatment that we know of can we get anything else but oxygen and hydrogen from water. Hence we conclude

(1) That by means of electricity we can split up or decompose water into two perfectly different substances, oxygen and hydrogen gases; and into nothing else.

(2) That water, when thus decomposed, yields twice as large a volume of hydrogen as it does of oxygen. (Roscoe, op. cit.)

Roscoe was engaged in generating the empirical data which could then be used to provide explanations. The numerous experiments in his book emphasised the 'discovery' nature of science, rather than 'demonstrated' the truth of chemical laws.

#### LANGUAGE AND EXPLANATION

With the Experimentalist textbooks, several new features relating explanation and textbook language become apparent. Science began to dominate the rhetorical style. Science as a discipline became the focus of the book, and teaching that discipline became the central purpose of the book. There were several consequences of this. A comparison of the passages quoted thus far in this chapter show that there was a marked change in the Experimentalist texts with respect to vocabulary, with an increase in both the number and range of specialized terms: scientific vocabulary, laboratory vocabulary, and mathematical vocabulary.

More generally, however, the style of writing changed to match the demands of informing and instructing. This can be seen in several ways. Firstly, the emphasis on experimentation was important. Experiments demand sequenced directions or

instruction, imposing an order on the writing. They also demand description, such as of equipment or procedure, which require accuracy and clarity.

Secondly, along with experimentation there is an emphasis on observation. While this could allow scope for the use of much descriptive language, it was generally the case that, in fact, the readers were told what to observe. Scientific observation imposed restrictions on the permissible uses of language to describe what was seen or heard or felt. No longer are the readers to be allowed to respond, as were the characters in the Conversationalist textbooks, with such 'observations' as this: "How big does the moon look?" said Miss Mary. "Why, about as big as a large plate," said Rollo.

Thirdly, experimentation and observation allowed the writer to use these methods to draw conclusions. These conclusions could either be concerned with explanation of a phenomenon, or with the properties of a substance. In either case, the drawing of conclusions demanded strict logical reasoning. The phrases "Hence we learn that.." or "Now we see that..." and several other variations of these connective phrases are evidence of their presence in these texts. Such conclusions are carefully expressed, because they are taken to be true discoveries about nature. The following is a brief example.

We have learnt--

1. That the candle soon goes out if it be burnt in a bottle of air. (This sort of conclusion could have found in an earlier type of textbook)
2. That a colourless invisible gas called carbonic acid is formed in the bottle after the candle has burnt.
3. That the carbonic acid gas comes from the carbon or soot contained in the wax.
4. That water is also formed when the candle burns.

We therefore have learnt that the wax of the candle has not been destroyed or lost, but that it has changed its form and has been converted into carbonic acid and water. This sort of an entire change is called a chemical change. (Roscoe, op. cit.)

This passage also serves to emphasise a further point about such language; theory is tied to objective data collection. The conservation of matter is not presented as a theory that will 'explain' the disappearance of a candle as it burns, but rather the reverse. This demand imposes a structure on the argument--the conclusions which collect as a body of knowledge about substances can be used to develop a chemical theory only if logical appeals can be made to the results of experiments. It is not that clear cut of course; for example, limewater is used as a test for carbonic acid gas, but no explanation is given as to why it goes milky.

Finally, the Experimentalist approach is dependent upon measurements being made. Again, these measurements must be accurate, linked carefully to the experiment, and properly manipulated and expressed. Measurement adds in a new dimension of abstractness, both in terms of the symbol systems used (e.g., the notion of various temperature 'scales') and in assigning numerical values to states of a system or object (e.g., a temperature of 50 degrees, or a hardness of 7).

Generally, then, what is distinctive about the Experimentalist writers' language of explanation stems from their concern to lead the reader carefully through the process of discovery and demonstration. This required the use of a more formal rhetorical style, influenced by the need to carefully collect evidence, make measurements, and draw conclusions, proceeding in

a more structured manner than either the Catechetical or Conversationalist writers.

#### EXPLANATION IN THE FORMALIST TEXTBOOKS

With the Formalist textbooks, the shift to Science as the focus of the text is complete. While the Experimentalist could still talk in their prefaces about training the mind in certain ways of enquiry, the Formalist writers were chiefly concerned with science as a body of knowledge that must be transmitted. The reader is not someone whose mind must be disciplined, but, most often, an examination candidate. Science itself, as shown in Section A, was generally seen by these writers as a collection of findings rather than as a method. As a consequence, there is a shift from the explanation of methods and properties as in the Experimentalist texts, to an explanation of the formal structure of the discipline. Physics and chemistry in particular came to be seen as formal deductive systems similar to geometry, where the application of axioms and laws led to deducible results confirmed by numerical solutions. Particular phenomena were of small concern compared to the universal power of the deductive system; they serve only as examples of general results.

As a result, explanations based on Aristotle's Four Causes do not appear in these texts, and will not be examined here. Unlike the Experimentalists, who had Huxley's Introductory as a guide, the Formalist authors do not have an explicit model of explanation to follow. Their texts, therefore, often present a mixture of explanatory structures in one volume.



### CAUSE AND EFFECT EXPLANATIONS

The Formalist authors make no mention of God as the First Cause. Nor do they commonly use causality explicitly as an explanatory structure. Consider the following quotation from Noakes' New Intermediate Physics.

Consider first the evaporation of a liquid into a closed space, initially evacuated. The energy of the faster-moving of the molecules near the surface of the liquid will enable them to get beyond the attraction of the neighbouring molecules, and they will pass out into the surrounding space. As more and more molecules enter the space, the pressure they exert by their collisions with the walls of the enclosure increases. But the molecules moving in the space above the liquid collide with the liquid surface also, and those striking the liquid surface may be supposed to return to the liquid....Eventually as many molecules return to the surface per second as leave it per second; when this happens, the number of molecules present in the vapour state remains steady, and the pressure of the vapour has reached a maximum steady value. (Noakes, 1970)

The explanation of evaporation is based on rapidity of motion as the cause. This rather informal use of causality is typical of the Formalist textbooks. It is, however, rarely used at all. Noakes, for example, like the great majority of Formalist authors, does not offer any explanation at all for the expansion of a metal bar on heating. Those texts that do mention thermal expansion tend to dismiss any explanation of it with phrases like 'thermal expansion is caused by heat'.

Chemistry texts, too, rarely display causal explanations. The following passage is from The Australian Academy of Science's chemistry text, Elements of Chemistry.

Solids have a vapour pressure which is usually considerably smaller than that of the corresponding liquid. As in the case of liquids, evaporation of solids is due to particles (atoms, ions or molecules) at the surface which instantaneously have sufficient kinetic energy to

escape the forces of attraction of their neighbours. (Bucat, 1983)

Again the explanation is causal, but on a very informal level. This may be due to a concern for offering the appropriate level of explanation to the readers' current understanding. If so, there is no mention of this in the prefaces. But even these low levels of explanation are often lacking altogether. The following is from Walker's Introduction to Physical Chemistry.

Solids are said to sublime when on heating they pass directly into a vapour, which on being cooled does not condense to a liquid but directly to a solid. Sublimation takes place with ease under ordinary conditions when the solid has at its melting point a vapour pressure not far removed from the external pressure, or, what practically comes to the same thing, when the melting and boiling points of the substance are comparatively close together....By sufficiently reducing the external pressure, the boiling point of any substance can always be lowered to the neighbourhood of its melting point, and sublimation can take place. (Walker, 1910)

The account of sublimation given here is purely descriptive. The concern of the text is clearly to tell the reader what happens, and the conditions under which it can be made to happen, but not to explain why it happens.

#### EMPIRICAL ACCOUNTS OF EXPLANATION

The writers of Formalist textbooks quite naturally adopt one of the various empiricist viewpoints because, whether philosophically correct or not, empiricism has allowed science to progress enormously. Yet if the success of science is so plainly based on the assumptions of empiricism, it is surprising that these assumptions have never found a place in the content of textbooks. This is clearly important to the ability of the textbook writer to successfully assign meaning to fundamental

concepts, and the depth or level of explanation attempted. As outlined in Part A, it seems that both empiricism and the inductivist/deductivist approach have difficulties in assigning unambiguous meaning to such concepts. Axiomatics, it will be recalled, says in effect that a concept such as force is not to be understood by reference to muscular effects or physical analogies, as these introduce intuitive and anthropomorphic notions; nor by operations such as pulling on standard masses with springs in the laboratory, because such basic terms as 'mass' are left undefined; nor by referring to mass multiplied by acceleration, because the formalism is too open-ended for physical meaning. It is of interest, therefore, to see the ways in which Formalist textbook writers have handled this problem. The stricter empiricist physics and chemistry textbooks refer the readers to experiments made in the laboratory, the results of which are generalized into laws such as the law of conservation of momentum. The following extracts are from Mayfield et al.'s Fundamentals of Senior Physics, 1975, a currently popular senior level physics textbook used in Australia.

The...treatment of energy...is in line with the modern approach to mechanics through multi-flash photography and frictionless motion. (From the preface)

This chapter is about energy, an idea which you have no doubt heard about and a word which you have certainly used. In fact, one of the difficulties we might have in understanding the concept of energy stems directly from the wide variety of ways in which the term is loosely used. Our approach will be more precise... (The text now refers the reader to experiments contained in the practical book on collisions between gliders on an air track).

...it would seem that the law of conservation of momentum does predict the actual outcome of an interaction, but it does not preclude other

possibilities which never occur in practice. There must be another law (or laws) which accounts for one outcome and precludes the others...The problem was solved by the Dutchman Christiaan Huygens when he correctly suggested that the scalar quantity mass times velocity squared was conserved as well as the vector quantity momentum. (Mayfield et al., 1975)

The statement that there "must be another law which accounts for" observed phenomena not only illustrates the textbook's commitment to a deductive system based on natural laws, but also shows the use of empiricism to provide an explanation. Thus the outcomes of experiments are given an explanation by reference to a law which must underly them, while at the same time the experiments are being used to uncover the laws. This is an important shift from the procedure adopted by the Experimentalist writers, who were only concerned to uncover causes as explanations. For example, Roscoe's Chemistry includes a section on combustion, one part of which tries to determine the cause of what is observed during the burning of a candle. The concern was not to uncover a law, but a cause. The following two extracts are from a Formalist chemistry text, Bailey and Bausor's School Certificate Chemistry.

Many elements...are capable of combining together to form more than one compound. Let us now perform some experiments with a view to finding out whether in two compounds of the same elements there is any simple relation between the relative proportions of these elements.

(This is followed by two experiments-oxidation of lead, and water in copper sulphate).

These and all similar cases may be summed up in the following statement, which is known as the Law of Multiple Proportion... (Bailey and Bausor, 1929)

The above is a discussion of multiple proportions, and the following is an extract from their treatment of combustion.

The Candle Flame.--The inflammable matter in a

candle is the wax or tallow, consisting of compounds containing carbon and hydrogen. The wax is melted and passes up into the wick, which serves as a still supplying the vapours of carbon compounds to the space immediately surrounding it. That such a space exists containing combustible vapours may easily be shown by the following experiment:-

Exp. 180.--Depress a sheet of stout paper quickly into a candle flame to the level of the top of the wick, and hold it steadily there for about a second. On withdrawing it, a ring of sooty deposit will be seen, and within it a clear space....

The changes which take place in this zone are very complex. The formation of dense hydrocarbons and separation of carbon particles is continued. (Ibid)

There are no laws of combustion to uncover, and the text is seen to limit its discussion to pure description. There is not even a low level causal explanation for the observation of the sooty ring, unless the reader is expected to make the assumption that the ring results from the complex "separation of carbon particles".

It is very common in the Formalist texts to find empiricism, as reflected in the place of the laboratory in schools, being used in a supporting role. Experiments have one of two functions in the textbook. Either they are used to uncover a law of nature (e.g., the law of momentum, or multiple proportion) or they are used to demonstrate the correctness of theory (e.g., by showing the soot is really there). The latter function is also achieved by using experiments to determine the values of certain physical constants, like coefficients of expansion or electrical resistivity. These constants are predicted by theory and quantified by a mathematical formalism, which the laboratory confirms.

# INDUCTIVIST/DEDUCTIVIST ACCOUNTS OF EXPLANATION

To begin to examine the place of deductive explanations in these texts, the following extract from a Formalist textbook will be useful. Smith's Intermediate Physics, first published in 1932, was reprinted 12 times to 1944. It has already been mentioned in Chapter 3 that its central purpose was to "cover the syllabus" for examination candidates. In the passage below, the structure of the presented explanation is, for the moment, more important than the language.

Momentum and Force.--Bodies only move relatively to their surroundings if they are acted upon by some external agency, and by experience we know that it is more difficult to move some bodies than others. This is because the bodies have different masses, where mass is defined as the quantity of matter in a body... The external agency which is capable of imparting motion to a body is called force...The momentum  $I$  is defined as the product of the mass,  $m$ , of the body and its velocity  $v$ , so that  $I = mv$ . (Smith, op. cit.)

In the text, this first section is used to introduce some important terminology. It does so through the formal method of defining them, much as Newton did in the Principia, or indeed as any formal system must do. The next section in the Smith textbook states Newton's laws of motion, then adds this paragraph.

A formal proof, analytical or experimental of these laws is not possible, but on them is based the whole system of dynamics, including astronomy. Since the results obtained and the predictions made by astronomers are in good accord with facts, it becomes difficult to imagine that the laws on which their arguments finally depend are erroneous. (Ibid)

The text has now developed some definitions and a set of laws. From these, two types of consequences flow. The first is a

tidying up of the formal system by establishing quantitative relationships, systems of units, and further terminology.

Force.--Newton's second law provides us with a means of measuring forces. The proportionality implied in the law may be made into equality by an appropriate choice of units. If the velocity changes from  $V_1$  to  $V_2$  in time  $t$ , the force  $F$  is given by

$$F = m(V_2 - V_1)/t = ma$$

only when this particular choice of units has been made, the force is equal to the change of momentum per unit time.

Units of Force.--When the mass of a body is given in pounds, and the acceleration in feet per second per second, the force is expressed in poundals. The absolute unit of force in the F.P.S. system is the poundal, which is defined as that force which, acting on a body of mass 1 lb., will impart to it an acceleration of 1 ft. per second. (Ibid)

The second consequence is simply using the system to solve specific problems, where assumptions about 'uniform' conditions and 'ideal' properties (e.g., massless strings) are specified.

Example.--A mass of 15 lb. is pulled along a horizontal table by a light inextensible string passing over a smooth pulley and carrying a mass of 1 lb. Find the tension ( $T$ ) in the string, and the acceleration ( $a$ ) of the system. (Ibid)

The formal structure of this presentation is typical of the general pattern for explanation in these textbooks. Remembering, however, the discussion in Part A concerning argued and unargued purposes, the nature of explanation in these textbooks is rarely explicitly mentioned. The writers do, however, expect the readers to use the formal structure to answer questions and perform calculations. In this sense, the laws are used in the sense of explanation outlined in the 'covering-law' model of Hempel, and expressed more clearly by Passmore, in his book Science and its Critics.

Merely to assert that mass and energy are

mathematically related does not of itself explain anything. But it can be used to explain a great deal. So although one can see why the positivists insisted that the propositions of mathematical physics do not explain it does not follow that science itself does not explain--unless, as some philosophers of science appeared to do, we identify science with the set of equations of mathematical physics. (Passmore, 1978)

The type of formal system referred to by Passmore is sometimes referred to as an axiomatic system. Meaning is assigned to the terms and concepts of science by their place in the axiomatic system. Recall, however, the difficulty with assigning physical meaning to important terms in such a formal system.

It is important, then, to examine the textbooks themselves for their treatment of some of these important quantities to see if these difficulties are evident in the writing. All of the textbooks to be cited below were published either in England or Australia, and were recommended for use by senior level students of physics.

ENERGY.--A body which resembles a wound-up clock in being ready to do work by letting its parts run down into the position which they tend to take, is said to contain potential energy or statical energy. "Energy" in dynamics and in physics generally, means capability of doing work. Everett, Textbook of Physics, 1900.

MATTER.--At the present moment, the question what is matter? is almost unanswerable. We know much about its intimate structure and properties, but still remain ignorant of its exact nature. A definition of the term is desirable; and of the many which have been suggested, it is perhaps sufficient to state that matter is that which can occupy space. Gregory and Hadley, A Classbook of Physics, 1925.

ENERGY.--If a body is capable of doing work it is said to possess energy and the quantity of work which it can do is a measure of its energy...The energy possessed by a body because of its motion is called kinetic energy. Energy possessed by a body on account of its state or its position is termed potential energy. Martin and Connor,



Basic Physics, 1945.

MATTER.--The mass of an object clearly depends on the amount of matter it contains. An increase in matter produces an increase in mass.

...inertial mass is defined so that the momentum of a system of objects, whether similar or dissimilar, is conserved during interactions. The mass of the object has been defined operationally. Ingram et al., Physics: A Laboratory-Orientated Approach, 1973.

The definitions given clearly indicate the problem with such an informal method of assigning meanings to these terms. In what sense do bodies "possess" energy? What is the physical or 'commonsense' meaning of mass if it is simply defined to conserve momentum, which is itself mass times velocity? Dissatisfaction with such an informal method is just the point of the criticism expressed by Mach, Poincare, Eddington and O'Leary in Part A. Formalism is an attempt to confront these difficulties, and Formalist textbooks are anxious to develop a mathematical formalism as soon as possible. While the formalist method can provide a logical structure, it may leave a conceptual, and perhaps perceptual, vacuum, allowing the reader to attach varying understandings to the symbols.

Interestingly, chemistry does not seem to experience this difficulty to the same degree. Dealing as it does with substances and processes, it rarely needs to refer to abstract entities such as energy or force. The writers of Formalist chemistry texts have therefore been able to use operational definitions more freely than the writers of physics texts.

...we may give as a preliminary definition of an acid: A substance which turns blue litmus red and contains hydrogen partly or wholly replaceable by a metal. (Cavell, 1946)

Oxidation was defined...as being a process in which a substance unites with oxygen. This is the

first idea of the process, and examples have been given in illustration--e.g., the burning of elements in oxygen... the second idea of the process (is)--namely, that the taking away of hydrogen from a compound is a process of oxidation. (Taylor, 1942)

These definitions allow the reader to assign meaning to a term or process by referring to a laboratory operation. There is still some difficulty with oxidation, however, with reference to abstractions such as "the taking away of hydrogen". Such phrases are theory-bound, in the sense that acceptance of theoretical statements is assumed before sense can be made of the definition. Still, a substance which has undergone the process of oxidation will be, in some senses, a different substance, and these differences can be made a criteria for the process having taken place.

#### LANGUAGE AND EXPLANATION

Part A of this chapter outlined the importance of carefully considering the types of explanations offered by authors, because once a model of explanation has been adopted, it strongly influences the language of the text. An explanation as a prose structure contains a certain set of terms, it proceeds in a specified direction, it makes appeals only to certain types of evidence, and it generally operates at a certain level of abstraction. In addition, the type of explanation reflects on the authors' view of science and science education.

In the Formalist texts, all the explanatory types discussed are tightly structured, and the language of the textbook reflects this formality. As detailed in Chapter 5, formal is a term often used to characterise textbook language, when it is taken

as the opposite of informal or 'chatty' or somehow less serious. This understanding of the word 'formal' is best considered in relation to the above discussion of Formalism as a method of explanation. The Formalist textbooks writers have been very concerned with a view of science as a body of knowledge structured by a formal deductive system. This view has led to the adoption of certain language patterns associated with such a system. This can be shown on three different levels of textbook organization.

1. On the level of the sentence and phrase, Formalist textbooks are characterised by such expressions as: if...then; ...when X occurs, then...; ...by Y is meant...; ...from Z it follows that...; ...because X is true, then... The use of such phrases occurred, for example, 18 times in the ten page chapter on Forces and Gravitational Fields in Fundamentals of Senior Physics (Mayfield et. al., op. cit.).

2. On the larger level of paragraph or other organizing unit within a chapter, the following devices are common: definitions (whether operational or not); reference to experimental results, usually from another book; logical deductive arguments using the phrases mentioned above; and mathematical formalisms culminating in a set of equations.

3. On the broadest level, that of the textbook itself, the structure of the entire work reflects a progression from basic axioms to derived results. The ordering of the chapters reveals this characteristic, as well as comments made in the prefaces. It can be seen that the first two levels directly determine language used; the actual words used in the phrases, and the limited range of possible wordings used in the larger units.

Common examples of such wordings would look something like the following:

Thus it is possible to show, as in Expt. 27...that one gram of hydrogen combines with 8 grams of oxygen. This relationship is an example of a universal rule known as the law of equivalent proportions... (Cavell, 1946)

If some quantity can be determined at every point in a region, a field is said to be defined. For example, if the air pressure is measured at many places over a continent, the set of readings forms a pressure field. (Mayfield et al., op. cit.)

The constant  $m$  is called the inertial mass of the object and is defined so that the momentum of a system of objects, whether similar or dissimilar, is conserved during interactions.

i.e.,  $(MV)_1 = -(MV)_2$

The mass of the object has been defined operationally. (Ingram et al., op. cit.)

If the kinetic theory is applicable to gases, we should expect pressure to be affected by other factors than the number of moles per unit volume. For example, the mass of the molecules and their velocities should be important, as well.

To measure the temperature of a gas we immerse some kind of thermometer in it. If the thermometer is colder than the system, heat flows into the thermometer until the gas and the thermometer are at the same temperature...When there is no net flow of heat, the thermometer is said to be in thermal equilibrium with the gas. (Chem Study, 1963)

These examples are the direct result of the adoption of an empiricist view of assigning meaning, and the desire to formalise the structure of knowledge into a deductive system.

A final point concerning the language of these Formalist texts deals with its appropriateness for their purposes of meeting examination demands, and presenting science as an organized body of knowledge. With regard to the first of these purposes, it is difficult to judge appropriateness without having a range of different textual styles to compare in terms of examination results. As has been shown, for example, the writers of the

Experimentalist textbooks were themselves examiners for the DSA, and wrote textbooks in the belief that they would meet such examination demands. There is no evidence that a given textbook style has consistently ensured increased examination success, especially given the wide range of other factors of equal importance--teachers, pupils, curricula and laboratories. The second purpose above, that of presenting science as an organised body of knowledge based on an empiricist model, raises similar difficulties that deserve closer attention.

It can be argued that if the organizing principles, and foundation assumptions, of science are not elaborated for the reader, then the body of knowledge will remain diffuse and unorganized, and the textbook could be seen as a compendium of facts and principles. The above section on explanation in Formalist textbooks makes clear the emphasis placed by the authors on using a deductive system to organise the content, but it has also shown that no discussion of the system takes place; there is still uncertainty as to whether an explanation has indeed been given to the reader.

### SUMMARY

The explanations presented to readers by the four textbook types are seen to differ, reflecting on the authors' views of science. And, in each case, the second order classification system of Section B can be consistently applied to them.

The Catechetical texts show the influence of religious ideas, with God as the 'first cause', but by far the most common explanations are based on logical deductions from stated results. The readers are simply told what is the case. Science

could be seen as a collection of such knowledge. This corresponds to their classification as within the genre of information, and as expository.

Conversationalist texts predominately use causal explanations. The characters are depicted as finding the causes for things, either through their own efforts or by being told by an authority figure. Science is again the collection of the results of such finding out. This corresponds to their classification within the genre of instruction, and as didactic/expository.

The Experimentalist authors regarded cause and effect as the basis for explanation in science, and their texts emphasised the methods by which scientists came to determine those causal relations. This corresponds to their classification within the genre of instruction, and as didactic/expository.

Formalist texts depict science as a formal, deductive system, and the explanations are logical exercises based on the underlying laws and principles of the science; the role of the laboratory in establishing such laws and principles is secondary. This corresponds to their classification within the genre of information, and as expository.

CHAPTER 7: THE INSTRUCTIONAL LANGUAGE OF TEXTBOOKS

## INTRODUCTION

The previous chapter used the notion of 'explanation' to investigate the authors' views of the nature of science. It was assumed that a central purpose of textbook authors is to present explanations for phenomena to readers as part of the informational content of the text. This chapter looks at the closely associated purpose of instructing the reader. For in order to learn, the reader must come to understand the explanations presented by the author.

More specifically, an investigation of instruction can reveal several things. Firstly, there will be differences in the instructional priorities of the authors. This question of content can be linked to authorial purposes as examined earlier; i.e., experimental, theoretical, religious, ideological. Thus, this chapter will consider which parts of that content the authors felt were in need of explicit instruction. Secondly, if it is possible to develop some idea of what it is to instruct by means of written prose structures, then judgements are possible on how well textbooks fulfill this purpose. Thirdly, instructional language can be used to establish the authors' views of the nature of science education, for instruction is obviously linked to the pedagogical purposes of the authors. For example, if the purpose of science education is seen as establishing in the mind of the reader a view of the world as causally connected and established by God, then the text would

be expected to support that purpose not only by providing causal explanations, but also by using language in such a way as to bring the reader to such a view.

As a consequence of the above it is important to establish two things; what is meant by instructing, and what are the ways of instructing referred to.

### INSTRUCTION VERSUS EXPLANATION

The word instruction may seem too ambiguous a term for the various pedagogical intentions of textbook authors. But it is intended simply to summarise those uses of prose to teach rather than simply to inform. Instruction is used in preference to the phrase 'to explain' because explaining is too closely associated with the term explanation to be useful here. To avoid possible confusion between explanation as presented in Chapter 6, and the act of explaining as treated here, the term instruction will be used.

An important step in distinguishing between explanations and the act of explaining (instruction) was taken by J. R. Martin in Explaining, Understanding and Teaching (1970). Martin develops the argument that an explanation is not an action: "An explanation is not a doing at all...although the things one does with or to explanations may themselves be doings, the explanations one does things with or to are not doings, (but) sentences or statements of some sort or other." (Martin, 1970). This corresponds to the idea of an explanation as a prose structure within textbooks. Martin discusses "explaining" by identifying four types of explaining; explaining as 'gap filling', as 'question answering', as 'reason giving' and as 'a



use of language--e.g., clarification' (Ibid). In terms of pedagogical purpose, it is sufficient to focus on the activity Martin refers to as "explaining something to someone", which is distinguished from "explaining something".

Explaining something and explaining something to someone differ from one another, then, in that the latter is an activity and the former is not. They differ also in that one who explains something to someone is trying to get that person to learn or understand something. He is imparting knowledge (or at least trying to), not seeking it. His problem is one of communication, of getting something across to someone. (Ibid)

Explaining something to someone is what is meant here by the term instructing. Instructing is an activity performed by someone for the purpose of 'imparting knowledge'.

#### INSTRUCTION AND LEARNING

Martin suggests that learning and understanding, considered as the aims of pedagogy, can be achieved by successfully imparting knowledge. Such a view allows this analysis to consider the explanations offered by authors as examples of the knowledge to be imparted, and instruction as the act of doing so. This activity, unlike explanation, is not discipline dependent, but is primarily an educational one. It is common to the everyday act of giving directions to someone who is lost, or lecturing in a University, or explicating a piece of poetry or religious doctrine. There is a sense in which one can instruct one's self, but that corresponds to Martin's idea expressed above of explaining something, which is a search for knowledge, rather than the giving of knowledge to another.

Given this definition, more needs to be said about the nature of instruction. What is meant here by 'imparting knowledge', and

what are the intended effects of the instruction on the readers?

The first of these questions can be considered from a pragmatic point of view, based on the link between the explanations and the pedagogical purposes of the authors, who must give their readers access to those explanations. Imparting knowledge can be taken to mean doing what is necessary to ensure that the new knowledge becomes part of the readers' world view, to use the language of alternative frameworks (e.g., Driver, 1978, 1983). This can be expressed slightly differently, in that successful instruction "...consists in reducing a situation to elements with which we are so familiar that we accept them as a matter of course..." (Bridgman, 1958). It may be argued at this point that many readers have no mature scientific knowledge of the 'familiar' things in their environment, or which are part of their world view. Gravity is certainly familiar to all students, yet few have any scientific knowledge, of the type contained in textbooks, concerning it. This is, of course, only an argument for levels of knowledge. As students progress through school, they supposedly encounter textbooks which are attempting to explain phenomena in greater and greater depth. But the initial learning, it seems, must either start with the familiar facts of the reader's experience, facts which 'make sense' from the child's world view, or attempt to immediately make the new concepts as familiar as the old. Using the example of gravity, it is easy to see the reluctance of the writers of introductory physics textbooks to explain gravitational phenomena using the Special Theory of Relativity, because the concepts involved must be made gradually familiar, keeping in

step with the developing understanding of the learner.

The phrase 'developing understanding of the reader' used above introduces the second question: what were the intended effects of instruction on the reader? The analysis thus far has paid no attention to the role of the reader of the textbook in the instructional process. Textbook writers, as shown in Section A, have not explicitly addressed questions of learning theory. While they intended to change the readers in some way, it is not clear exactly what changes, in a psychological sense, were intended. Phrases such as 'greater understanding', 'increased knowledge' or 'deeper awareness' occasionally occur in the textbook prefaces of all four types. This suggests that the method of instruction to be used was considered to be in some measure independent of the psychological changes referred to. There is, however, considerable differences in the types of knowledge to be imparted, as shown in Sections A and B. A major purpose of the analysis of the textbooks within this chapter is to examine the relationship between the authors' view of the important knowledge to be transmitted (the authors' view of the nature of science education) and the ways of transmitting it (the authors' instructional language).

#### INSTRUCTION IN TEXTBOOKS

Surprisingly few studies have been done on the nature of instruction when taken as an activity designed to explain, and most of them have been directed to those preparing lectures or technical manuals. Smith and Meux (1970) see instructing as "... (giving) the rules, definitions, or facts which are used to justify decisions, judgements, actions, etc." This of course is

only the top layer of instructing, for those rules, definitions and facts are often themselves in need of further detailing. Yet the former is a very common view of instructing adopted by modern textbooks, and makes the assumption that providing reasons appropriate to the discipline will make sense to a learner of that discipline. The tendency is to reduce the notion of instruction to that of outlining a logical system. Clearly this is not sufficient to meet the demands for instruction--there is no hint of 'making sense' or 'familiarity' in such a view. Miltz (1972) lists several factors involved in instruction, of which the ones relevant to written material are: vagueness (or clarity); precision of statement; frequency of examples; amount of material covered; length; rule--example--rule format; and length of sentences. There may, however, be conflicts here. What if "precision of statement" demands the adaptation of a mathematical formalism inaccessible to the reader? It is important to note that Miltz does not list factors which take into account the audience, the recipients of the instruction. It is also important to note how several of his criteria are identical to the criteria identified by Formalist textbook authors in their prefaces as valuable aims for textbook language. In this the textbook authors are seen to be operating on a 'Tabula Rasa' model of the students' minds. A crucial point that must be clearly made here is that the criteria for instruction set down by the researchers mentioned above are not derived from the content of any particular textbook or even science generally. They come from educational theory, learning psychology, and studies on textual reading. Therefore the acts of instruction need not be drawn from, or

make use of, the language and method of science.

#### INSTRUCTION AS PROSE STRUCTURES IN TEXTBOOKS

Instruction can be done in many ways; drawing analogies, building models, reasoning from prior experience, defining, pointing out or pointing to, demonstrating, giving examples, drawing maps or diagrams, using metaphors, and constructing logical arguments (both inductive and deductive). It may well be the case that certain ways of instruction are best suited to certain concepts; nonetheless, if the aim of instruction is imparting knowledge, then these ways are the means by which this may be achieved.

Textbooks of course are limited to those ways of instructing that can be written, but that still includes a wide range. Indeed, as was shown in Chapter 2, writers of Catechetical and Conversationalist texts felt that there were few things texts cannot offer that a teacher can, and many things that a teacher lacks resources for can be easily done by a textbook. What an author cannot do is be responsive in the way a teacher can by taking advantage of necessary interaction. Of necessity the textbook writers must get it right, unambiguously. They have the advantage of not being asked to 'think on their feet'--they can take the time to construct a clear, simple, meaningful instructional sequence. A well-sequenced, carefully prepared set of activities could take the reader from initial contact with a subject to the desired level of understanding. That, at least, is and has been the operating premise of all self-help books from the earliest autodidactic readers to today's 'teach yourself' books. They share the view that, while it may be true

that some things are more difficult to explain than others, they should not necessarily be harder to explain in textbooks. It has even been argued by the writers of self-help textbooks that those phenomena felt to be only explainable by having a learner witness something, or carry out a particular operation, can in fact be handled by a textbook by presenting a set of exactly those instructions--go and see, or go and do--which are the equivalent to what a teacher can do in similar circumstances.

Though there is a vast practical literature in science teachers' journals on how best to teach, or prepare, or demonstrate, a particular phenomenon or unit of work, the effect of different literary or rhetorical devices for instructing contained in textbooks has received little attention. The existing ones have tended to concentrate on two such devices: metaphor (Ortony, 1975; Miller, 1976; Petrie, 1974) and models (Ziman, 1978; Harre, 1975). The central difficulty for teachers and writers is that any instructional device, be it metaphor, examples, or whatever, is not always the best in every circumstance. That is, while all ways of instructing might be equally valuable, it is clear that at different times one may be more appropriate than another. Writers of textbooks traditionally have not, as shown in Chapter 3 on Prefaces, paid much attention to the pedagogical language of their text. Yet they do claim to be writing readable textbooks that will inform the reader at the appropriate level, whether that level be stated as an age group, or an examination level.

This chapter examines the textbooks for answers to the following questions concerning the pedagogic purpose of the authors. What do the authors feel is in greatest need of textual instruction?

What range of instructional devices do they employ? Are there patterns, or clear preferences, in how they attempt to instruct? And finally, has there been a change over time in the answers to these questions?

#### INSTRUCTION IN THE CATECHETICAL TEXTBOOKS

Instruction in these question-and-answer texts was, generally, quite straightforward--it was a matter of telling. Yet they often had a pedagogic purpose; recall the Preface to Dr. Brewer's Guide to Science.

No science is more interesting, than that which explains the common phenomena of life. We see that salt and snow are both white, a rose red, leaves green, and the violet a deep purple; but how few persons ever ask the question why! The object of the present book is to explain above 2000 of those questions... (Brewer, op. cit.)

So what is to be explained is clearly "the common phenomena of life", the 'why is the sky blue' sort of question. How is this instruction to be done? The following is an extract from Brewer's textbook.

Q. Why does fire produce heat?

A. Because it liberates latent heat from the air and fuel, by chemical action.

Q. What chemical changes in air and fuel are produced by combustion?

A. 1st--Some of the oxygen of the air, combining with the hydrogen of the fuel, condenses into water: and 2ndly--Some of the oxygen of the air, combining with the carbon of the fuel, forms carbonic gas. (page 39)

Q. Does the heat of the human body arise from the same cause as the heat of fire?

A. Yes, it does. The carbon of the blood combines with the oxygen of the air inhaled, and produces carbonic acid gas. (This takes place in the capillaries) (page 87)

Q. Why does running make us warm?

A. Because we inhale more air, and cause the blood to pass more rapidly through the lungs. Running acts upon the blood in the capillary vessels, as a pair of bellows on a common fire. (page 90)

(Ibid)

The first two answers are simple instances of telling, of stating what is the case. In order for these statements to do any instructing, the assumption must be made that all the terms used--liberate, latent heat, chemical action, combining, condensing--and the names of elements and compounds, are already understood by the reader. Given this assumption, the statements serve to show that this instance is merely an extension of something with which they are already familiar. For this to be true, the readers must have had considerable experience with the discipline of chemistry for these statements to be meaningful. The questions could then be seen as checking on the students' understanding of what they enquired into in the laboratory. As this was not the case with the users of these textbooks, the instructing can do little more than ask that the reader take the author's word that what is written is true. What it cannot do is make the terms used in the instruction 'familiar' in the way that has been argued is necessary for understanding.

The third question and answer, coming later in the text, uses a previously stated result to explain a new phenomena. This is not an analogy, because the two things being considered--fire and animal heat--are stated to be two aspects of the same thing. Thus this type of instruction is more properly described as establishing connections between similar phenomena, therefore providing examples of a general phenomenon.

The fourth question and answer are more complex. "Because we inhale more air" is an empirical statement, based on the well known effects on breathing rate when running. The readers know they breathe faster, and that is then connected with inhaling



more air. "...causes the blood to pass more quickly through the lungs" also sounds empirical, except for the word "causes" which links the inhalation of air with blood flow to the lungs. This link would need to be experimentally demonstrated, but in this text it is simply stated as the result of logical reasoning. The first sentence as a whole supports a model of 'animal heat' based on chemical combustion:  $AIR + BLOOD = HEAT$ . Since this is not experimentally supported, 'animal heat' is to be understood by reference to common heating experiences, like candles. The second sentence, however, contains a specific analogy, which can be expressed as a proportion:  $RUNNING:BODY\ HEAT :: BELLOWS:FIRE$ . Such an analogy, for the only time in the section quoted above, allows the act of instruction to meet the demands of Bridgman for "reducing a situation to elements with which we are ...familiar."

The question "Why does fire produce heat?" could be anticipating a teleological response of the type "Because it was so ordered by God for the benefit of man." Such responses were not uncommon in textbooks like Brewer's, as when he asks in a later passage "What is the use of snow? To keep the earth warm and to nourish it." But in this instance, "Why does fire produce heat?" might appear to be answered as if the question was how does fire produce heat. A 'how' question in science can reasonably be expected to force the answer to be either empirical, or one using familiar mechanisms, or one based on a given model. Asking 'why' allows the answer to remain theoretical, as is the case here. And the empirical statements that follow--"Some of the oxygen of the air, combining with the hydrogen of the fuel, condenses into water."--don't do any

instructing either. And since there is no reference to how those empirical statements themselves were arrived at, they remain unexplained, and incapable of aiding instructional purposes.

The types of instruction found in this textbook are rather narrow. Instructing is largely stating, and then showing how other phenomena are instances of these statements. There are rare examples of analogy, and of forming links with common experience. Such a limited repertoire of instructional devices works against the author's stated intention of explaining the common phenomena of life to the readers.

The following is another example of this style, taken from a much later textbook, Carter's Physics for Everyone.

Q. How is heat produced?

A. ... (b) From chemical energy, as when concentrated sulphuric acid is added to water, or when wood or coal is burnt and heat is produced by the violent combination of such substances as oxygen and carbon; oxygen combustion being the important phenomenon we know as fire. (page 60)

Q. Why does a candle burn?

A. The melted wax, drawn up by the wick, is rapidly decomposed by the flame. The hydrogen in the wax, combining with the oxygen of the air, forms water; whilst the carbon of the wax, combining with the oxygen of the air, forms carbon dioxide gas. When the elements of the wax combine with the oxygen of the air, latent heat is liberated by the chemical changes taking place. (page 68)

Q. Why are roads salted in frosty weather?

A. To dissolve the ice. Water freezes at 32F., but salt and water will not freeze till the air temperature has dropped to 27 or 28F. Salt added to frozen water (ice) dissolves it. (page 71). (Carter, op. cit.)

The similarities to the Brewer textbook are evident; the science is better, but the teaching hasn't changed. All the answers are statements, telling the reader what is the case. Instruction in both these texts is seen to consist of supplying an answer, but

of course this in no way guarantees an understanding of that answer. In this sense, these textbooks rarely do any real instructing .

The concern above with appropriate levels of instruction is also reflected in any consideration of what these Catechetical textbooks cannot do. The question and answer format constrains the variety of methods of instruction and excludes the use of experiment or enquiry--in fact, the whole range of instruction that depends on the readers doing something, acting on their environment, is necessarily absent. Thus the instruction can never allow the degree of familiarity with the introduced concepts that the reader has with the things commonly handled and acted upon. The whole range of understanding phenomena that comes from interacting with them is missing. The Catechetical textbook writer cannot even make reference to described experiments, or outline the principles underlying the experimental exploration of nature.

#### INSTRUCTION IN THE CONVERSATIONALIST TEXTBOOKS

These textbooks were, it will be remembered, written in fictional story form. The topic of the textbook centred around discussions between family members, friends and people encountered during daily life. Some, like the Scientific Dialogues of Joyce (op. cit.) were strictly conversations; others, like the Rollo books (op. cit.) were complete stories, with characters, activity and plots. A contrast of these two types will indicate the range of ways of instructing contained in them. First, a selection from Joyce.

#### ASTRONOMY. FIRST CONVERSATION. OF THE FIXED

STARS.

Father---James---Charles

Charles. The delay occasioned by our unusually long walk has afforded us one of the most brilliant views of the heavens I ever witnessed. What a delightful study must Astronomy be! What does Astronomy mean, Papa?

Fa. The word Astronomy implies that science which explains the motions of the heavenly bodies, and the laws by which they are governed: it is derived from two Greek words aster "a star" and nomos "a law": and it is my design to explain this wonderful study to you in our ensuing conversations, and I trust it will lead you to admire the wisdom and omnipotence of the Almighty, and to be ever ready to acknowledge His power and goodness in all that you survey.

Ja. Oh! thank you, Papa, I shall be delighted with the study, I am sure...Is it possible to count the stars, Papa? I have heard that they are numbered, and even arranged in catalogues according to their apparent magnitudes. Pray, explain to us how this was done. (page 97)

Ja. Can you confirm your explanation...by experiment?

Fa. You shall be gratified. In every case you ought to require the best evidence that the subject will admit of--

To ask or search I blame thee not: for heaven  
Is as the book of God before thee set,  
Wherein to read His wondrous works, and learn  
His seasons, hours, or days, or months, or  
years.--Milton

I will show you two experiments which will greatly help to remove the difficulty.

Here are two common looking glasses, which, philosophically speaking, are plane mirrors.....  
(page 98) (Joyce, 1821)

Consider the ways of instructing used so far. Firstly of course there is simple telling, as in giving a definition of the word astronomy. And there is the use of described experimentation, unaccompanied by diagrams, which the reader had to imagine taking place. Notice too the references to God, and the use of poetry, both quite common in these early readers.

Fa. Bring me your multiplying glass. Look through it at the candle. How many do you see? or, rather, how many candles should you suppose there were, did you not know that there was but one upon the table?

Ja. A great many: and a pretty sight it is.

Ch. Let me see! yes, there are very many, but I can easily count them. There are sixteen.

Fa. There will be just as many images of the candle, or any other object at which you look, as there are different surfaces upon your glass. For, by the principle of refraction, the image of the candle is seen in as many places as the glass has surfaces: consequently, if, instead of 16 there had been 60, or, if they could have been cut and polished so small, as to be 600, then the single candle would have given you the appearance of 60 or 600. What think you now about the stars?

Ja. Since I have seen that reflection and refraction will, individually, afford such optical deceptions, I can no longer doubt but that...a thousand real luminaries may have the power of exciting in my mind the idea of millions...  
(page 99) (Ibid)

In this passage an attempt has been made to refer to an object of common experience--a multiplying glass--to explain the phenomena of the numbers of stars seeming so much greater than actual count makes them. This is not an analogy, but a demonstration that unfamiliar phenomena can be understood by reference to familiar occurrences in the reader's world. Notice too the use of reasoned argument for explaining. The argument takes the form of an induction, from the empirical counting of the 16 images of the candle flame, to the "idea of millions" of stars. A great number of arguments used to explain are of the following general form: if a stated fact is true (preferably demonstrated to be true, but often simply given), then a second fact logically follows. A third feature of interest for instructing, in both of the passages cited, is the use of conversational questions to raise queries the reader might also have wished to ask, or which a teacher might have wanted raised. These questions, of course, are similar to the Catechetical approach, except they can be much less formal: e.g., "What think you now about the stars?". But their similarities to the

Catechetical text questions is striking, as the following examples illustrate.

Ch. What do you mean by stars of the first magnitude? (p. 100)

Ja. What are constellations, Papa? (p. 101)

Ja. What is the ecliptic, Papa?

Ch. Why was it called the ecliptic?

Ja. Can we trace the circle of the ecliptic in the heavens?

Ch. Is the moon, then, always in the ecliptic? (p. 106) (Ibid)

In the light of these sort of questions, the Joyce textbook can be seen as somewhat transitional between the Catechetical and the Conversationalist, asking the same types of questions, but allowing a greater range of answers.

The authors of the traditional story form of Conversationalist textbooks, like the Rollo Series, or the Peter Parley Series, have an even greater range of instructional devices, because they depict the characters doing and acting as well as talking. To illustrate this, the following section will analyse a chapter from the textbook Fire in the Rollo series. The second chapter of this small book (192 pages) is called Lamp-Lighting, and runs for 15 pages.

The chapter begins with Rollo's mother trying to light a small oil lamp, without success, from a small piece of paper. Rollo's father, noticing this failed attempt, says in conversation:

"You will have to get a longer lamp-lighter, unless you have some spirits of turpentine to put on the wick."

"Spirits of turpentine?" repeated Rollo.

"Yes," said his father. "In hotels, where they have a great many lamps to light, they have a little bottle of spirits of turpentine.....then it will light very quick."

"Why, sir?" asked Rollo.

"Because spirits of turpentine is very combustibile, or rather inflammable."

"That means it will burn very easily, I suppose," said Rollo....

"That makes me think of something Jonas said, which I was going to ask you," said Rollo. "He said that, in books, burning was always called combustion, and I told him I meant to ask you why they couldn't as well call it burning."...

"It is true, no doubt," added his father, "that, in philosophical books, philosophical terms are very often used, instead of the common language which we ordinarily employ."

"Why are they, father?" asked Rollo. "I think that the common words are a great deal easier to understand." (Rollo, op. cit.)

This first section of the chapter is typical of the Conversationalist format; the scene has been set with characters, a situation, and the introduction of a theme that will be explored. The discussion of combustion takes place embedded in a discussion of scientific vocabulary and the necessity for words used with precise meaning. In terms of instructing, the reader's curiosity has been aroused by the way the questions have arisen naturally from the simple problem of lighting a lamp, and the father's statement concerning spirits of turpentine.

Rollo's mother has finally lit the lamp using a longer lamp-lighter, and says she too would like to hear the remainder of the discussion between Rollo and his father.

"But, father, why will the wick light any quicker?"

"Why, different substances take fire at different temperatures. For instance, if you were to put a little heap of sulphur, and another little heap of sawdust, on a shovel together, and put them over a fire, so as to heat them both equally, the sulphur would take fire very soon, but the sawdust would not until the shovel was very nearly red hot...There is a great difference in different substances, in regard to the temperature at which they inflame."

"What do you mean by temperature, father?" asked Rollo...

...he (Rollo's father) said it would be a very interesting experiment to take a long iron bar, and put a small quantity of several different substances on it, in a row, and then heat the bar

gradually, from end to end, all alike, until it was very soft, and so see in what order the various substances would take fire.

"Well, father," said Rollo, "I wish you would. I should like to see the experiment very much."

"No," said his father, "I cannot actually try such an experiment as that...It could not be done very well, except in a chemical laboratory..." (Ibid)

There are three types of instruction in this extract. Simple telling: "...different substances take fire at different temperatures." Validity is given to this statement by the description of a simple experiment using sulphur, sawdust and a shovel. Defining: Rollo's father gives a definition of temperature as "heat". And a thought-experiment, using the iron bar, which can be done, but only in the laboratory. Later in this passage, Rollo is instructed to get some iron filings from the blacksmith's on his way home from school, to demonstrate that iron too is combustible. This experiment is performed by Rollo's father.

The rest of this chapter is concerned with a discussion of the effects of wick size and length on lighting lamps, wick trimming, and lamp extinguishing.

"There is one thing more I want to tell you, and that will be all I have to say about lamps to-night; and that is, to explain to you the philosophy of putting them out. You must understand that two things are necessary to carry on combustion or burning. First, there must be air; and, secondly, the body burning must be kept above a certain degree of heat...

"Now, when we blow out a lamp, we stop the burning by cooling it...On the other hand, when we put it out by an extinguisher, we stop the burning by means of shutting out the air..." (Ibid)

This last section illustrates again the use of instructing by logical argument. If combustion needs air and a minimum temperature, then preventing one or both of those conditions will cause combustion to cease.



The rest of the Rollo book shows Rollo and his family making gunpowder, burning tree stumps, making hot air balloons, visiting the blacksmith and engaging in lengthy discussions about all they've seen and done and heard. The children are shown asking questions about their daily tasks, and conducting private experiments which often go wrong, providing father with an opportunity to correct, explain and suggest new activities.

These Conversationalist textbooks show very clearly that it is possible to make scientific concepts familiar to readers who are unlikely to have the advantages of a well-equipped school science laboratory available, or the presence of a well-trained science teacher. Science is shown to enter into the everyday lives of the characters in the story. It is given meaning and understanding by the numerous ways of instructing which the story format makes available: analogy, metaphor, models, examples, definition, description, logical argument, thought-experiments, demonstrations, stating--all linking the concepts being discussed to the everyday world of the characters.

#### INSTRUCTION IN THE EXPERIMENTALIST TEXTBOOKS

It is best to begin a study of instruction in the Experimentalist texts by recalling one of the chief purposes of the authors, expressed in the prefaces. "...the thing to be aimed at is, not so much to give information, as to endeavour to discipline the mind in a way which has not hitherto been customary, by bringing it into direct contact with Nature herself. For this purpose a series of simple experiments has been devised, leading up to the chief truths in each science."

(Roscoe, op. cit.). Unlike the Conversationalists, who investigated burning in chimneys and tree-stumps, the Experimentalists resorted to bell-jars and lime water. This removal to the laboratory is extremely important, both for science education and for instructing. It narrows the context and discourse available to the author by portraying science as an activity done using unique ways of questioning and operating on nature.

This emphasis on the role of the laboratory was clearly made by T.H. Huxley in the Introductory volume of the Macmillan Science Primers.

In strictness all accurate knowledge is Science; and all exact reasoning is scientific reasoning. The method of observation and experiment by which such great results are obtained in science, is identically the same as that which is employed by every one, every day of his life, but refined and rendered precise...

But those who have never tried to observe accurately will be surprised to find how difficult a business it is...

Scientific observation is such as is at once full, precise, and free from unconscious inference.

Experiment is the observation of that which happens when we intentionally bring natural objects together, or separate them, or in any way change the conditions under which they are placed. Scientific experiment, therefore, is scientific observation performed under accurately known artificial conditions. (Huxley, 1902).

The general pattern of instruction used in these Experimentalist textbooks can be outlined quite simply. A given observation (e.g., the disappearance of a candle as it burns) is followed by a given question (e.g., is it lost?). This is answered by a set of experiments, each designed to directly address a particular aspect of the problem (e.g., burning a taper in an inverted jar). Each experiment ends with another observation--in this case, the taper goes out--which leads to another question, such

as Why? A why question demands an hypothesis to be tested; e.g., perhaps the air in the bottle has changed. How can that be determined? Another experiment must be done, and so it goes.

We next have to discover why the taper goes out. For this purpose let us see whether the air in the bottle is now the same as it was before the candle was burnt. How can we tell this? Let us pour some clear limewater first into a bottle filled with air in which no candle has been burnt, and then into the one in which our taper was burnt. You see the difference at once! In the first bottle the limewater remains clear, in the second it becomes at once milky. Hence we see that the air has been changed in some way, by the burning of the taper. This milkiness is nothing else but chalk, and chalk is made up of lime and carbonic acid. Carbonic acid...turns the limewater milky, and puts out a burning taper. (Roscoe, 1913)

There are instances in the quotation above of telling, however, particularly the last two sentences. Unfortunately these two are precisely the ones that are meant to round off the explaining of why the taper went out, and why we observed what we did. There are some key points which are not subject to instruction. For example, why investigate changes in the air in the bottle in the first place, why does chalk form in the limewater, why and/or how does carbonic acid put out the taper? The whole sequence of experiments and observations serves only to establish the presence of carbonic acid, not its effects on the taper. This passage only counts as 'reduction to the familiar' if certain assumptions are made about the reader's level of background knowledge. As well, using limewater to test for the presence of carbonic acid has only been established in a laboratory context. Thus it can hardly be helpful in making the experiment 'make sense' to the reader in the way Bridgman uses the term. This is the clear danger of basing instruction chiefly on laboratory operations. To understand why the candle

went out, chemical theory is also essential. It can be argued that an optimal blend of theory and practical would serve the purpose of instruction better.

Quite clearly, instructing is to be done by reference to laboratory experiments, with the occasional use of pointing out or pointing to, demonstration, definition, and logical reasoning. The main force of the instruction comes from constantly asking the question "how do we know that?", and answering by doing. Recall, however, that the Experimentalists were not in accord with the idea that all students were to do the experiments themselves--teacher or pupil demonstration would serve just as well. Nor were they consistent in their attempts to always use laboratory experiments to explain phenomena--only chemistry fitted this criteria with consistent success.

In order to see if explaining in chemistry may be atypical of the Experimentalist approach, it is necessary to see if the pattern is also apparent in physics. The following selection comes from the introductory chapter on motion and force in Balfour Stewart's Physics.

The section starts with a definition of motion as "change of place."

"Well, then, if I sit on a chair in a room I may say that I am at rest, but if I walk up and down the room I am in motion. Now in order to understand my movements, you must know something more than the mere fact that I am moving about; you must know the direction or line in which I am moving, and you must also know the rate or velocity with which I am moving." (Balfour Stewart, op. cit.)

This is followed by examples of walking to the train station, discussion of the motion of the train, and leads to the question about the causes for change in motion. Again there is an

initial definition: "In fact that which changes the state of a body is called force, whether that state be one of rest or of motion." This definition is at once followed by two simple experiments.

Experiment 1.--To prove this, take a tin pan with some peas in the bottom of it, and hold the pan in your right hand. Now quickly raise your right hand, with the pan in it, until your right arm is brought to a stop by a fixed bar of wood, which you have placed a little above it...

Experiment 2.--Now put some more peas into the pan, having spilt the last ones; but instead of raising the pan quickly upwards, lower it as quickly as you can...

Let us pause for a moment, and see what we really learn from these experiments. We learn from the first, that...it requires force to stop their upward motion, and this force we could not apply by means of the bar of wood...You see, therefore, that it needs force to stop a moving body.

Again, in the second experiment, we communicate a downward motion to the pan, but the force of our arm which does so, does not affect the peas which lie loosely on the bottom of the pan. They, therefore, keep their state of rest, and lag behind the pan until at last the force of the earth brings them downwards to the floor. You see, therefore, that it needs a force to start a body at rest. (Ibid)

These simple experiments are used to illustrate the concept of force, using materials available to every student. Such an approach is very similar to the use of experiments in the Conversationalist textbooks. As such they are in some ways exceptions to the usual pattern of basing discovery on laboratory experiments, and in fact they are the only such experiments in the Balfour Stewart's textbook. Importantly, they emphasise the fundamental role of experimentation in instructing in these textbooks.

Laboratory experiments are not always possible, of course, and so the Experimentalists were content to use imaginary ones, or thought-experiments, in order to explain common phenomena.

Lockyer's Astronomy textbook is forced to do this, as for example when trying to explain why, "...if you watch a ship going away from you the hull will disappear first."

"Now what does this mean? Let us make an experiment. Get a smooth table on which there are two flies, let us say, and if the flies are not there, pretend that they are; and suppose them to be moving about. Now it is clear that the flies, as long as they keep on the surface of the table, will always be in full view of each other.... Another experiment. We will take an orange this time, and suppose a fly standing still at the top....and another fly at the bottom.... Therefore the earth is like a ball or an orange, and not flat like a table." (Lockyer, 1904)

Such imaginary 'experiments' carry the bulk of instructing in this textbook, committed as it is to "help the reader, by means of simple experiments, to form true ideas of the motions of the heavenly bodies." (Ibid). Lockyer is keen to use everyday apparatus in his instructing--tables, oranges, flies--which are far removed from the laboratory methods of Roscoe and Stewart. Yet the ways of instructing in these Experimentalist textbooks are still limited by the notion that all conclusions and understanding must flow directly from experiment, observation, and scientific reasoning. As a result, only a handful of instructional devices are used: logical argument, examples, definitions, and simple telling are the most common. Figurative language is avoided, despite the fact that the authors are often speaking in the first person. All experiments are formalized; that is, they are given as a set of procedures to be performed. In the Conversationalist texts, by contrast, many experiments arose out of the curiosity of the characters, often went wrong, and were rarely unambiguous or precise. The greatest value of the Experimentalist approach may lie in this very consistency of

method, which insisted that all true knowledge comes from Science, and that instructing readers about this knowledge must be done using the method of Science itself.

### INSTRUCTION IN THE FORMALIST TEXTBOOKS

In considering the Formalist textbooks, it is hard to isolate a fully representative example. Great numbers of them have been published since 1900, and some of them have become classics in their field. One possibility is to concentrate attention on those which were the most popular in terms of longevity of school use. This can be determined in some cases from written recommendations for their use by examining authorities, and by their long publishing lifetimes. Such choices will indicate something about what was considered good at the time, at least by teachers, and they can serve as standards of comparison with other Formalist texts. With the proliferation of physical science courses since the beginning of the 20th century designed to meet the needs of a wide range of students (e.g., examination versus non-examination candidates, medical students, slow learners, humanities students), Formalist textbooks tended to specialise, with the result that some of them had a limited audience in mind. As this study is concerned in the main with textbooks written for readers in the senior level of secondary school, specialist audiences will not be directly considered.

The first Formalist textbook to be considered is Watson's A Text-Book of Physics, first published in 1899 and going through at least four editions up to 1926. The following extract is from the section on energy.

We find by experience that in certain circumstances bodies are capable of doing work. Thus when a weight has been raised up above the surface of the earth, it possesses the power of doing work during its return to the surface of the earth...Hence we see that in certain circumstances bodies possess a capacity for doing work; and this capacity for doing work is called Energy. (Watson, 1910)

This example first illustrates the emphasis the Formalist authors placed on basing instruction on considerations of what something is, unlike the Experimentalists, who wanted to concentrate on how we determine what is the case. It is not, therefore, surprising to see the frequent use of a definition to instruct. Usually, these definitions are supported by examples.

Examples of potential energy abound in everyday life; thus when a clock-weight is raised we do work against the attraction which exists between the weight and the earth...When winding up a watch, in the same way, work is done in bending the spring. (Ibid)

The examples are not far removed from daily experience, but a degree of abstraction has appeared with such terms as 'body' and 'capacity for work'. Also, it is not clear precisely what is meant by the idea of a body 'possessing' the 'power' to do work. There is a confusion over just what is to be understood in the passage--the nature of energy, or what it is to possess energy. The signposts to the type of instructing evident in this passage are the words which come from the systems of formal reasoning--'hence', 'thus' and 'in the case of'. It is not clearly established by the passage why the concept of energy is needed, or why the capacity for doing work needs special treatment, unless they are formally necessary to establish a deductive system in which energy can play the role of a convenient abstract fiction. At any rate, the view of science



as a deductive system is not explicitly presented in the Formalist textbooks, and it is therefore difficult to see how such instructional uses can serve to reduce a concept like energy to the familiar in the sense necessary for understanding. Energy remains, at best, an abstract principle or, perhaps worse, something objects 'possess'.

It could be argued that instruction of something so abstract as energy demands such devices as definition and examples. It then becomes necessary to examine an attempt to teach something more concrete. A textbook more recent in time, Noake's New Intermediate Physics is another popular Formalist textbook; the first edition appeared in 1957, the fifth in 1970. The following comes from the 1970 edition, and deals with the expansion of solids on heating.

Increasing the temperature of a rod causes it to expand, that is, to increase in thickness and length. This expansion in length must be proportional to the length of the rod; for if a rod one metre in length expands by one millimetre, two such rods placed end to end to make a rod two metres long expands by two millimetres. At least within the accuracy of ordinary observation and within the narrow range of temperatures of most ordinary experiments, the expansion is nearly proportional to the temperature rise. The expansion also depends on the material of the rod; when equal lengths are heated through the same difference in temperature, it is found that the expansion of iron is about two-thirds that of brass and about half that of zinc. (Noakes, 1970)

There is a clear pattern of instruction here; first a statement of what is the case, presented without empirical proof, and then an illustration of the point. Noakes does not discuss why a metal bar expands upon heating at any point in his textbook, nor why it does so proportionally to length, temperature rise or type of material. All these empirical statements are simply

stated. It appears that once expansion is given as a fact, and the proportionalities and coefficients of expansion stated, the text is really concerned to offer instruction in three things: one, how the changes in length can be quantified; two, what assumptions will be made in the equations to follow; and three, the notation adopted.

We shall use the formula  $l = l'(1 + a'T)$  where  $l'$  denotes the original length,  $l$  the final length,  $T$  the rise in temperature, and  $a'$  the mean coefficient of expansion over this range.  
(Ibid)

The intent is the same as in the earlier example from Watson--to establish a formal system through and by which phenomena can be quantified and mathematically manipulated. There has been a falling away of any intention to discuss the phenomena of the everyday world in such a way as to satisfy the definition of instructing as "making sense, in the way the things with which we are familiar make sense."

Taken as a general rule, the Formalist textbook writers can be seen as viewing science as a system of organized knowledge. As teacher/authors, they are keen to only outline the ways problems are solved within the formal deductive system that is science, and only information necessary to allow this problem solving to take place successfully is detailed. Consequently, their instructional role is much reduced.

There are two points that must be mentioned with reference to the writers. Firstly, there were a number of texts written by notable scientists which fall under the Formalist category; not all were teachers. Examples include W. Ostwald's The Fundamental Principles of Chemistry (1909) and J.J. Thomson's Conduction of Electricity Through Gases (1906). As in the case

of the teacher/authors, however, the main purpose of these texts was to present, in clear and simple outline, the principal conclusions and results of the particular science concerned. This is not to argue that some of the Formalist authors were not, and are not, better at such a task than others. Rather, it seems clear that none were specifically concerned to take advantage of literary and rhetorical devices for instructing learners. Secondly, it may appear paradoxical that teachers are seen to be producing textbooks less concerned with instruction than either the Conversationalist story-tellers or the Experimentalist scientists. However, the presentation of material in the Formalist textbooks reflects greater concern with structuring the information in a logical, sequential form consistent with syllabus demands, than with constructing instructional passages to assist the learning of the information. It may be, in part, because teachers came to see a role for the textbook as a resource to support teaching, not as an instructional tool in its own right.

It would be incorrect to create the impression that the Formalist writers were not interested in the laboratory at all. The examination of their prefaces showed that many of them thought theory and practice were both necessary for a complete education in physics. But the role of experimentation within the textbooks themselves has always been secondary. The experiments were designed to illuminate theory, not reveal a unique way of questioning. As a result, the experiments were often 'recipe-book' practicals, or were included in a separate 'lab manual'. The concern for the scientific 'method' did not influence the ways the Formalist authors presented their

material; the laboratory work could simply be referred to in passing as 'demonstrating' or 'illustrating' laws and principles. And thus the laboratory's possibilities for instruction were much reduced. In considering this point, it will be helpful to examine a currently used Australian textbook, Physics--A Laboratory-Orientated Approach (Ingram et al., 1973), reprinted three times to 1977. The preface makes no mention of the laboratory, and all laboratory work was contained in a separate manual. The textbooks (called study guides), however, are not intended to dominate the course.

Much of the interest in any physics course and the deeper understanding of concepts are fostered by considering (their) consequences and applications. For this reason it is most important that the guides are not elevated to a position where they are treated as a course in themselves. To discourage this highly undesirable possibility a large number of suitable references has been suggested for your consultation. (Ingram et al, 1977)

The following extract is from the section on momentum.

#### Interactions Between Identical Objects

We will begin by studying two-body interactions in which the two bodies are as nearly identical as we can make them.

We can study experimentally the interactions between similar gliders on a linear air track and similar trollies on a bench...Measurement of the initial and final velocities leads us to the conclusion that the total final velocity equals the total initial velocity.

Therefore, in all cases,  $V(1) + V(2) = V(1)' + V(2)'$ . That is, in these one-dimensional interactions between similar objects, velocity is a quantity of motion which is conserved.

#### Interactions Between Dissimilar Objects--Defining Momentum

However, when the interactions between dissimilar objects are investigated, we find that velocity is not conserved...

We want to define a quantity of motion in such a way that, for a system of bodies whether similar or dissimilar, the total quantity of motion is not altered by interaction between the bodies. We will call this quantity momentum.

From your laboratory assignment, you have seen that all moving objects possess momentum.  
(Ibid)

This extract intends to teach what momentum is, and how it is derived from phenomena. To fairly interpret this passage, it is important to assume that the readers have had the experiences in the laboratory to which the passage refers. The instructing is done as follows. Reference is made to a particular set of laboratory results: e.g., "Measurement of the initial and final velocities..." These results have been empirically determined, and they lead to generalised conclusions: e.g., "Therefore, in all cases...velocity is a quantity of motion which is conserved." For this to count as instruction leading to understanding, assumptions must be made about the reader's understanding of and familiarity with such terms as "quantity of motion" and "conserved". Further empirical investigation reveals occasions when velocity does not appear to be conserved. The response of the authors is to create a definition so that quantity of motion will be conserved despite the difficulties with dissimilar bodies. This may be clearly necessary for the construction of the logical argument, but it in no way links the role of the laboratory in generating empirical data with the concept of momentum. Finally, in this passage, the text assures the reader that their laboratory experiments have allowed them to see that all objects possess momentum, when only a few lines before it had been expressed as a useful definition.

Again, this difficulty may be one of trying to describe and define an abstract concept. The following, then, is an extract concerned with electrical resistance. It comes from Abbott's Ordinary Level Physics, first published in 1963 and reprinted 14

times until 1974.

Experiments with a gold-leaf electroscope  
 (4) To test the insulating properties of various materials

The insulating or, conversely, the conducting property of a given substance may be tested by holding a sample of the substance in the hand and then bringing it into contact with the cap of a charged electroscope. If the substance is a good insulator there will be no leakage of charge through it and the leaf divergence will not alter. If, however, the leaf collapses instantly it shows that the substance is a good conductor. (page 383)

An experiment to compare the electric conducting powers of various substances was described on page 383...

As far as current electricity is concerned, we usually think in terms of the ability of a substance to resist the flow of electricity through it. A good conductor is therefore said to have a low resistance and a poor conductor a high resistance.

We shall see later that the resistance of a wire depends on its dimensions and the material from which it is made. (page 426). (Abbott, 1974)

Consider the 'experiment' first. The intention is to "test the insulating or conducting property" of various substances. The assumption is therefore that objects have such properties. The defining character of a "good insulator" is its lack of effect on a charged electroscope--"...no leakage of charge through it..". An operational definition is offered as explaining what a good conductor is; i.e., reference is made to a phenomena, not to the internal structure of the substance.

The sentence after the description of the 'experiment' uses the term "electric conducting power" without making it clear what that in fact means. The next section speaks of the "ability" of a substance to resist the flow of electricity. In both cases of definition--good conductors and low resistance--no attempt has been made to describe or understand the phenomena. It is clearly impossible for passages of this type to engage in any

meaningful instruction because there is not one link between the world of the reader and the world of the phenomena presented. Even more than the Experimentalists, these writers confine themselves to the world of the scientist's laboratory.

### SUMMARY

This chapter used the authors' purpose of 'instruction' to examine prose structures within the four textbook types. Instruction was defined as the act of 'imparting knowledge', where the type of knowledge to be transmitted to the readers is determined by the authors' view of the nature of science, and the purposes of science education. Various ways of instructing in textbooks were mentioned, and the textbooks examined for their presence.

The Catechetical texts could be characterised in the following ways.

1. Instructing is mainly telling. The question and answer format does not allow enquiry and reference to laboratory activities.
2. Use of logical argument to link stated principles and related phenomena.
3. Examples are commonly drawn from the familiar world of the reader, so that abstractions are often avoided.
4. A very limited range of instructional language is contained in these texts.

The Conversational texts showed the following characteristics.

1. A wide range of instructional language in these texts; e.g.,

figurative language, demonstration, descriptions, logical argument.

2. The phenomena discussed come from everyday experiences of the readers, and often based on tasks being performed by the characters.

3. Instructing takes place until the curiosity of the character is satisfied.

4. Many important principles needed for instruction to take place are, however, often simply stated by parental authority, and then used to explain particular cases.

The Experimentalist texts showed the following characteristics.

1. Instruction is based on the attempt to use the laboratory, whenever possible, to guide the reader through an investigation.

The method of enquiry is itself the instructional act.

2. Instruction is removed from the everyday world of the reader by being placed in the laboratory, which may or may not be part of the experience of the reader.

3. The focus on the laboratory, and arguing from empirically determined results to general conclusions, narrows the range of instructional language found in these texts.

The Formalist texts showed the following.

1. The primary instructional pattern is to offer a definition, give examples of the principle either in the laboratory or from real life, and then argue logically from the principle to particular conclusions.

2. Instruction is generally limited to statements of what is the case.



3. The role of the laboratory is reduced to verifying results, and the world of the readers' common experience is used to provide examples of scientific concepts.

4. The authors are not concerned with either arousing curiosity or satisfying it by reducing scientific concepts to the already familiar.

There are thus important differences in the ways the authors have chosen to meet the instructional purposes of their texts. It is very curious that Formalist texts, written by teachers, pay less attention to instruction than the Conversationalist writers, who were often neither educationalists or scientists. Perhaps this indicates a reluctance to intrude on the pedagogical role of the teacher. The Experimentalists, as scientists, perhaps underestimated the need to provide a wider range of instruction than the methods of science alone. The Catechetical writers, on the other hand, occasionally expressed the view that their format was chosen to match current opinion on correct teaching method. In this case, limited attention to instruction may be the result of inadequate understanding of learning theory and methodology.

## CHAPTER 8: CONTENT ANALYSIS

### INTRODUCTION

This chapter is intended to show that the results obtained to this point are not based on textbooks which are atypical or uncharacteristic. It is important to demonstrate in a quantitative way that the system of classification developed by this thesis can be usefully applied to a large range of textbooks.

By containing numerous examples and some numerical data, such a chapter will be quite different in style and structure from the others of this thesis. For several reasons, it seems best to place this quantitative information together in one chapter. Firstly, confining such an analysis to one section permits a more coherent argument to be presented in the other chapters; the discussion and qualitative analysis is not continually interrupted by quantitative data. Secondly, while one or two examples serve to make a point, a multiplication of validating examples distracts from the force of the point being made. And thirdly, content analysis provides the opportunity to explore certain aspects of the argument in greater depth, an opportunity out of place within the structure and purpose of other chapters.

Content analysis is used in this chapter to examine more closely claims made in Section C concerning explanation and instruction. Those claims were that it was possible to classify textbooks by the types of explanations offered, and by the instructional

language used by the authors to explain concepts, principles and methods. In addition, a substantial section is devoted to detailing the traditional prose style of the Formalist textbook presentation of concepts to readers. This will allow an examination of claims made about Formalist textbook language made in Chapter 5 (Style).

## METHODOLOGY

### 1. IDENTIFICATION OF PROSE STRUCTURES.

In order to obtain the necessary information from the texts, a systematic application of one of many content analysis techniques is required. Berelson (1952) in his comprehensive examination of content analysis as a research tool, maintained that a wide range of techniques of varying quantitative detail are available, and should be adopted according to need. More recent reseachers (Macdonald-Ross, 1978; Tamir, 1983) also make this claim when discussing the role of content analysis in the evaluation of curriculum materials. In fact, some measure of content analysis of varying degree of detail is recommended by almost all commentators on textbook evaluation. The specific task of this analysis is to provide some quantitative information concerning what was said, how it was said, and how it was argued for. This need not always be a simple counting procedure, as the above researchers make abundantly clear. The problems of faithfully analysing and interpreting prose of the complexity of the textbook are considerable, and are similar to those of the critic of literature or drama. What are the elements of which the work is composed? How are they to be isolated? Is their numerical occurrence significant? How are

they used? What role do they play? These are the kinds of questions such an analysis must consider. Concerned as it is with the characteristics of textbook language on a larger scale than that of the sentence or word, this thesis seeks to isolate language components that permit such quantitative treatment as well as reflecting on the claims made earlier. To be consistent with the early assumption that authors write textbooks with a set of purposes in mind, it is appropriate to isolate prose structures which are written to achieve those purposes. Such prose structures may be of any length, from sentence through paragraph to, of course, the text as a whole. As it is the text itself which is to be examined, however, no structure longer than a section is considered, a section being defined as a prose unit devoted to a single idea. Sections are usually signalled in the text by typographic markers; e.g., headings in bold type or italics, clear physical separation from preceding and adjoining sections, and subheadings. The following seven structures were chosen to be isolated and counted for the reasons given.

#### SEVEN STRUCTURES TO BE IDENTIFIED AND COUNTED BY CONTENT ANALYSIS

A(1). Laboratory Experiments Worked Through In the Text. If the authors' purpose is to portray science as a method by which nature is questioned and made to give up its answers, such laboratory experiments would be prevalent in the textbook. Such structures are usually introduced by distinctive prose markers that are not isolated textually or physically from the rest of the section, and which are generally of the form "In order to

answer this question, we must make an experiment..." or some equivalent phrase. The experiment itself is worked through step by step, with justifications being given for each procedure. Finally conclusions are drawn which are either used to start a fresh experiment, or are generalised. The main point is that they are integral to the prose, which cannot be coherently read without them. Their presence is also an indication that the text is included in the genre of instruction as well as that of information.

#### A(2). Laboratory Experiments Used to Introduce/Develop Concepts.

In many cases the authors' purpose may be to make use of laboratory operations only to illustrate the need for a particular scientific concept, or to provide examples of how the concept can be usefully used or examined within the laboratory. In such cases, it is common to find these experiments separated out either physically or typographically from the rest of the section. Also, the experiments are written in the familiar style of the laboratory manual; a set of instructions is given for the setting up of equipment, special procedures to follow, measurements to be made, and the form in which the data is to be presented. Such experiments are usually of the measurement-type, where the purpose may be to determine the value of some physical constant. Many more recent Formalist textbooks have stripped their pages of these experiments, placing them in a separate laboratory manual, thereby expressing a conviction that they are not essential to the development of the argument of the text.

A(3). Laboratory Experiments Referred to Only. If the authors' main purpose is to convey a view of science as a logical body of knowledge, or as a well-structured deductive system, then the place of the experiment may be reduced still further. In this structure, the laboratory experiment is a piece of research that has generated the foundations for generalisations and laws. As these generalisations and laws are science, the experiments themselves need only be referred to as having taken place, or as possible things to do. Very occasionally, these experiments are described in brief form; more generally, they are marked by prose such as "Repeated experiments with moving bodies led scientists to the conclusion that...". Such structures tend to be of one or few sentences in length, as opposed to structures A(1) and A(2) above, yet they often form the entire justification for crucial concepts.

B. Real Life Situations Used As Examples. This structure is related to the authors' purpose of showing either how scientific concepts can be used to illuminate real life situations, or how these situations can illuminate scientific concepts. In either case, the educational purpose of relating science to the world of the reader is served. One of the crucial questions in science education has always been the connection between the world, the laboratory, and the concepts of science. How much reference is made to the real world can be indicated by looking for references to non-laboratory events and examples within the textbooks. It was claimed in Chapter 7 that such references were integral to the Conversational textbooks, neglected in the Experimentalist, and common in the Catechetical and Formalist.

C. Enquiry Statements (Narrative of Enquiry). These are prose structures that allow some measurement of stylistic matters. Again, they are related to the authors' purpose of educating through enquiry rather than through telling. Many such enquiry statements are , or contain, questions addressed to the reader. But also very commonly they are passages of considerable length in which the author describes the conceptual and experimental difficulties that accompany the development of scientific concepts. Included under this heading are passages that discuss such matters as the role of theory, law, models, and experiment, showing their particular role within scientific enquiry. Again, it was claimed in Chapter 7 that the presence of such enquiry statements are an indication that the textbook falls within the genre of instruction, and that they should be more common in the less formal textbooks.

D. Statements Made Without Justification (Rhetoric of Conclusions). These statements are used to inform the reader of results rather than lead the reader through a process of enquiry. Again, they may be of varying length. They are straightforward, and should be more common in the Formalist textbooks than the Experimentalist. Their presence would be an indication that the text belonged in the genre of information.

E. Logical Arguments Used To Introduce/Develop Concepts. This is a prose structure which corresponds to the authors' purpose of providing explanations based on scientific concepts. In Chapter 6 on explanation, it was claimed that the most common

model for scientific explanation is the covering-law model. One of its chief components is the ability to reason logically from established laws to the particular phenomenon under consideration. When to this is added the common belief of certain textbook writers (evidenced in their prefaces) that science is chiefly a system of such logical deductions from law to phenomena, the textbook can be expected to show instances of the application of such logical reasoning to everyday and laboratory phenomena. Such logical structures are often marked by sentences containing the form "...if...then..." or "By applying the law to this case, it can be seen that...". Often whole passages are taken up by this logical argument: concepts are stated, and from them conclusions are derived, implications and inferences are drawn, thereby linking more and more phenomena together.

## 2. CHOICE OF THEMES FOR EXAMINATION.

The seven prose structures detailed above are, then, used to examine the claims made earlier in the study regarding Explanation, Instruction and Style. It is still necessary to ensure that equivalent sections of textbooks are examined to avoid bias, as one section may be more suited to laboratory work than another, for example. And roughly equal amounts of each textbook need to be examined, for, although this does not allow differences in verbosity or conciseness to be considered, it does ensure that the textbooks have equal chances to reveal as much of their full range as possible without examining the whole text. Therefore, it was decided to examine all four types of textbooks, whenever possible, for their treatment of WATER. In



the physics texts, this usually means hydrostatics or hydrodynamics; in the chemistry texts, it means water as a substance, with reference to its physical and chemical properties. Interestingly, the treatment of water occupies roughly the same number of pages in the large majority of textbooks. It is a theme which has persisted in textbooks for a great length of time, it is a theme which can be treated by the authors in a multitude of ways, and it is a theme of sufficient importance to assume it will be given close, careful attention by the authors of any science text. In cases where water is not treated by the textbook, another substance (like air, or sedimentary rocks) or a major concept subject to a wide range of interpretations (like time, or pressure) will be substituted.

### 3. MODE OF PRESENTATION OF DATA

Each textbook will be examined for its treatment of water or equivalent, and the results displayed in the form below. The numbers of textbooks of each type that are examined represent approximately 10% of the total number of that type available.

Author, Title, Publisher, Date of Publication, Number of Pages.

Number and Title of Chapter, Number of Pages in the Chapter.

- A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT (N1)
- A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS (N2)
- A(3). LAB. EXPERIMENTS REFERRED TO ONLY (N3)
- B. REAL LIFE SITUATIONS USED AS EXAMPLES (N4)
- C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY) (N5)
- D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS) (N6)
- E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS (N7)

N1 -- N7 refer to the number of occurrences of that prose

structure within that section. Final tallies are made for each of the four types of textbook for comparison and discussion.

### CONTENT ANALYSIS OF THREE CATECHETICAL TEXTBOOKS

Brewer, Dr. A Guide to the Knowledge of Things Familiar.  
London: Jarrold, 1855. 442 pp.  
Chapters XXV: Water; and XXVI: Ice. Pages 359-377.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	3
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	40
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	38

Turner, R. Introduction to the Arts and Sciences.  
London: Longmans, 1832. 348 pp.  
Part II: Science of Water--Hydrography. Pages 153-167.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	10
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	27
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	12

Pinnock's Catechism of Chemistry.  
London: Whittaker, 1823. 72 pp.  
Chapter IV: Of Atmospheric Air; and Chapter V: Of Hydrogen.  
Pages 13-21.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	1
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	4
B. REAL LIFE SITUATIONS USED AS EXAMPLES	2
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	16
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0

TOTALS FOR THE CATECHETICAL TEXTBOOKS.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	1
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	4
B. REAL LIFE SITUATIONS USED AS EXAMPLES	15
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	83
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	50

Comments.

Some general comments can be made based on these results. These texts are clearly characterised by stating, without proof, what are the accepted facts, and then logically arguing from them to particular conclusions. They are concerned overwhelmingly to simply inform. The role of the laboratory is minor compared to the use of real life situations. Written as they were for autodidactic readers, this is to be expected. What the above table does not reveal are the religious references in these textbooks. Although there are none in the sections from either Turner or Pinnock, there are three in the 18 pages of the Brewer text. Two of these are questions which ask the reader to "Shew the wisdom of God in so organising the world." The third is of greater interest. Referring to the anomalous expansion of water upon freezing, it states "It is wisely ordained by God that water should be an exception to a very general rule..." (Brewer, op. cit.) While not developed, there is a hint here of the establishment of natural laws, or general rules, by God, for

the benefit of mankind.

Often whole sections consist of a long logical argument from stated principles to particular phenomena. Thus Turner's section begins with the definition of fluidity. From this definition, the text asks "What are some of the consequences of this property of fluidity?" These consequences are meant to logically follow. A later question, referring to the phenomenon of equal heights of liquid in inter-connecting vessels, asks "What is one of the inferences from that?" (Turner, op. cit.). It is interesting here to recall T.H. Huxley's criticism of such texts as "omnium gatheriums--no means to lead the mind of a child to what might be called purely scientific considerations; the design of that education was pure information..." (Huxley, op. cit.). Such a verdict is borne out by the limited content analysis above. As a consequence, it seems justifiable to place these texts in the genre of information, and to assign them to the category of the "rhetoric of conclusions". It is also clear that the level of explanation occasionally referred to God, but generally rested on general rules or laws. While scientific explanation is not elaborated within the text (as shown by the absence of inquiry statements), some aspects of the covering-law model--(principle--> deduction--> example) are used. Finally, it is clear that explaining was basically a question of telling and then drawing logical conclusions.

#### CONTENT ANALYSIS OF THREE CONVERSATIONALIST TEXTBOOKS.

Joyce, J. Scientific Dialogues. London: Bohn, 1846. 555 pp.

## Section III: Hydrostatics. Pages 204-217.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	9
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	2
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	14
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	7
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	4
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	20

Tomlinson, C. First Steps in General Knowledge:  
The Starry Heavens.

London: Society for Promoting Christian Knowledge, 1870.  
 161 pp. Chapter XIII: Division of Time. Pages 143-154.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	7
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	4
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	5
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	4

Rollo's Philosophy: Water.

Boston: Phillips, Sampson, 1855. 192 pp.  
 Chapter VI: Hydraulics. Pages 83-95.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	8
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	6
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	2
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	7

TOTALS FOR THE CONVERSATIONAL TEXTBOOKS.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	9
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	2
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	29
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	17
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	11
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	31

Comments.

The three selected texts can be seen to exhibit an even distribution of structures, with the exception of laboratory work. This is to be expected if it is remembered that the authors of these texts were primarily concerned with reading and story rather than with science, and that they were writing for a young audience. However, it is important to point out the richness of the structures used in the Joyce textbook. In contrast to the Rollo text, which emphasised reading comprehension, the Joyce textbook is specifically concerned with teaching science, and is in the form of a dialogue rather than a story. All the 'action' takes place indoors where laboratory equipment is to hand. By contrast, the Rollo textbook uses the outdoor and everyday experiences of the characters as the focus of discussion. The Tomlinson book is like the Rollo text in this regard, but as it deals with astronomy, laboratory work is more difficult to incorporate into the conversations. In regard to style and structure, the Conversationalist textbooks are seen to be very diverse. Attention must be given to this point when considering the analysis of the other textbook types.

There were three religious statements in the Tomlinson chapter, not unexpected considering the publishers. Each of these references referred to the works of nature revealing the majesty of God. They were not used to introduce natural law or the ultimate levels of explanation.

In consequence, it seems justifiable to draw the following conclusions about these Conversational textbooks. Firstly, they can be placed in the genre of instruction as well as information. That is, they do reflect a "narrative of enquiry", but not to the exclusion of a "rhetoric of conclusions".

Secondly, their stylistic concern with story encouraged the use of real life experiences to make science, in today's terms, relevant. And thirdly, explaining was an important part of the authors' purpose.

#### CONTENT ANALYSIS OF FIVE EXPERIMENTALIST TEXTBOOKS

Perkin, W.H. and Lean, B. An Introduction to Chemistry and Physics.

London: Macmillan, 1906. 183 pp.

Chapter IX: The Discovery and Composition of Water.

Pages 88-98.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	7
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	2
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	0
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	11
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	1
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0

Roscoe, H.E. Chemistry. London: Macmillan, 1913. 100 pp.  
Water. Pages 20-43.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	21
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	1
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	1
B. REAL LIFE SITUATIONS USED AS EXAMPLES	0
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	29
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	2
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	4

Stewart, B. Physics. London: Macmillan, 1884. 151 pp.  
Topic 6: Properties of Liquids. Pages 32-45.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	13
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	1
B. REAL LIFE SITUATIONS USED AS EXAMPLES	4
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	9
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	1

E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS 6

Geike, A. Geology. London: Macmillan, 1884. 144 pp.  
Topic 3: Sedimentary Rocks. Pages 23-37.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	4
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	7
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	10
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	2
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	10

Bert, P. First Year of Scientific Knowledge.  
London: Relfe Bros., 1887. 341 pp.  
Topic V: Chemistry: Composition of Water;  
Composition of Air. Pages 240-252.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	6
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	0
B. REAL LIFE SITUATIONS USED AS EXAMPLES	3
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	13
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	4
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	4

TOTALS FOR THE EXPERIMENTALIST TEXTBOOKS.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	51
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	3
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	2
B. REAL LIFE SITUATIONS USED AS EXAMPLES	14
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	72
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	10
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	24

Comments.

It does appear as if Roscoe's chemistry textbook, written under the common influence of the Experimentalist group (which published the Macmillan Science Primers), contains far more worked through experiments than the others. Presumably this is reflected in the nature of chemistry as a laboratory-orientated school subject--its conclusions can be more easily demonstrated



empirically with simple equipment. The physics text, on the other hand, seems more willing to take advantage of real life situations, perhaps because it does not have such easy laboratory experiences. Geike's geology text, too, faces the same problem. It is interesting to note that there are differences within this small sample between the use of logical arguments in the chemistry and geology texts. Because geological processes are not easily demonstrated in the laboratory, they are argued for logically from real life examples rather than from laboratory experiments. All these texts, however, show concern for science as enquiry rather than conclusion, and all prefer laboratory exercises that are conducted within the text rather than merely referred to or set apart as a laboratory exercise.

Argument in these textbooks is centred on the laboratory--the level of explanation is that of laboratory observation, measurement and use of equipment, which reveals facts that can be generalised into laws. The covering-law model outlined in Chapter 6 does not enter into these texts, for all the language of enquiry is directed to procedures rather than formal conclusions. Instructing is done by demonstrating, by pointing out and pointing to--hence, the low numbers of unjustified statements. While there are a significant number of logical arguments found in these texts, they are not used to argue for conclusions, but to reason from experimental results--hence, the lower numbers of real life situations than laboratory situations. The laboratory work is not intended to be used as an example of a general principle to be argued for, as are real life situations.

CONTENT ANALYSIS OF TEN FORMALIST TEXTBOOKS

Watson, W. A Text-Book of Physics.

London: Longmans, 1910. 873 pp.

Chapter XVIII: Molecular Phenomena in Liquids. Pages 180-191.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	2
B. REAL LIFE SITUATIONS USED AS EXAMPLES	12
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	18
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	23

Walker, J. Introduction to Physical Chemistry.

London: Macmillans, 1910. 411 pp.

Chapter VIII: Fusion and Solidification (of water).

Pages 61-74.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	3
B. REAL LIFE SITUATIONS USED AS EXAMPLES	5
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	17
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	20

Gregory, R. and Hadley, H.E. A Class Book of Physics.

London: Macmillan, 1933. 602 pp.

Chapter VI: Pressure in Liquids. Relative Density.

Pages 63-78.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	17
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	2
B. REAL LIFE SITUATIONS USED AS EXAMPLES	1
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	9
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	9

Taylor, W. A Course of Chemistry for Schools.

London: Harrap, 1942. 502 pp.

Chapter V: Hydrogen and Water. Pages 67-85.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	13
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	1
B. REAL LIFE SITUATIONS USED AS EXAMPLES	11
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	2
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	16
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	9

Martin, S.L. and Connor, A.K. Basic Physics: Vol. 1  
 Melbourne: Whitcombe and Tombs, 1945. 489 pp.  
 Chapter 15: Surface Tension. Capillarity. Diffusion.  
 Osmosis. Pages 282-301.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	1
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	2
B. REAL LIFE SITUATIONS USED AS EXAMPLES	16
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	17
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	7

Mee, A.J. A Modern School Chemistry.  
 London: Dent, 1946. 457 pp.  
 Chapter IV: Water; Hydrogen. Pages 64-79.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	6
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	10
B. REAL LIFE SITUATIONS USED AS EXAMPLES	2
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	1
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	19
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	6

Cavell, A.C. An Introduction to Chemistry.  
 London: Macmillan, 1946. 502 pp.  
 Chapter XIII: Water. Pages 149-160.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	5
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	4
B. REAL LIFE SITUATIONS USED AS EXAMPLES	4
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	17
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	5

Nuffield Chemistry. Students' Book I.  
 U.K.: Penguin, 1970. 399 pp.  
 Topic II: Solvation. Pages 355-374.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	2
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	3
B. REAL LIFE SITUATIONS USED AS EXAMPLES	2
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	33
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	10

Noakes, G.R. New Intermediate Physics.  
 London: Macmillan, 1971. 965 pp.  
 Chapter 9: Viscosity and Surface Tension. Pages 158-180.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	0
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	6
B. REAL LIFE SITUATIONS USED AS EXAMPLES	3
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	0
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	36
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	28

Abbott, A.F. Ordinary Level Physics.  
 London: Heinemann, 1974. 593 pp.  
 Chapter 10: Pressure in liquids and gases. Pages 118-131.

A(1). LAB. EXPERIMENTS WORKED THROUGH IN TEXT	0
A(2). LAB. EXPERIMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	3
A(3). LAB. EXPERIMENTS REFERRED TO ONLY	3
B. REAL LIFE SITUATIONS USED AS EXAMPLES	10
C. ENQUIRY STATEMENTS (NARRATIVE OF ENQUIRY)	1
D. STATEMENTS MADE WITHOUT JUSTIFICATION (RHETORIC OF CONCLUSIONS)	9
E. LOGICAL ARGUMENTS USED TO INTRODUCE/DEVELOP CONCEPTS	13

TOTALS FOR THE FORMALIST TEXTBOOKS.

Classification	Physics	Chemistry	Total
A(1).	0	0	0
A(2).	24	26	50
A(3).	15	21	36
B.	42	23	65
C.	1	3	4
D.	89	102	191
E.	80	50	130

Comments.

The immediately obvious characteristic is the complete lack of laboratory experiments that are worked through with the reader. All laboratory work is either separated off from the text, included in a separate practical manual, or simply used to measure physical values (e.g., the specific density of glycerol). There is an interesting discrepancy between the physics and chemistry texts with respect to A(2)--experiments used to introduce/develop concepts. With the exception of the Gregory and Hadley text, which includes a large number of experiments within the chapter but separate from the main body of prose, the physics texts tend to include far fewer experiments than the chemistry ones. Chemistry seems to be more of a 'laboratory' science than physics. Physics relies more on arguing logically from real life situations, as the above totals suggest. These and other differences between the sciences are elaborated more fully in Chapter 9.

The high number of unjustified statements and logical arguments supports the claim that these texts use the covering-law model in argument; but the low number of enquiry statements indicates that explanations are not elaborated or made explicit to the reader. In Chapter 7, instruction was interpreted to mean the success of the author in making the material understood by the reader. It was claimed that the Formalist textbooks paid little attention to this aspect of writing. The lack of reference to the laboratory or to common experience in these texts, compared with the emphasis on logical argument and simple stating, justifies this view. Clearly these texts should be placed within the genre of information. They also clearly display the characteristics of the "rhetoric of conclusions". Their level

of argument is based on the principles and laws of the discipline rather than on laboratory operations. And stylistically, as shown by the small numbers of enquiry statements, they are formal.

#### CONCLUSION TO THIS SECTION

For comparison, the totals for the four types of text are displayed together below. Immediately under each total is the percentage of that type of structure. These results are also displayed in diagrammatic form on the following page.

STRUCTURE	CAT.	CONV.	EXPT.	FORM.
A1	0 0%	9 9%	51 29%	0 0%
A2	1 .6%	2 2%	3 2%	50 10.5%
A3	4 2.6%	0 0%	2 1%	36 7.5%
B	15 10%	29 29%	14 8%	65 13.6%
C	0 0%	17 17%	72 41%	4 .8%
D	83 54%	11 11%	10 5.6%	191 40%
E	50 33%	31 31%	24 13.6%	130 27%
TOTAL NO. OF STRUCTURES	153	99	176	476

These results demonstrate the following points.

1. Despite the different numbers of structures considered, the average number per book is fairly consistent: Cat.(51), Conv.(33), Expt.(35) and Form.(48). The differences between the

# CONTENT ANALYSIS

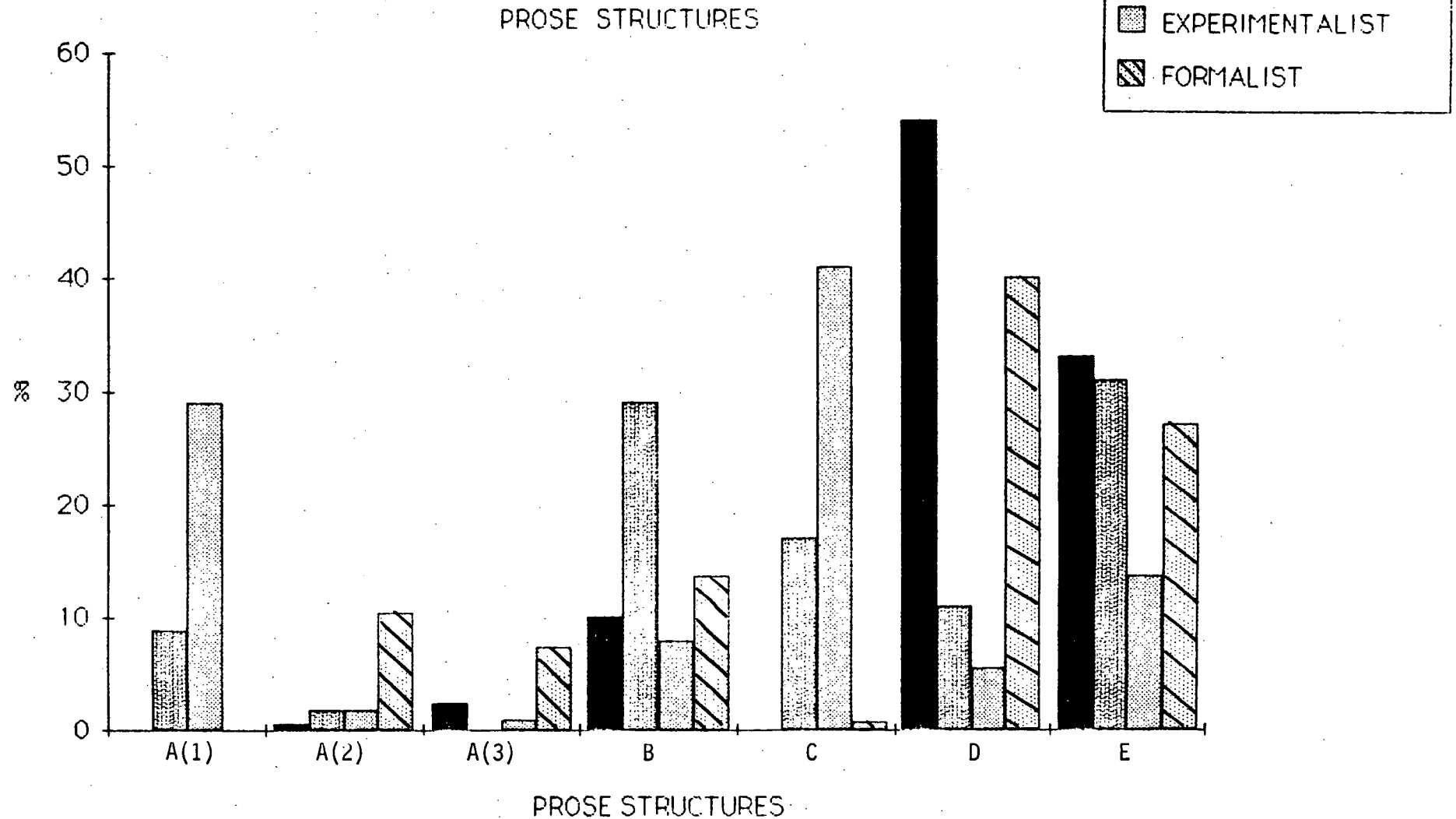


Figure 6. A comparison of the percentages of the seven prose structures appearing in the four textbook types.

Catechetical and Conversationalist are easily explained. The high number of structures within Catechetical texts is due to every sentence being either a question or an answer; therefore, every answer is likely to be a structure or part of a structure. The low number of structures within the Conversationalist texts is due to the story format; a great deal of text is taken up with descriptions of scenery, or moving the characters around, or conversation not related to the science content.

2. More intriguing are the differences between the Experimentalist and Formalist averages. A large amount of prose is needed to work through an experiment, step-by-step, with the reader. Therefore, fewer structures are possible per page within the Experimentalist texts. However, if the structures refer to experiments only, or simply state what is the case, far more can be accommodated in the same number of pages.

3. The question and answer format of the Catechetical texts has severely limited the ability of the text to instruct or offer explanations. An average of 87% of the textbook prose is given over to stating the results of science, and logically linking them to common phenomena. The role of the laboratory is negligible. Earlier claims made about these texts, that their explanations were limited to telling, and that instructing becomes is simply stating that one phenomenon is a case of a general rule, is therefore confirmed by analysis.

4. The Conversationalist textbook analysis shows greater attention was paid to real life experiences and the language of enquiry, though the laboratory was still neglected. It was claimed for both the Catechetical and Conversationalist texts that the style imposed constraints on the science to be taught.



The decision to use a story format, combined with the purposes of the authors to teach far more than science with their books, has necessarily reduced concern with laboratory operations. Thus the claim that explanation in these texts plays only a minor role seems correct--the emphasis is on neither the methods of science (e.g., laboratory experiments), nor on formal deductive systems of laws and principles. And, while the table above cannot be used to show the range of ways of instructing claimed for these texts, it does indicate that the knowledge was intended to be presented to the reader in a far more diverse manner than by the Catechetical approach.

5. It was claimed in Chapter 7 that instructing in the Experimentalist texts is to be done by reference to laboratory experiment, with occasional use of pointing out or pointing to, demonstration, definition, and logical reasoning. Given the differences in the use of the laboratory between physics, chemistry, geology and astronomy, the Experimentalist authors have still managed to justify that claim. The experiment, and its logical consequences, form the heart of the text. Similarly, it was claimed in Chapter 6 that explanation, for these authors, meant that not only had causes to be discovered through experiment and observation, they had also to be demonstrated. These two facets of explanation are revealed not only by the emphasis on laboratory work, but in the prominent use of the language of enquiry. While the level of explanation is not necessarily any deeper than in the Catechetical or Conversationalist texts, the nature of explanation is more fully developed with the reader as a result of this enquiring language. As the table indicates, this language was used in

conjunction with laboratory work more often than, say, for discussing 'real life situations' or in connection with 'unjustified statements'.

6. Interestingly, it would appear that the only major difference between the Formalist and Catechetical texts is that the former are concerned to use the laboratory to provide activities for the reader to perform in order to obtain the values predicted by theory. While such a statement could be supported by the percentages in the table above, it ignores the significant differences in language, style, and purpose between the two types of text. Keeping in mind the uniformly larger size of the Formalist textbooks, and the evidence that they have stripped their pages of the language of enquiry and the close attention to the role of the laboratory of the Experimentalists, the large average number of structures shown in the table would be evidence for their conciseness, and their concern "...not so much to inspire as to instruct." (Gregory and Hadley, op. cit.). But, as was claimed in Chapter 7, these Formalist texts may not be meeting their purposes to instruct, due to their over-riding concern to inform. For, without a language of enquiry, their role as explainers is much reduced.

7. Explanation, as was claimed in Chapter 6, was centred in the Formalist texts on the development of the sciences as formal deductive systems similar to geometry, where the application of axioms and laws led to deducible results confirmed by numerical problem solutions. To this view of science must be added to use of laboratory 'practicals' to confirm these axioms and laws. Given that an average of 67% of the prose structures considered were devoted to just such a deductive view of science, this

claim too seems justified.

## A PROCEDURE FOR CONTENT ANALYSIS OF FORMALIST PROSE IN SCIENCE TEXTS.

### INTRODUCTION

A counting procedure cannot hope to convey the actual wording of a passage of prose. The concern of this thesis with the traditional language of Formalist textbooks, and the view of science and science education that underlies that language, stems from the rigidity of textbook language in the face of over ten decades of research in reading, learning psychology, readability studies, and cognitive psychology research on learning from text. To substantiate this claim for such rigidity, and for the formal, deductive view of science held by these authors, this section extracts passages from Formalist textbooks sequentially over time--five from physics and five from chemistry. Those from physics range over 84 years (from 1900 to 1984) and chemistry over 71 years (from 1899 to 1970). The physics texts are treated first, after a short discussion of the reasons for the choice of topics, and a discussion of the approach to be taken.

### METHODOLOGY

In order for the extracts to be realistically compared, they are all taken from the treatment of the same topics. The physics texts will be examined for their presentation of the topics of Energy and Fields, the chemistry texts for States of Matter and the Gas Laws.

### RATIONALE FOR TOPIC CHOICES

The choice of these topics was not arbitrary. Physics textbooks have been shown (in Section C) to deal with abstractions such as force, momentum, energy, magnetic flux, to a greater extent than chemistry texts. It is appropriate, therefore, to use two such abstractions, energy and fields, to examine the language of these texts. In the same way, chemistry texts deal with processes and substances through empirical laboratory investigation and discussion to a greater extent than physics texts. Therefore, matter and the gas laws are appropriate themes to use to examine them.

1. Energy. Energy is a central organizing and explanatory concept of both physics and chemistry. Within physics in particular, it serves as one of the cornerstones of physical theory. Its importance alone would justify an examination of its presentation in school textbooks. In addition, however, it has the characteristic of being a theoretical concept, difficult to define precisely except through a mathematical formalism. From the language and teaching point of view, therefore, it presents fundamental problems of presentation. For example, should it be argued for empirically, or developed through real life situations? Or is its historical background important? Teaching about energy also raises the problem of understanding concepts that are not easy to handle empirically. Piaget (op. cit.) drew attention to the fact that science inevitably goes beyond empiricism in its efforts to make sense of the world. This presents problems for learners when they are forced to do the same. In short, abstractions like energy raise problems with which textbook writers must deal carefully through their prose.

2. Properties of matter. Matter is the second great concept of physical science. It is also a topic whose treatment by textbooks has, more strongly than energy, reflected changes in the scientific understanding of its nature. As a theme, it has tended to either reflect a growing concern to express its underlying atomic structure, with all that implies about the types of explanations of phenomena presented to readers, or it has remained on the level of descriptions of the properties of substances. Such differences should be mirrored in the language of presentation. It is also suited to this analysis because it forms an interesting contrast to energy by being a theme more easily subject to empirical laboratory investigation. Matter of course is a substance which can be operated upon and studied, at least macroscopically, by sensory impressions. It may, therefore, be more easily understood by the learner than an abstraction like energy. Its treatment by textbooks, and the corresponding language, may be expected to reflect this characteristic.

3. Fields. Fields are of interest here mainly from the language point of view--how the authors have treated a purely abstract explanatory concept, the nature of which has changed and developed since its introduction by Faraday and Maxwell (in the case of electric fields) in the 19th century. But fields differ from energy in a crucial way. Fields were originally developed by Faraday and Maxwell to serve a heuristic purpose--to act as a pictorial aid for thinking about action-at-a-distance in electromagnetic phenomena. The field was not originally imagined to have any actual physical reality, but was intended solely as a model. Such a topic, therefore, allows the

opportunity for the author to investigate the role of models in physics, and indeed the whole question of explanation. It also allows this analysis a further examination of the descriptive language of textbooks, and hence a look at questions of style; how often, for example, is an analogy used, or a model constructed, or an historical reference made? This topic is clearly more limited to physics textbooks.

4. The Gas Laws. These have the two advantages of redressing the emphasis given to physics textbooks with the treatment of fields, and because they are an experimentally determined set of laws. Such laws, as has been shown in Chapters 6, have a role in explanation to play in science. If science is seen by the authors as the activity of generating such laws, their presentation to readers is clearly crucial.

Thus these four choices allow the analysis of four different types of concepts. Firstly, an abstract, theoretical/explanatory concept (energy); secondly, an empirically determined concept (properties of matter); thirdly, an abstract, descriptive concept (fields); and fourthly, an experimentally determined concept (the gas laws).

A further word needs to be said about the four choices as a group. Each was selected because it is a concept, taken here to mean a central organizing idea within the discipline of study. They are not themes, in the sense of centres around which teaching experiences are organized. It is true that some textbook authors have debated the idea of thematic versus conceptual approaches to textbook organization. Such arguments have frequently hinged on the view of learning favoured by groups with varying allegiances. Briefly, some educationalists

have felt that subject matter should be based around the concepts that arise out of the work of Piaget: conservation, object invariance and the like. Their concepts are psychological. Associated with this is a concern with elementary sub-concepts and their links with perception, along with an interest in theories of learning. Others have argued that the concepts of the discipline itself should form the organizing framework for the content: energy, atomicity, gene specificity and so forth. This is close to the scientist's concern with major conceptual notions associated with the structure of science as a discipline. These latter concepts have tended to predominate in the textbook writing of Formalist authors. A third group has urged the use of thematic approaches to organizing content: water, change, environment are examples. This group is often composed of teachers looking for ways of integrating material within the classroom, but educationalists and textbook writers from Pestalozzi through the Experimentalist writers often recommended this approach either for its unifying power and facilitation of learning, or for relating the teaching to a simple, more empirical world view--that of the child. For example, Roscoe's Chemistry (op. cit.) organizes its chapter headings under the themes Fire, Air, Water, Earth, Non-Metallic Elements, and Metals. A popular Formalist chemistry text, Mee's A Modern School Chemistry (1946) arranges its chapter headings far more conceptually: Substances and Solutions, Physical and Chemical Change, The Air; Combustion, Water; Hydrogen, The Gas Laws, Equivalents and so on for a total of 37 chapters. Since the Formalist textbooks are more concerned with the concepts of science than with either thematic approaches or psychological

concepts, it seems appropriate to use the four concepts discussed above for this final section of the concept analysis.

### The Textbooks Used.

The textbooks listed below have been included for three reasons. Firstly, they are strongly representative of the Formalist type under which they are characterised. Secondly, they have enjoyed sufficiently long publishing lifetimes to mark them as successful. And thirdly, the writers were, in most cases, educationalists and/or scientists of some reputation.

- Everett, J.D. Textbook of Physics. 1900  
 Watson, W. A Text-Book of Physics. 4th Edition. 1910.  
 Gregory, R. and Hadley, H.E. A Class Book of Physics. 1941.  
 Noakes, G.R. New Intermediate Physics. 1970.  
 Parham, R.T. and Webber, B.J. Fundamentals of Senior Physics. 1973.  
 Walker, J. Introduction to Physical Chemistry. 6th Edition. 1910.  
 Taylor, W. A Course of Chemistry for Schools. 1933  
 Cavell, A.C. An Introduction to Chemistry. 1946  
 Goddard, F.W. and Hutton, K. A School Chemistry for Today. 1961  
 Nuffield Students' Book 1. 1970 (Only some sections of this multiple-author text are classifiable as Formalist)

### ANALYSIS OF THE CONCEPTS

#### ENERGY.

1900. Everett, J.D. Textbook of Physics 11th Edition. London: Blackie & Son

A body which resembles a wound-up clock in being ready to do work by letting its parts run down into the position which they tend to take, is said to contain potential energy or statical energy. "Energy", in dynamics and in physics generally, means capability of doing work, and it is measured in the same units as work, for example in foot-pounds. The water in a mill-dam is an excellent example of potential energy...The work done by a blow of a hammer is another example. A moving body is therefore to be regarded as possessing energy in virtue of its motion. This is called kinetic energy or energy of motion. It must not be confounded with momentum; for momentum is proportional to velocity, whereas kinetic energy is proportional to the square of the velocity. If a gun perfectly free to recoil is 100 times as heavy as the ball which is fired from it, the kinetic energy of the ball will be 100 times that of the recoiling gun, but



their momenta will be equal. (Page 37).

1910. Watson, W. A Text-Book of Physics. London: Longmans

We find by experience that in certain circumstances bodies are capable of doing work. Thus when a weight has been raised up above the surface of the earth, it possesses the power of doing work during its return to the surface of the earth...Again, a body which is in motion possesses the power of doing work while it is losing its motion, as, for instance, a bullet when it strikes a block of wood...Hence we see that in certain circumstances bodies do possess a capacity for doing work; and this capacity for doing work is called energy. (Page 85).

1925. Gregory and Hadley. A Classbook of Physics. London: Macmillan

All moving bodies possess energy. Moving air or wind drives round the sails of a windmill and so works the machinery to which the sails are attached; it drives along a ship, thus overcoming the resistance of the water...It may therefore be said that the energy of a body is the power of overcoming resistance or doing work.

Expt. 86.--Support a weight by a thin thread. Show that though the thread will support the weight at rest it will be broken if the weight is allowed to fall. (Page 115).

All these examples are cases of the energy of moving bodies, or the energy of motion, or kinetic energy. Kinetic energy is the energy of matter in motion. All energy which is not kinetic is known as Potential Energy. Potential energy is capable of becoming kinetic or active when the conditions become suitable. Imagine a mass raised from the ground and placed upon a high shelf...On the shelf the mass, by virtue of its position, possessed a certain amount of potential energy exactly equal to the work expended in placing it there. (Page 116)

1971. Noakes, G.R. New Intermediate Physics. 5th edition. London: Macmillan

Work is done when a force moves the body to which it is applied. It is measured by the product (force x distance moved in the direction of the force).

The Potential Energy of a system is the capacity for doing work possessed by the system on account of the relative positions of its parts.

The capacity for doing work, possessed by a moving body on account of its motion, is called Kinetic Energy.

If a graph of force  $F$  against distance  $s$  is plotted, the area of the space between the graph and the  $s$  axis for any interval represents the work done during that interval.

All physical events can be regarded as transformations of energy from one form to another, or as transferences of energy from one body or system to another. (page 82)

The work that is being done in raising it can only come from a reservoir of work that the body itself possesses as it leaves the hand; or the body possesses energy because it is moving. (page 80).

1984. Parham, R.T. and Webber, B.J. Fundamentals of Senior Physics. Melbourne: Heinemann. First published in two volumes, 1969 (Vol 1), 1970 (Vol 2).

This chapter is about energy, an idea which you have no doubt heard about and a word which you have certainly used. In fact, one of the difficulties we might have in understanding the concept of energy stems directly from the wide variety of ways in which the term is loosely used. Our approach will be more precise and a helpful way to begin is to recall some of the results from the previous chapter. (Page 73).

There are many examples of one dimensional collisions in which several outcomes seem equally likely, all in agreement with the law of conservation of momentum, but one outcome only is found repeatedly to occur. What is it that restricts the possibilities to one particular outcome? Is there a similar restriction for collisions in more than one direction?

From these two examples it would seem that the law of conservation of momentum does predict the actual outcome of an interaction, but it does not preclude other possibilities which never occur in practice. There must be another law (or laws) which accounts for only one outcome and precludes the others. The conservation of momentum has been so successful that we look for another quantity which might be conserved.

The problem was solved by the Dutchman Christiaan Huygens when he correctly suggested that the scalar quantity  $m(v \times v)$  was conserved as well as the vector quantity momentum...The quantity  $\frac{1}{2} m(v \times v)$  is called the kinetic energy of the particle. (Page 74-75).

### Discussion.

These extracts show that energy has traditionally been presented as something (whether material or not is unclear) which an object can "possess". While the amount of energy can be quantified, and related through equations to other, more fundamental quantities such as mass and force, it is not made clear whether energy has the same reality as other properties which objects also possess, such as specific density. Another difficulty presents itself through the idea of energy giving the object possessing it the "capacity" or ability to do work, a distinctly anthropological suggestion. The most radical break with this tradition is the Parham and Webber text, which attempts to invoke the necessity for a concept such as energy

from the results of laboratory operations. Again, energy is presented as a "quantity", but one that is not possessed by objects but conserved by systems, and how it was actually developed is hidden behind a reference to Huygens. In dealing with such an abstract concept as energy, the Formalist texts have relied heavily on a mathematical formalism to deduce energy from simpler concepts, and to justify this process by reference to familiar examples from real life or from abstract examples. It is possible to see a movement from the concept of energy as a quantity possessed by an object to an abstract organising principle, a convenient fiction to allow sense to be made of experimental results. But the presentation is still formal in style and rhetoric.

#### FIELDS.

1900. Everett, J.D.

If we consider any moderate-sized portion of space--say a space measuring several yards each way--near the earth's surface, and not near to artificial magnets nor to masses of iron or steel, we may regard it as a uniform magnetic field, because a magnetized needle will point in the same direction, and behave in all respects precisely alike, in all points of it.

The direction which the needle tends to assume under the magnetic influences which pervade this region or field, is called the direction of the lines of force of the field; a line of magnetic force being an imaginary line drawn in the direction in which resultant magnetic force acts. (Page 272)

1910. Watson.

The region of space surrounding a magnet in which magnetic phenomena are exhibited is called a magnetic field, the lines of force showing the direction in which the magnetic forces act. The fact that a suspended or pivoted magnetic needle, even when no magnet is in the neighbourhood, sets itself in a definite direction, shows that the space on the surface of the earth must be a magnetic field...(Page 587).

If a small body, charged with the unit positive charge, is brought into the neighbourhood of a charged body, this unit charge will be acted upon by an electrical force, which at every point of the space surrounding the charged body will have a definite direction and magnitude.

The space in the neighbourhood of electrified bodies in which electrical phenomena, such as attraction, are exhibited is called an electrical field. (Page 62-623)

1925. Gregory and Hadley.

When a suspended magnetized needle is allowed to swing to and fro round its point of suspension, the manner in which it swings suggests that there are invisible forces acting on the needle...Whenever these invisible magnetic forces appear to be influencing a suspended magnetized needle, it is said to be in a field of magnetic force. (Page 381).

Dr. Gilbert, who was a physician to Queen Elizabeth, observed these effects in 1600, and he described a lodestone or magnet as being surrounded by an "orb of virtue". About the middle of the last century Faraday substituted the term magnetic field. (page 382).

An instructive analogy, due to Faraday, compares the properties of the magnetic lines to the forces which could be exerted by stretched elastic threads, coinciding in direction with the lines of force, which tend to shorten themselves from end to end and to repel one another from side to side. (Page 384).

1971. Noakes, G.R.

The effect experienced by B (due to A) can be considered in another way. Since it is observable over the whole region around A, we say that A is surrounded by an electric field. The mechanical force experienced by B is greatest when it is closest to A, increasing as the potential graph becomes steeper. The gradient of the potential-distance graph (in calculus symbols  $-dV/dx$ ) at any distance is taken as measuring the electrostatic field-strength at that point. (Page 706).

The region around a magnet in which its effect on other bodies is observable is called a magnetic field. The effect on the suspended magnet can be regarded as the result of surrounding it by the magnetic field of the second magnet. The effect is greatest near to the poles of the second magnet, so that its field is strongest close to the poles. (Page 715).

Associated with a magnetic field is a quantity which is called magnetic flux. Nothing is actually flowing, as the name might imply, but the flux is regarded as something to be represented by continuous lines instead of by lines that start and end on poles...

There is an analogy in the streamlines indicating the flow of air past an obstacle of a special type, such as the section of an aeroplane wing. The lines represent the direction of the moving air, and the speed of the air is greatest where they are closest. The body experiences a viscous drag in the direction of the lines (analogous to a magnetic force on a magnetic pole in the direction of the magnetic field), and the spacing of the lines represents the size of the drag. (Page 716-717).

1984. Parham, R.T. and Webber, B.J.

We have described, using Newton's relationship, the gravitational interactions between the earth and any of its

satellites. The earth, however, can be considered as having a gravitational influence in the space around it, not just with its satellites. We need to develop a way of describing that influence at any point in space. To do this we introduce the idea of a field. (Page 137).

If some physical quantity can be measured at every point in a region of space, a field may be defined. For example, air pressure can be measured at any point over a continent and from a set of many readings a pressure field can be defined. (Page 138).

If a heavy object were freely suspended on a fine string, the line of the string would indicate the direction of the gravitational force acting on the object. If the line were suspended from a spring balance, the magnitude of the force would also be determined. A set of values (magnitude and direction) of the force taken at different places would describe the vector force field in the region tested. (Page 139-140).

A charged object exerts a force on all other charged objects by an action-at-a-distance force. We can describe this effect by saying that the charge has associated with it an electric field which extends into space in all directions around it.

We have introduced the electric field as a mathematical abstraction. Like other force fields, however, we can represent the electric field pictorially by lines of force... (Page 150-151).

## DISCUSSION

These passages reveal a significant level of uncertainty in presenting the field concept to the reader. Consider the often used reference to the behaviour of a magnetized needle. How is it known if a needle is magnetized, unless it shows certain behaviours in a magnetic field? And how is a magnetic field detected, except by using a magnetized needle? The circularity here is obvious, but forced on the writers by their reluctance to address the reality of the field. The action-at-a-distance difficulty is answered by Everett through "magnetic influences", which does not explain the action of the forces, and is at worst worthy of the scorn with which science has reacted to the notions of 'mesmeric influences' or 'psychic influences'. The Formalist concern to express the logical structure of science, rather than explore its difficulties and assumptions, is clearly

seen here.

The analogy expressed in the Gregory and Hadley text is far more useful, suggesting to the student that here is a way of thinking about, or picturing, the field, as well as giving at least a hint of the heuristic nature of the field concept.

These extracts also show the common Formalist approach of using a definition to not only present concepts to the reader, but also to give meaning to them. The apparent belief is that by labelling something, understanding is gained. Noakes clearly wants only to examine the mathematical formalism of the field, assuming that having defined it as the space in which certain things happen, the reader is clear as to what it is. The analogy he uses of "streamlines" in air flow around obstacles has the potential to be illuminating, but may allow the reader to draw the conclusion that lines of force are of the same level of reality as the air streams.

The Parham and Webber text make an interesting contrast, for they see the field concept as necessary to "describe" what happens, rather than to account for what happens, using, as they admit, a mathematical abstraction. By equating fields with sets of readings, it becomes difficult to see their possible role either as an intermediary for force, or as a direct causal agent, or as a property of space. They certainly cannot account for action-at-a-distance.

#### THE CHEMISTRY FORMALIST TEXTBOOKS

The first theme to be considered is the Gas Laws.

1899. Walker, J. Introduction to Physical Chemistry. London:

Macmillan.

The student is doubtless familiar with the fact that the laws regulating the physical condition of gases are of an extremely simple character and of universal applicability. Pressure and temperature affect the volume of all gases to nearly the same degree, no matter what the chemical or other physical properties of the gases may be, so that we can state for gases the following general laws:...

Any one of these laws may be deduced from the other two, and as an example we may take the deduction of the third law from the laws of Boyle and Gay-Lussac...

Since if pressure and temperature are constant the quantity of a gas is proportional to the volume taken, the actual value of the expression  $pV/T$  is proportional to the quantity or volume considered. Now, since according to Avogadro's principle the gram-molecular weights of all gases occupy the same volume under the same conditions of temperature and pressure, it follows that for these quantities the expression will have a constant value, no matter what the nature of the gas is, or the conditions under which the volume is measured. (Page 26-27).

1933. Taylor, W. A Course of Chemistry for Schools. London: G.G. Harrap.

By using a pump, and so increasing the pressure on the gas, a comparatively large volume of air can be squeezed inside the smaller space provided by a football bladder (or by a pneumatic tyre). This shows that a gas decreases in volume when the pressure on it becomes greater.

In 1622 Robert Boyle measured the changes in the volume of a certain mass of air produced by measured changes in the pressure. He found that the volume of a gas varies inversely with the pressure when the temperature is constant. In simple language, if the pressure is doubled the volume of a gas is halved, providing always that the temperature is constant. (Page 253).

The fact that air expands when heated has been known for a long time. It may be demonstrated by fitting a flask with a right-angled bend, the end of which dips below the surface of water in a beaker. When the flask is warmed by the hand bubbles of air escape through the water.

In 1787 Charles discovered that oxygen, nitrogen, hydrogen, air, and carbon dioxide expand equally between 0 degrees and 80 degrees. In 1802 Gay-Lussac amplified this work by experiments on many other gases, and came to the conclusion that differences in the properties of these gases had no influence on their expansion, but that gases expand equally for the same rise of temperature. This result is summed up in Charles' law. (Page 254).

In a mixture of gases each gas exerts a certain pressure, which is part of the whole pressure of the gaseous mixture... Dalton found that these partial pressures obeyed the law that the total pressure of a mixture of gases is the sum of the partial pressures of the separate gases. (Page 256).

1946. Cavell, A.C. An Introduction to Chemistry. London: Macmillan.

The following paragraphs explain how Boyle's law and Charles' law can be applied to the reduction of the volume of a gas to S.T.P. or N.T.P.

Boyle's law. This law may be stated as follows:

When the temperature is constant, the volume of a gas is inversely proportional to the pressure.

Thus if we double the pressure on a gas we halve its volume, and conversely, if we halve the pressure we double the volume. The law may be expressed in the algebraic form:... (Page 52)

Charles' law. When gases are heated under constant pressure they expand by  $1/273$  of their volume at 0 degrees C., per degree centigrade rise in temperature. Conversely, when they are cooled through one degree centigrade they contract by a similar amount... (Page 53)

In equivalent weight determination it is customary to allow for the water vapour in reducing the volume of the hydrogen to S.T.P.; but this correction is probably not justified, because in most experiments nothing like sufficient time will have been allowed for the hydrogen to become saturated with water vapour. (Page 56).

1961. Goddard, F.W. and Hutton, K. A School Chemistry for Today. London: Longmans.

In chemical experiments a gas is usually collected and its volume measured under the conditions of temperature and pressure in the laboratory at the time of the experiment. In order to calculate the weight of the gas, it is necessary to know what this volume would be under standard conditions of temperature and pressure; this may be worked out from the following Gas Laws.

Robert Boyle in 1664 carried out a series of experiments, applying pressure to a gas, and discovered the law that:

The volume of a fixed mass of any gas at constant temperature is inversely proportional to its pressure.

This means that if we double the pressure of a fixed mass of gas, then its volume will be halved; or, in general, if  $V$  is the volume of the gas and  $P$  its pressure, then:  $P \times V = \text{constant}$ , if the temperature is constant;... (page 118-119).

Ordinary experience would lead us to expect that any gas would expand in volume if its temperature is raised, e.g. if a balloon is heated, the gas expands, thus stretching the balloon until it bursts; the quantitative relation between volume and temperature was investigated in about 1782 by Charles, and also by Gay-Lussac, who discovered that:

If the pressure remains constant, the volume of a given mass of gas increases by  $1/273$  of its volume at 0 degrees C. for every 1 degree C. rise in temperature.

When temperatures are expressed on the absolute scale, Charles' Law becomes:

The volume ( $V$ ) of a given mass of gas at constant pressure is proportional to its Absolute Temperature ( $T$ ).

The gases produced by an explosion... expand to about ten times their volume as their temperature is raised from 300 K. to 3000 K. by the heat of the reaction... (Page 121-122).

1970. Nuffield Students' Book 1. England: Penguin.

Having studied the results of a large number of reactions



involving gases, the French scientist Gay-Lussac in the years just after 1800 saw that the volume measurements were very simply related....He expressed this in his Law of Gaseous Combining Volumes, which he published in 1808:

When gases react, the volumes in which they do so bear a simple ratio to one another, and to the volumes of the products of gaseous, all volumes being measured under the same conditions of temperature and pressure.

An explanation of the law in terms of atoms and molecules was sought, and in 1811 the Italian scientist Avogadro put forward his theory:

Equal volumes of gases, under the same conditions of temperature and pressure, contain equal numbers of molecules.

How this theory applies to the results of experiments can be seen by taking an example...

Assuming the correctness of Avogadro's theory, it is possible to compare the masses of different molecules, by comparing the masses of equal volumes of different gases (measured under the same conditions of temperature and pressure). (Page 42-43).

It is important to remember that all measurements of gas volumes are dependent upon temperature and pressure. The volume of a given mass of gas is inversely proportional to its pressure,  $p$ , if its temperature remains unchanged (Boyle's law) and directly proportional to its absolute temperature,  $T$ , if its pressure remains unchanged (Charles' law). (Page 44).

#### DISCUSSION.

It is necessary to immediately state that the above extracts do not, in each case, give a fair treatment of the development of the gas laws within the texts. The majority of Chemistry texts do surround such extracts with laboratory experiments. In some cases, the experiments precede the formal presentation of the law, providing a set of data which is generalised to provide empirical foundations for the laws. In other cases, the experiments immediately follow the laws, and are used to demonstrate their validity. While the extracts do show the traditional nature of Formalist textbook language, they do not show the concern for empirical argument claimed for them earlier in this chapter. However, the concern here is with language of presentation.

A feature common to these five textbooks is their unwillingness to explore the underlying physical phenomena that led the

proponents of the laws--Boyle and Charles--to their generalisations. Commonly this is left expressed as the "result of many experiments". The laws are then illustrated by examples. Secondly, none of the five authors attempts to link the law-like behaviour of gases to the kinetic-molecular theory. While this may not be important to the discussion of the gas laws that these authors wish to present, it means the laws are presented as regularities in nature, perhaps empirically determined, but unrelated to the nature and behaviour of gases in any fundamental way.

There are slight differences in the statement of the laws, but it has become traditional to provide the example of "...if we double the pressure we halve the volume...". The laws are then expressed in a mathematical formalism, and sample problems are worked. (Notice too the discrepancies attached to the dates of appearance of the laws).

The essential Formalist features of these extracts are the following. Firstly, the laws are stated to be empirically derived from experiment, but the process by which that is done in science is left unexplored; i.e., there is no narrative of enquiry. Secondly, the laws are shown to be deducible one from another, emphasising their formal and mathematical nature. Thirdly, only feeble links are made to the everyday world of experience of the reader; e.g., filling football bladders or balloons. Thirdly, the practice of simply stating the results of experimental work done by others; e.g., "When gases are heated under constant pressure they expand by  $1/273$  of their volume...". And fourth, the laws are used to explain certain phenomena, but they themselves are not subject to analysis at a

deeper level of explanation.

# PROPERTIES OF MATTER.

1899. Walker, J.

When a solid such as glass is heated, it gradually loses its rigidity, and by degrees, as the temperature is raised, assumes the liquid form, passing through the stages of a tough, inelastic solid and of a viscid, pasty liquid. It cannot be said, therefore, to have a definite melting point. A crystalline substance such as sulphur, on the other hand, when heated remains solid up to a certain temperature, after which the further application of heat liquefies it, the temperature remaining constant during liquefaction. This constant temperature is the melting point of the solid, and is a characteristic property of each particular crystalline substance. (Page 61).

The properties of substances, when studied in relation to their composition and structure, have been divided into three classes. In the first class we have those properties which are possessed by the atoms unchanged, no matter in what physical or chemical state these atoms may exist. Such properties are called additive, and the best instance of an additive property is found in weight (or mass). (Page 153).

When oxygen...is attached to one carbon atom, it contributes more to the molecular volume than when it is partially attached to carbon and partially to hydrogen. Here we come across an influence which modifies the additive character of all properties except weight, and radio-activity, namely the influence of structure or constitution. The molecular volume is not a purely additive property--it is in part constitutive, i.e., is dependent not merely on the number and kind of atoms in the molecule but also on their arrangement. (Page 154).

1933. Taylor, W.F

One of the distinguishing properties of a liquid is its density.

Definition. "The density of a substance is the mass of unit volume." The unit of volume most commonly used in finding density is 1 cubic centimetre, or 1 c.c. (Page 19)

The most obvious characteristic of a crystal is its shape; but a piece of glass cut into the shape of a crystal is not a crystal. It is the internal arrangement of the material particles of the crystal which is its essential characteristic. (Page 295)

Properties (of nitrogen). Physical. Nitrogen is a colourless, odourless gas which is slightly less dense than air. It is even less soluble than water than oxygen, so that air which is dissolved in water is richer than ordinary air in oxygen. This can be shown by boiling dissolved air out of water (Expt. 7) and finding the fraction of the gas absorbed by yellow phosphorous (Expt. 20a). Dissolved air contains 36 per cent. of oxygen.

Chemical. Nitrogen has no action on litmus, does not itself burn, and does not support burning, except in special circumstances, with metals like magnesium and calcium, when

nitrides are formed... (Page 64).

1946. Cavell, A.C.

Physical properties of water. Pure water is a colourless liquid which freezes to ice at 0 degrees C., and boils at 100 degrees C. under atmospheric pressure. It has a maximum density of 1 gram per c.c. at 4 degrees C., and this is why ponds, lakes, etc., freeze from the top downwards...

Chemical properties of water. One of the most important chemical properties of water is its action on metals. Thus cold water attacks sodium and potassium, violently, giving an alkali and hydrogen:... (Page 157-158)

The properties of compounds and mixtures. Firstly, we know that a compound has a definite composition, whilst a mixture can have any composition, because there is no limit to the number or weight of substances which can be mixed together.

Secondly, the ingredients of a mixture retain their own properties, whilst the constituents of a compound do not do so...

Thirdly, the ingredients of a mixture, but not of a compound, can be separated by physical means. Thus, a mixture of sugar and sand can be separated by making use of the fact that only the sugar is soluble in water;... (Page 11).

1961. Goddard and Hutton.

In order to find out what things are made of, we must know how things behave. The behaviour of a substance is considered by the chemist under two headings, namely physical properties and chemical properties.

Physical Properties

The most obvious physical properties are those which affect our five senses, i.e. sight, touch, smell, taste and hearing... We shall find the colours and smells of substances very useful for recognizing them; normally no substance should be tasted...

We soon find, however, that physical properties which can be measured... are much more useful.

If we find a colourless liquid which has a freezing-point of 0 degrees C., a boiling-point of 100 degrees C., a density of 1 gm./c.c. (i.e. a specific gravity of 1.0) and a specific heat of 1.0, (as well as having no taste or smell), we may be fairly sure that it is water... (Page 9).

A metal is an element which has a characteristic lustre, is a good conductor of heat and of electricity, and can be worked into shape by hammering (i.e. is "malleable") or by pulling into wire (i.e. is "ductile"). (Example: iron).

As in nearly all classifications, there are certain border-line cases, such as arsenic; but if we draw up a fairly complete list of properties of metals and non-metals... we shall find that the distinguishing line becomes clearer. Chemical properties, especially the properties of the oxides, are then found to be the most useful in deciding to which class an element belongs. (Page 44).

1970. Nuffield.

At its melting point, the electrical conductivity of sodium is high; the value is  $10.4 \times 10000$  /ohm.cm. This implies that electrons are freely available as charge carriers in the system

and such electrons are said to be present in a conduction band. It is known that each atom of sodium, in the solid or liquid state, provides one electron as a charge carrier. (Page 152). Water molecules however have two hydrogen atoms and two non-bonded electron pairs each and so can form an average of two hydrogen bonds each. There is therefore the possibility of water molecules being bound by hydrogen bonds into a three-dimensional lattice. This is so in ice...

Although these structures account for very many of the properties of ice they do not account for all of them, and the structure of ice is not fully understood. The structure of water is even less certain and is still under discussion. In water the strong hydrogen bonding still succeeds in retaining some coordination of oxygen atoms, and there is a short-range order but no long-range ordered structure... (Page 340).

## DISCUSSION

The Formalist chemistry texts are not concerned with the properties of matter in the sense of hardness, malleability, porosity and so forth; nor in investigating the difficulties associated with the physical states--solid, liquid and gas--and the transitions between them. There is an important historical shift from considering the macroscopic properties of substances to providing an atomic model to account for phenomena. (Interestingly, an atomic model is not provided by these authors for the gas laws). This historical shift corresponds to a shift in the conceptual demands made on the readers of textbooks. The physical properties of substances are perhaps felt by chemistry authors to lie in the realm of the physicist. Yet there is a great deal of attention paid to the chemical properties of substances, with whole chapters being given over to, for example, the metals, or the halogens. The nature of these two influences on the texts--the shift from a 'natural history' view of substances as having macroscopic properties to a scientific view of an underlying atomic explanation, and the distinction between physical properties and chemical properties--is not explored by the authors.

The Walker text shows the Formalist pattern of simply stating, when it talks of the melting point, or the characteristics of crystals. There is an interesting discussion of three classes of properties (two of which he refers to as additive and constitutive) which, as an organising concept, has disappeared from chemistry textbooks but which, again, as the example shows, consists of telling, or stating. The Taylor text repeats this formal expression when it "explains" density by defining it, or when it simply lists the properties of nitrogen.

Goddard and Hutton do comment on the role of properties, but provide no discussion of what the properties are, or how the reader is to understand them. For example, what is the relationship between the properties of a substance and the way it behaves? What is the connection between how it behaves and what it is made of? In what ways are the properties of a substance and how it strikes the senses related? Why does water, for example, have the properties listed, and are they the only possible ones? What does science have to do before it can state that water boils at 100 degrees Centigrade at atmospheric pressure?

The selected passage from the Nuffield text also uses formal language in its discussion of the properties of water, though this passage should not be taken as representative of the Nuffield approach in all areas. The properties are stated to be the result of molecular configurations. There is, however, an admission of the current limitations of understanding. This is not expressed in the language of puzzlement or enquiry, but simply stated as being an example of something that still needs to be found out. The Nuffield example is particularly

interesting because, as cited in Chapter 3, the preface to this text claimed it was not a textbook, but written as an integral part of a laboratory course. Yet in sections it cannot break away from the formal rhetoric of the modern textbook.

### CONCLUSIONS

The extracts from the Formalist physics and chemistry texts demonstrate how little the style of presentation of certain themes has changed over significant stretches of time. Rather than repeat the essence of the discussions given above, this summary, by contrast, comments on what these texts have not shown.

1. Language characteristics. Regardless of any shifts in emphasis placed on theory or practical, the language of the textbooks has not shown significant changes from the formal style present at their origin. There is not an increase in the use of figurative language, or of models, or of quotations from scientists, or of uses of primary sources. There has not been a change in the numbers of sentences that are questions, or are addressed to the reader, or that refer in enquiring terms to the experiences of the readers' everyday world.

2. View of science. There have not been any shifts away from the emphasis on stating information, as even the practicals are written in such a way as to stress the information (e.g., the proper way to set it up, to draw graphs, to filter precipitates, to take temperatures). In other words, the laboratory techniques are part of what is to be learned, rather than tools to uncover information.

3. Stylistic characteristics. While there may be a case for

changes in sentence length (Everett averages over 25 words per sentence, Parham and Webber only 17), there persists a tendency to use shorter sentences for statements of fact, and longer sentences for explaining both the development of the fact and its consequences.

#### CONCLUSION TO SECTION C

It is now possible to extend the second order classification presented at the end of Section B, to form a third order classification based on the results of this final section.

The Catechetical texts retain all of their second order characteristics, and add the following.

Explanations: characterised chiefly by stating facts or principles, and applying them to specific cases; no use of the laboratory.

Instructional language: characterised by simple telling, and the infrequent use of analogy; lack of figurative language; uses examples from the readers' world.

The Conversationalist texts add the following to their second order characteristics.

Explanations: characterised by both stating by authority or by finding out through enquiry; causal explanations dominate.

Instructional language: rich diversity of prose due to story format; many different types of instructional types present as a result; no use of the laboratory, but examples based on real-life situations.

The Experimentalist texts add the following to their second



order characteristics.

Explanations: cause and effect, based on the laboratory; scientific method of enquiry central; use of inductive/deductive explanations also present.

Instructional language: chiefly a language of enquiry, guiding the reader through laboratory experiences or logical reasoning; the scientists' world referred to far more often than the readers'.

The Formalist texts add the following to their second order characteristics.

Explanations: inductivist/deductivist; the laboratory plays a secondary. verificationist role; great deal of logical reasoning from first principles.

Instructional language: formal language stating conclusions, and detailing logical reasoning; examples drawn from both the scientists' world and the readers'.

## CONCLUSION

## CHAPTER 9: THE PHYSICAL SCIENCE TEXTBOOK SINCE 1800--AN OVERVIEW

### INTRODUCTION--THE TEXTBOOK AS A MIRROR OF SCIENCE EDUCATION

This thesis has examined the language of the physical science textbook from the point of view of what that language can reveal about the nature of science education. In doing so it has emphasised a series of key interactions that must be taken into account. The historical analysis reveals that there have been changes in contemporary views of the nature of science and science education, and of the interactions between these two. These views shape the characteristics of textbooks which, in turn, can reflect those views. The textbooks reveal an interaction between purpose, explanation and instruction that influences their language. And the interaction between that language and the reader powerfully determines what is learned, and shapes reader response to those contemporary views of science. Thus an interesting and important feed-back loop is formed which places the textbook in a crucial role in science education.

This chapter summarizes and synthesizes the results of this thesis, focusing firstly on some overall features of the interactions between science education, the text, and the reader, and then narrowing to specific considerations directly examined by the study.

The historical approach adopted has some special benefits that only become clear when the overall evidence is reviewed. The pressing and difficult problems facing science education today

can be seen from a perspective which, while not necessarily answering urgent contemporary questions, allows them to be approached with greater insight, awareness of a wider range of possibilities, and an equal awareness of the successes and failures of the past. Except perhaps for the unique problems faced by Third World countries in developing appropriate science education programmes, a study of textbooks leaves the distinct impression that there are no new problems in science education. From the beginnings of science education as a school subject, debates have taken place over every aspect from its place in the life of the child to the best design for a physics laboratory. Few of these questions have been answered satisfactorily, and consequently the same questions are still being raised. These questions centre around the most fundamental issues. What is the purpose of science education? What is the value of science in the life of the student? How is science best learned and best taught?

What has emerged from this study is the possibility of using the textbook as a mirror of the history of the varying answers to such questions. These changing responses are reflected within the text itself, and also in debates about its place and value in learning. This is necessarily so. For it often, perhaps too often, happens that when decisions are made concerning science education, and new courses are designed and implemented, then textbooks are written to reflect and support those decisions. In some instances textbooks, long after the convictions that led to their creations have fallen from favour, continue to dominate the classroom. Or, just as powerfully, when science educators assemble to consider the nature of perceived necessary changes

to science education, their thinking is constrained by the textbooks available, or familiar to them, or which have shaped current opinion and belief about what is possible. There is a very powerful 'hidden curriculum' in the textbooks which is enduring and can confound or confuse curriculum development. Textbooks compose that valuable tool of historical research, the 'original sources'. More enduring than teacher practice, more accessible than student behaviours, closer to reality than curriculum descriptions and ideals, textbooks present a record of what was thought and practiced and believed about science education from its inception.

Textbooks, perhaps in common with all literary genre, change over time. Just as epic poems and Renaissance sonnets are no longer written, so all but the Formalist textbooks and its variants have disappeared. Perhaps an educational 'natural selection' has weeded out those textbook types 'unfit' to survive. In any case, the modern Formalist textbook did not evolve from the Catechetical, passing through the Conversational and Experimentalist to reach a peak of 'fitness'. Instead, the 'formalist' view of science, and its brand of pedagogy, have been found to be most in harmony with the reality of science education in schools today. This may be an unpalatable observation for many educators. In 1900, a choice of textbook types was possible, each with a different view, format, style and purpose. Gradually, alternative possibilities in science writing have disappeared, leaving the often unwieldy Formalist compendium, or those stripped of prose structures longer than a small paragraph, but abounding in graphics. This consolidation of the Formalist textbook can be seen to go hand in hand with

the formalisation of science as an examinable school subject, in which information and problem-solving skills take precedence. This development has had a number of major influences on other aspects of the textbooks' message. One is the removal from the textbook of all that is seen to be extraneous to the facts of science. Religious and moral aspects have been eliminated, both those which saw the ultimate explanation of natural law in Christian divinity, and those which saw science and natural history as a legitimate vehicle for the admiration of God. But also gone are those views which saw science as one facet of universal, integrated knowledge about a marvelous, inspired world; and those which saw science as the best training in ways of thought felt to be en-nobling, giving a sense of human understanding of, and mastery over, the natural world; and finally, those which saw science as intimately connected with social change and the improvement of the individual and society. These developments are linked with a further factor, the demise of the cleric, the religious laymen, and the outstanding scientist/educator as authors. Their metaphysical, scientific and social perspectives no longer appear in the modern text, whereas in earlier texts such ideas, whether boldly or modestly, sought connections between science and the rest of human experience.

The historical treatment has highlighted the important--and still-continuing--debate over the connection between the concepts of science, the laboratory, and the world of everyday experiences. This debate had two powerful central foci; one was the authors' view of what science is, and the other was the authors' view of what science education is. For the

Catechetical writers, science was a distant generator of facts and generalities, and science education was the transmission of those conclusions (plus suitable religious and moral additions) to a curious public which included school children. Those conclusions were transmitted by using them as answers to questions about phenomena and substances of common experience; of snow, soot and iron, or burning, falling and pumping. For the Catechetical authors, the laboratory did not exist, nor was there a scientist in every reader.

For the Conversationalists, science was a source of fascinating facts of practical importance in everyday events; it was also a vehicle for a story, a story about children, their friendships and relations with their parents, about moral duties and proper behaviour. Science education was the possession of a collection of facts and principles helpful in understanding familiar events. The story format and concern for a wider range of issues than just science allowed these authors great scope in language use, and no textual structure predominates. For both the Catechetical and the Conversationalist authors, the world was to be presented as understandable by children; it was taken for granted that children were curious; that the details of discovery were less important than possession of the facts, facts which could be acted upon; and that science education was no different in essence from education in any other facet of life. The same authors who were writing the Rollo series, or Harry and Lucy, or Joyces's Dialogues, or Pinnock's Catechisms were at the same time producing similar volumes in exactly the same styles on geography, poetry, religion, ancient history and heraldry. They were writing before the maturing of science as a

school subject, and they were writing for autodidactic readers. Their writings were enormously popular, commonly selling tens of thousands of volumes and going through numerous editions. Indeed, their very success may have been their undoing, for it may have added impetus to the growing movement to put science into schools. For once these authors found their books taken up by teachers for lack of anything else, they began to modify them for school use--questions at the end of the chapter, problems to work, and a matching of content to examination demands.

It was indeed the debate over the nature of science education in schools that took place in the late 19th and early 20th centuries that saw the demise of the early autodidactic texts, the conflict between the Experimentalist and Formalist writers, and the gradual dominance of the Formalist text.

For the Experimentalists, science was, in Huxley's phrase, "...perfected common sense." However the idea had been arrived at, it seemed obvious to these authors--many of them eminent scientists--that common sense consisted of putting nature to the question through experiments. The connection between the concepts of science, the laboratory and the world of everyday experience was to be found in the precise and unambiguous world of the laboratory. This had never been common sense before, and it began to turn science education into an activity remote from the common experiences of the learner. With great skill, and with a concern to lead the reader through the processes by which the various Truths of Nature were revealed, these pre-eminent scientists created, in the case of the Macmillan Science Primers, a series of slender textbooks which greatly influenced the direction and understanding of science education. They were



not based on the 'enquiry' approach to experimental work of our time, but concentrated as far as possible on demonstrating the techniques, the types of reasoning, and the attitudes which they considered to be at the heart of scientific endeavour.

They were displaced by the Formalist textbook writers, who had been producing volumes of science information side-by-side with the earliest Catechetical and Conversationalist texts, but who suddenly found their format and style in harmony with the development of an 'examinable' school science. For these writers, science was a collection of facts and principles arrived at by a rigorous combination of empiricism and logic. Its results represented a summation of all knowledge of the natural world; though by the early 20th century 'natural' no longer included God or metaphysical beliefs. Science education increasingly became the presentation of this completed knowledge, its absorption and recall, and its manipulation through mathematical formalisms. Associated with science was a 'body of knowledge' that was the focus of science education. This knowledge had been generated empirically, and so it was necessary to provide opportunities for the reader to perform set, prepared lab practicals, to themselves generate the physical constants and numerical ratios, in order to verify the text. In this sense, science education was seen to be an introduction to the knowledge characteristic of the discipline; at the same time, it hoped to develop powers of logical reasoning through its emphasis on numerical problem-solving. While there was a displacement of the laboratory as the centre of classroom practice, Formalist authors were freer to use examples from everyday experience, either to introduce and

develop scientific concepts, or to be illuminated and explained by reference to those concepts. Increasingly, these texts were written by academics, teachers, or committees that included psychologists and science educators. Increasingly the influence of publishers and market-research was felt--formats changed, and graphics took precedence over prose.

In this over-view of the results of using an historical approach, some finer detail is also noted. Clear differences can be seen between the physical sciences in terms of their school-level empirical possibilities. Chemistry emerges as the laboratory science, lending itself to classroom experimentation and manipulation of equipment more than any other. Physics is next, but many of its basic concepts have not, historically, been as empirically developed in school laboratories with the rigour of chemistry. Geology and astronomy, with their special problems of time and distance, present even greater difficulties. Even the Experimentalist writers found this problem, and their textbooks reflect it. Where the laboratory could not be used, thought experiments, analogies and models were used.

Again, the historical analysis reveals no real concern at any time by any group to address science as a human endeavour--its impact on society is not explored, its history is mentioned but not examined, its unique way of arguing and interpreting conclusions is rarely mentioned, far less detailed (Huxley's Introductory may be an exception here). In other words, none of the conclusions about the connection between the laboratory, science, and the real world mentioned so far in this chapter are made available to the reader.

Finally, the historical analysis reveals some common features of the textbook of every type. Four features in particular are of importance to a language-based study. Firstly, textbook authors never explain to their readers what it is they are trying to do throughout the text. The reader is not offered justifications for sequence, for approach, for choice of topics and experiments, for emphases attached to particular concepts, for the value and purpose of thinking/doing/believing one way rather than another. This is not to deny the occasional claims made in the prefaces and introductions, nor the occurrence of the 'narrative of enquiry' in some textbooks. What is meant here is something subtler, the interaction of the writer and reader throughout the text. This interaction has been one-sided for the whole history of textbooks, due perhaps to the long-standing belief that reading is a passive process. It has led to the production of what have been termed "inconsiderate" textbooks, to a lack of attention paid to stylistic matters until very recently, and to that lack of personal voice justifying itself to the reader as the text proceeds.

Secondly, textbooks have never expressed any doubts about the ability of language to correctly convey the true scientific understanding of things. There are obvious limitations to what written language can do in giving meaning to certain concepts, meanings that only laboratory experience can give. Beyond this, however, is the relationship between language and science, language and meaning, language and everyday experience. Until these are explored, phrases like 'energy is the ability to do work', and 'carbonic acid turns lime-water milky' remain equal in terms of truth value; lines of correspondance are not

drawn between the words used and the world described.

Thirdly, and related to the above, textbook authors never discuss the underlying reality of their concepts, even when they specifically discuss heuristic constructs such as models. No distinctions are made between the varying 'realities' of such things as electrons, semi-conductors, acids, solids, magnets, sound waves or friction-less pulleys; or between such properties as specific density, solubility, latent heat, expansivity, electric charge, refractive index or atomic mass; or between such concepts as energy, fields, conservation, force, entropy, equilibrium or orbitals; or between the three categories--things, properties and concepts. Each of these three categories has a different reality status, and a different role to play within science, but no attention is paid to them in the textbook.

Fourthly, the textbook writers have never felt it to be important to take the student into the reality of the scientists' working world. Science as a profession, done by people for a living, is not portrayed in science texts. This may not seem appropriate for science education, yet it would appear to offer opportunities to show how problems raised in the text are actually approached by researchers. Not an idealised account, but a realistic one; not just the type of reasoning, but the type of equipment used; not just the finished product but the failures; and not just the idealised answer but the approximations and assumptions. The world of the industrial and academic scientist has not been used by textbooks.

All the above are observations and findings derived from the

historical approach adopted by this thesis. They are for the most part descriptions rather than explanations. What must now be done is see how successful the historical and rhetorical analysis has been in throwing light on the three central issues with which this thesis began. They are best considered in the same order of their presentation in the Introduction.

### 1. THE CHARACTERISTICS OF TEXTBOOK LANGUAGE

In the description and rationale for the method of analysis used in this thesis, the Introduction implied that there are two ways by which language can be characterised--one, by its structural components (its grammar, vocabulary, and syntax ), and two, by what the language can achieve. This thesis chose to focus on the latter, choosing three large scale features of textbook prose--purpose, explanation and instruction. These features can be used to characterise language when the textbook is considered as a whole prose work, or discourse. There is an interesting parallel between the concerns of science education either with what things are, or with what they can do. Science education too has generally placed a greater emphasis on the latter.

In this first section, each of the four types of textbook is characterised by its language and rhetorical structure. Purpose, it seems clear, will be more suited to examining the second issue of the development of these characteristics. For what the purposes of a textbook author are is more likely to be a function of the historical setting; how those purposes are met is a function of the language. The characteristics of this language combine to form a style, and stylistic characteristics

are also be included below. Since, however, these stylistic characteristics are not free from historical and traditional influences, they will be considered again in the later discussion of the development of textbook characteristics.

#### Language characteristics of the Catechetical Textbooks.

There are nine important characteristics identified by this study.

1. The structural characteristics of a Question and Answer format. This structure imposes significant constraints on what the language can do, and strongly shapes the characteristics which follow.
2. The predominance of short factual statements. These statements contain the information which form the bulk of the content of these texts. The majority of answers consist solely of these statements. They are not justified, but simply given.
3. The use of logical reasoning to connect general principles to particular instances. The combination of general principles and logical reasoning constitutes both explanation and instruction in these texts.
4. The use of definition as the major explanatory structure. This is a consequence of the question and answer format, as many questions are of the form "What is...?". By far the greater number of principles are introduced in this way, and subsequent questions elaborate their application to phenomena.
5. The presence of common phenomena and things of everyday life in the examples and as objects of study. This limits the amount of abstraction, and avoids the difficulty of referring to unfamiliar equipment and processes.

6. The presence of references to God. These were of three main types. Most commonly they were expressions of admiration for His wisdom and concern for man, as evidenced through His works. More rarely, they were appeals to ultimate explanation, with God as the creator of natural law. And even more rarely, Biblical passages were used to illustrate points made concerning phenomena.

7. The language contained no expectations about prior scientific knowledge. It was characterised by low levels of scientific complexity, and the expectation that the readers would not have laboratory experience.

8. The content analysis indicates that these texts contain a limited range of prose structures. They are also characterised by a small number of ways of instructing, containing no figurative language, models, demonstrations and so forth.

9. Their style is characterised by brevity, and a concern to be precise and clear in both definition and description. It is a very unadorned style.

Bringing together the classifications from all three Sections:

First order classification by purpose:

1. Catechetical, based on the whole-text characteristic of the Question and Answer format.
2. Purpose: to inform autodidactic readers, often under the belief that this format was modelling the best method of instruction found in schools.

Second order classification based on language:

1. Rhetorically. type: expository; style: genus humile (appropriate to thing).

2. Generically. genre of instruction.

3. Stylistically. seeks to be precise, concise, brief and unadorned; attempts to avoid figurative language, informal author/reader relations.

Third order classification based on rhetorical structure:

1. Explanations: characterised chiefly by stating facts or principles, and applying them to specific cases; no use of the laboratory.

2. Instructional language: characterised by simple telling, and the infrequent use of analogy; lack of figurative language; uses examples from the readers' world.

Language Characteristics of the Conversationalist Texts.

There are eight important characteristics identified by this study.

1. The use of a story format. This structure imposes constraints, particularly if reading comprehension and not science is the chief focus of the story.

2. The presence of a language of enquiry. As the story unfolds and the reader is led through the various explanations offered, there is a constant interchange of question, answer, instructing and demonstrating between the characters. This enquiry, however, is limited to the elaboration of concepts and principles rather than their empirical bases or theoretical justification.

3. The presence of unjustified statements of fact, usually stated by an authority figure, such as a father or governess. These are often given in answers to questions coming from the characters. They are then used as the explanations for common



phenomena.

4. The presence of appeals to logical argument and reasoning, used to link stated principles with objects under discussion. They are important for instructing, commonly resorted to when connections are needed between something just seen or demonstrated and some other particular event. They take place within discussion between characters, and are not impersonal.

5. The language is characterised by the constant presence of things and events of everyday experience. The language is therefore filled with references to familiar things, avoiding much abstraction and unfamiliar terminology. The non-technical vocabulary, simple level of story and lack of assumed background scientific knowledge are also characteristic.

6. There are a wide range of prose structures present. The language is composed of many possible ways of instructing, with the exception of direct laboratory experiences. It is common to find figurative language, models, demonstrations, directed observations, constructions and thought experiments in these stories.

7. The language is characterised by a level of explanation based on stated principles only. There are no references to God as the ultimate explanation, no mention of the type of explanation that is uniquely scientific. It remains at the low level, generally, of mentioning and elaborating properties of objects.

8. Their style is characterised by all the components of fictional literature. It is a style suited to the story format, paying little attention to traditional demands for a formal style of informational writing.

Bringing together the classifications from all three Sections:

First order classification by purpose:

1. Conversational, based on the characteristic of dialogue between characters, and also reflective of the presence of the traditional elements of story--plot, characters, setting.
2. Purpose: to use fictional story format to teach secular material to autodidactic readers, often under the belief that this was the best way to learn.

Second order classification by language:

1. Rhetorically. type: literary/descriptive; style: genus medium (appropriate to person).
2. Generically. genre of instruction.
3. Stylistically. seeks to use language in such a way as to be vivid, personal, true to matters of fact, and to suggest emotional as well as intellectual attitudes to information. Comprehension more important than information. Use of figurative language common, along with a wide range of individual authorial language.

Third order classification by rhetorical structure:

1. Explanations: characterised by both stating by authority or by finding out through enquiry; causal explanations dominate.
2. Instructional language: rich diversity of prose due to story format; many different types of instructional types present as a result; no use of the laboratory, but examples based on real-life situations.

Language Characteristics of the Experimentalist Texts.

There are eight important characteristics identified by this thesis.

1. The language is characterised by references to finding answers by testing ideas. Often this is in the laboratory, but it characterises investigations in such subjects as geology and astronomy, where laboratory work presents greater difficulty. The procedures and results of investigation form the bulk of the language. The language thus includes not only descriptions of equipment and the psychomotor skills of manipulation of apparatus, but also observation and measurement statements.

2. The explanations offered by the language are the results of empirical investigation whenever possible. Thus the general principles of science are argued to be derived from empirical investigation.

3. There is a characteristic language of enquiry. This results from the intention of the authors to lead the reader through the process of investigation. There is a constant interchange of question, answer and process of finding out. This interchange is the dominant form of the instruction.

4. The language of explanation is dominated by the search for causes. Thus the investigations are often searches for the causes of particular phenomena, which are then generalised into causal principles.

5. The language is characterised by a technical vocabulary. It is further removed from the everyday language of readers than either the Catechetical or Conversationalist texts, and contains scientific abstractions. It assumes access to a laboratory, or to laboratory demonstrations.

6. Logical conclusions are characterised usually as short statements. They form brief connecting links between investigations and general conclusions. Also, there are

indications in the language of the need to think logically when planning an investigation.

7. The language is characterised by a relative lack of reference to everyday things and events. The investigations are usually confined to laboratory objects, idealised physical objects, or general phenomena.

8. Their style is characterised by personal authorial voice, frequent use of enquiring language, concern for precision in method, description and argument, a non-linear rhetorical model, and the occasional use of figurative language.

Bringing together the classifications from all three Sections:

First order classification by purpose:

1. Experimentalist, based on the central role of experimentation in both science as a discipline, and in science education as the chief focus of study.
2. Purpose: to instruct the reader in the processes of enquiry which are uniquely scientific.

Second order classification by language:

1. Rhetorically. type: didactic/expository; style: genus humile (appropriate to person and to thing).
2. Generically. genre of instruction.
3. Stylistically. The authors role is that of guide, or teacher, thus allowing a more personal, informal style. The prose emphasises words and sentences that correspond to enquiry; e.g., questions, directions and demonstrations.

Third order classification by rhetorical structure:

1. Explanations: cause and effect, based on the laboratory; scientific method of enquiry central; use of inductive/deductive

explanations also present.

2. Instructional language: chiefly a language of enquiry, guiding the reader through laboratory experiences or logical reasoning; the scientists' world referred to far more often than the readers'.

#### Language Characteristics of the Formalist Texts.

There are nine important characteristics identified by this study.

1. The large number of statements of fact. The reader is told what is the case. They include statements of laws and principles, definitions, results of experimentation, conclusions to arguments, and listings of properties. Many of these are unjustified, or argued to be logically necessary.

2. A common characteristic of the language of instruction is the use of examples (either from everyday experience, or abstract, or mathematical) to support stated facts and principles. Thus a definition is often followed by several examples of the concept in application.

3. The language makes use of logical arguments to connect stated principles with particular phenomena. This is an important characteristic of explanation. Logical arguments are often used to investigate particular phenomena felt to be of significance (e.g., soap films are often rigorously investigated using mathematical and logical analysis).

4. The language is also characterised by the common use of abstractions, both conceptual (e.g., fields) and mathematical (e.g.,  $V = IR$ ). Accompanying these abstractions is a technical vocabulary.

5. Instructing is generally of one form: stating a principle, giving examples, and then solving numerical problems. An alternative form is to give a few examples, deduce a common principle, and then work numerical problems.

6. There is a lack of any language of enquiry. The reader is not led through the process of investigation, but is presented with results. Thus instruction is characterised by telling and logically arguing.

7. Explanations are based on the level of established laws. However, explanations are not commonly offered for phenomena; they are simply investigated for their properties. For example, it is very unusual for an explanation to be offered of why a metal bar expands on heating, but very common for elaborate calculations of coefficients of expansion to be given.

8. The language is characterised by a uniformly high level of expectation concerning the readers' ability to follow logical arguments, deal adequately with abstract concepts, and have a background of scientific knowledge.

9. Their style is formal. That is, characterised by distant authorial voice, precision, reduced context, limited syntax, and linear rhetorical model.

Bringing together the classifications from all three Sections:

First order classification by purpose:

1. Formalist, based on their characteristically formal language structure.
2. Purpose: to inform readers of the results and structure of scientific disciplines.

Second order classification by language:

1. Rhetorically. type: expository; style: genus humile (appropriate to thing).
2. Generically. genre of information.
3. Stylistically. distant authorial voice, linear rhetorical model, reduced context, limited syntax, and the concern for precision, conciseness and impersonal expression.

Third order classification by rhetorical structure:

1. Explanations: inductivist/deductivist; the laboratory plays a secondary. verificationist role; great deal of logical reasoning from first principles.
2. Instructional language: formal language stating conclusions, and detailing logical reasoning; examples drawn from both the scientists' world and the readers'.

All of the above characteristics have been identified through the type of analysis presented in this study. They have been chosen because they illustrate what the language can do, as well as its stylistic features.

## 2. THE ORIGIN AND DEVELOPMENT OF THOSE CHARACTERISTICS

This thesis uses the textbook as a mirror of science education. It can do so because the characteristics of textbooks can be shown to be linked to the purposes of their authors. Those purposes in turn are products of the authors' conceptions of the nature of science and science education, the constraints imposed by traditional patterns of writing and schooling, and to the changing form of science education in schools. The history of science education is a history of changing purposes, and of transitions between purposes being played out in schools.

The Catechetical textbooks were written with a clear set of four

purposes.

1. To act as a vehicle for the admiration of God. There was a concern among the writers of these texts that all secular knowledge be seen to reflect on divine revelation. Science was not necessarily seen to be in conflict with religion, and therefore it could be used for the purpose of supporting religious sentiments.

2. To bring the results of scientific endeavours to autodidactic readers. To have learned a collection of scientific information, or more often Natural History, was seen as an integral part of general learning, certainly not to be confined to the upper levels of education.

3. To provide simple explanations for common phenomena for readers not at school. This purpose was linked to that of showing that the world is ordered and understandable, a purpose important both to the social and religious moods of the early 19th century.

4. To provide the learner, as a future adult, with mental training and a groundwork for possible later interests in science.

It is then clear why these texts developed the characteristics identified above. Their purposes are not centred on an education in science, but in influencing the development of the reader in specific ways. Science was a peripheral concern useful in furthering those other purposes, whether the perpetuation of certain religious attitudes or the inclusion of scientific information in the general education of the young. The texts themselves originated from the format used in religious catechisms of instruction, and the felt need for



similar works on secular themes.

The Conversational Textbooks originated in the readers and spellers developed for teaching purposes, though not necessarily in schools. They were based on the premise that stories were the best medium for learning. They too had four clear purposes.

1. To develop reading comprehension. This purpose tended to dominate the writers' choice of vocabulary, structure, rhetoric and style.

2. To inform readers of scientific and technical principles through story form. This purpose influenced the writing of a large number of similar books on different topics by the same writers. Thus science was not seen as a unique type of knowledge.

3. To influence the readers' mental development. Scientific information could be used as the basis for logical argument and problem solving, of an admittedly low order, and thus improve mental ability,

4. To entertain while instructing. This purpose was based on educational presuppositions about enjoying while learning; that education could be made interesting and rewarding.

These purposes are also not centrally concerned with science education. It is therefore not surprising that questions regarding explanation, the role of the laboratory, or the nature of science are not raised in these texts.

The Experimentalist textbooks originate with the rise of science as an examinable school subject. These texts were written for

learners in school. They had two fundamentally important purposes.

1. To support a particular viewpoint of science teaching. The authors were intent on seeing their conception of science education become the dominant one, and their texts attempted to demonstrate the practical validity of that view. That the texts show the characteristics identified above is evidence of their real, if only partial, success.

2. To emphasise a view of Science as "...the Knowledge of the Laws of Nature obtained by Observation, Experiment and Reasoning." (Huxley, op. cit.) Science is seen to be a unique activity, and that uniqueness must be reflected in the way it is taught.

These two purposes only hint at the crucial nature of the debate over science education which took place around the turn of the century in Great Britain. Influential scientists were concerned to see their view of science--not only its methodology but also their optimism regarding its benefits for mankind--guide the establishment of school science at a time when the whole purpose of science education was uncertain. Was it to be "Science for All" or for the training of future scientists? Was it to be the "Science of Common Things" or laboratory science? Was it to be made available to all levels within the school system or only to the academically gifted in the senior school? Was it necessary to train science teachers in special ways? Was heurism or guided instruction to be the preferred method of instruction? What were the connections between science and the everyday world? All these questions were of immediate concern to the writers of these texts, as they clearly were not for the

Catechetical and Conversationalist authors.

The Formalist textbooks originated in the desire to present secular information to young readers. Well before schooling was compulsory or science education a recognised part of the curriculum, publishers had been printing collections of scientific information, or works of Natural History, in substantial numbers. With the rise of school science, these collections became adapted to school use, and formed the Formalist textbook. They developed into textbooks under the influence of four important purposes.

1. To act as collections or compendiums of scientific information. They contained the information the students were to master. This is clearly still an important purpose.
2. To match syllabus demands. These texts soon became supportive of established views of what needs to be known in order to satisfy examination demands. As a result, they no longer paid great attention to elaborating or defending a particular view of science as an activity.
3. To train future scientists and technologists. As science education came under political influence, the scientific manpower needs of society became central to the purposes of science education; these textbooks supported this role.
4. To discipline the mind. This purpose became expressed through the large number of abstractions, logical arguments and numerical problems that were meant to train the mind to logical, objective thought.

It is clear that these texts were also written to support a view of science teaching, as were the Experimentalist. This view

claimed to be pragmatically concerned with the realities of large classes of mixed ability, the lack of suitably trained science teachers, and the consequent impracticability of heuristic approaches. And their view of Science, that its method was only applicable to scientific problems, tended to support their emphasis on results rather than processes.

There is another very powerful influence on these Formalist textbooks that must not be overlooked in discussing their origins and development, and that is the question of style. This thesis has highlighted the effect the origins of the modern prose style--especially as championed by the Royal Society as early as 1660--has had on the writing of both fiction and non-fiction. The Formalist textbooks were (and are) written under the assumption that this 'Attic' style is the only one appropriate for the presentation of science to learners. This traditional assumption has constrained these authors just as surely as the Question and Answer, or story formats, of other textbook types. And if it is true that what they could do was limited by their choice of format, it must be equally true for the Formalists. One effect has been the stagnation of stylistic development in these texts for over 100 years, with a persistence in ways of presenting, arguing and instructing.

It is thus clearly possible to establish important connections between the characteristics of textbook language and the purposes of their authors. These in turn are influenced by, and revealing of, historical views of science and science education, the established traditions of language use, and the changing nature of school science.

### 3. VIEWS OF SCIENCE AND SCIENCE EDUCATION

It has been argued in this thesis that the purposes of the authors have been shaped by their views of science and science education, and that these in turn are reflected in the language of the text. It is assumed that authors use language that they feel is most appropriate for meeting their purposes, two of the most crucial of these being to inform and to instruct. The language, therefore, must satisfy three central criteria. One, it must be best suited, in the sense of helping to realise, the purpose(s) of the authors. Two, it must be appropriate to the nature of the scientific discipline itself, and in particular to its way of offering explanations. And third, it must be appropriate to the reader, particularly in performing the act of instruction. Before each of these is examined in turn, it is important to recall some of the assumptions with which this study began. Firstly, it is assumed that the readers of these texts are of average reading ability, so that the special problems of slow or disadvantaged readers are not considered here. Secondly, that authors write so as to be understood and to meet their purposes. And finally, that the authors do not expect the teachers, as part of their professional responsibilities, to act as interpreters of their textbooks. Teachers may indeed have a crucial role to play in introducing their students to the textbook genera, but not to decode textbooks.

#### 1. Language and Authorial Purpose

In considering the purposes of textbooks as identified above, it

becomes clear that these purposes have been artificially isolated from the textbook. The textbook itself is a blending of all these purposes into one coherent piece of prose. This piece of prose, when seen from the readers' point of view, has only two purposes--to inform and to instruct. All the other purposes which have influenced the writers in varied and complex ways are not revealed to the reader, though the resulting prose does indeed reflect those influences to the researcher.

Considering the purpose of informing first, the analysis presented in this thesis allows the following distinction, based on purposes, to be made. The Formalist and Catechetical textbooks are appropriate to informing readers about the results of scientific endeavour, with the Formalist achieving this purpose more fully than the Catechetical. They are both primarily concerned with information, but the Formalist text are much more informed on questions of sequence, logical argument, formal mathematical rigour, and consistent treatment of important concepts. The Experimentalist and Conversationalist texts, on the other hand, are appropriate to informing readers about the processes of science, with the Experimentalist better than the Conversationalist. Both are primarily concerned with guiding the reader through discussions of the ways in which things are found out, but the Experimentalists are much more rigorous in their use of laboratory observations and manipulations. Of course, in neither are the results of science neglected; rather, they play a secondary role. Science is much more the focus of the Experimentalist authors than the Conversationalists, and therefore likely to instruct readers in science far more ably than their stories could.

## 2. Language and Views of Science

As just seen, from the readers' point of view, the two purposes of a textbook are to inform and instruct the reader in science. Science is what the textbook is about, and what the reader is hopefully to learn. Clearly, in a school situation the reader is presented with the author's view of science without choice in the matter; similarly, the autodidactic reader is presented with a view of science without being able to reflect on its validity. Therefore, decisions on the correctness and validity of the authors' views must be made from the teachers' and educators' point of view. The question they must ask of the textbook is whether the authors' views are correct or acceptable, and whether the language is conveying and supporting those views. This thesis allows a discrimination to be made based on views of science. Given science to mean a formally structured collection of laws, principles and facts, then the Formalist textbooks reflect this view most appropriately, if implicitly rather than deliberately. It would be equally correct to say that they are most appropriate for transmitting such a view to readers.

On the other hand, if science is seen as a method of observation, experiment and reasoning, then the Experimentalist texts most clearly match this view, and are most appropriate for quite explicitly transmitting it to readers. Neither the Catechetical or Conversationalist texts are appropriate to either of these views of science, because science is not their chief concern. These two types may instead have an important role to play in developing an interest in natural history and science in their readers.

### 3. Language and Views of Science Education

In order to learn, the reader must be instructed. Therefore, in making decisions on this facet of textbook language, instruction takes precedence over informing. This thesis allows a discrimination to take place, this time between types of instructional language and the readers of that language.

For younger, inexperienced readers with little formal scientific background, the Conversationalist textbooks may be most appropriate. Genre theory suggests that such readers are not yet ready to leave the story genre and enter uninitiated into the genres of information and instruction. Also, there is no conclusive evidence that the formal style of the Formalist textbooks facilitates learning. And the laboratory world of the Experimentalists is possibly too far removed from the everyday world of the younger reader. The Conversationalist textbooks, too, are appropriate because of their greater variety of types of explaining. This is not to claim they are sufficient or exclusive--there is of course a place for laboratory experience as well. But taken as a piece of prose from which to learn science by reading, they are most suitable for these readers.

In addition, the Conversationalist authors saw science education as linked to the readers' world of everyday experience, promoting an enquiring attitude towards the substances and phenomena of the world. This attitude is an important part of science education for readers of any age or level of schooling. For older readers with some background in science, but for whom science is not necessarily seen as a career, the decision is not so clear. This thesis would indicate that if Conversationalist



textbooks were written for older readers, they would still be highly appropriate for learning science. Given that they do not in fact exist, it seems clear that the Experimentalist are the most appropriate, as a result of their enquiring language, informal style and range of ways of instructing. They are sometimes distant from the world of the reader, but their language makes them more appropriate to learning from reading than the others.

Their chief difficulty, of course, is confining their enquiry to the world of the laboratory to a great extent. Their view of science education, which admittedly does include training the mind in certain ways, emphasises the method of science with all its specialised techniques as the best way to learn science. Connections between those specialised methods and those of the readers' everyday world are not easily made.

For older, experienced readers with a strong science background and specialised interest in the subject beyond general science level, the decisions are again complex. In considering the language of the text, it is necessary to leave out of account all considerations of examination demands, views of what science is, or societal demands for a certain type of knowledge. When considered solely as prose which expresses a view of science education, the Formalist textbooks are seen as very concerned with learning the results of science. Their stylistic features may make them difficult to read and learn from, and their levels of argument over-emphasise logical reasoning and formal deductive structures. Their lack of a range of prose structures designed to instruct increases the difficulties a reader has with learning the content. Their disregard for the context in which

science operates creates unnecessary distance between the world of the reader and the world depicted in the textbook. Their inattention to explanation conveys only the vaguest impression to the reader of what constitutes the uniqueness of science. By relegating the laboratory to a secondary role, they do not make the important connection for the reader between the world of sense impressions as the way of gaining understanding in the everyday world, and the special features of empiricism in science.

It is in this area of instruction that the early Conversationalists were most successful, but unfortunately they never achieved a level of rigour and sophistication in either science or story to meet the needs of the readers considered here. The Catechetical textbooks fail to meet any measure of instruction beyond the low-level presentation of information. Only the Experimentalists, therefore, are left to be considered. Can they be considered as having a language suited to a view of science education which is appropriate for such readers? As prose from which to learn, they must be the most appropriate of the four types. Their level of sophistication is sufficient for both the readers and the subject. Their prose style is easier to read and learn from. They have a language of enquiry which guides the readers through the processes of enquiry in science. They ground their explanations at a level of empiricism closer to the world of the reader. They contain more structures used for instructing. They do not necessarily form close links between the everyday world of the reader and that of the science laboratory, but they do make more conscious efforts to show that Science is a form of common sense.

It is now possible to go some way towards providing a set of criteria with which to begin to define the "good textbook". In the language of classical rhetorical studies, such a textbook would be primarily 'appropriate to reader', providing for both informing and instruction. It will provide explanations appropriate to the nature of explanation in science, and it will make explicit the reasons why they are uniquely scientific. It will contain a language of enquiry that will assist the reader to follow arguments, make the crucial connections between the world and the textbook, and demonstrate the human and scientific purposes behind both statements and processes. It will contain as wide a range of prose structures for instructing as possible. It will not be bound by a tradition that insists that the language of science is necessarily the appropriate language of instruction. It will encourage a process of non-fictional literary criticism to improve text quality and induce writers of merit into the field. It will be as concerned with the needs of the reader as with examinations and societal influences. And, finally, it will be concerned to foster an interchange between reader and author that will encourage learning through reading, rather than confining its purpose to informing.

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## APPENDIX 1

## TEXTBOOK COLLECTION

The textbooks are catalogued chronologically because they form an historical collection. The listings are in the following form.

Author. Title. Publisher, Place of Publication, Number of Pages. (Rhetorical type; Year of first edition if known; Number of reprints)

1821

Joyce, J. Scientific Dialogues: Vol. II--Astronomy. Baldwin, Cradock, and Joy London, 252 pp. (Conversationalist)

1823

The Moss-House. William Darton, London, 163 pp. (Conversationalist)

1827

Mitchell, J. First Lines of Science. Thomas Tegg, London, 347 pp. (Formalist)

1828

Pinnock's Catechisms: Volumes 1 -- 10. 16th Edition. G.B. Whittaker, London. (Catechetical)

1830

Lardner, D. The Cabinet Cyclopaedia: Natural Philosophy--Mechanics. Longman, Rees, Orme, Brown, and Green, London, 342 pp. (Formalist)

1832

Turner, R. Introduction to the Arts and Sciences. 20th Edition. Longmans, London, 348 pp. (Catechetical)

1833

Joyce, J. Scientific Dialogues: Intended as an Easy Introduction to Natural and Experimental Philosophy. W. Nicholson, London, 386 pp. (Conversationalist)

1835

Taylor, J. The Forest; or, Rambles in the Woodland. 3rd Edition. John Harris, London, 228 pp. (Conversationalist)

1836

Wesley, J. A Compendium of Natural Philosophy, being a Survey of the Wisdom of God in the Creation, in three volumes. Thomas Tegg, London. (Formalist)

1837

Chambers, W. Natural Philosophy: Laws of Matter and Motion. W.

and R. Chambers, London, 72 pp. (Formalist)  
Peter Parley's Wonders of the Earth, Sea and Sky. Darton and Co., London, 168 pp. (Conversationalist)

1839

Peter Parley's Tales About Plants. Thomas Tegg, London, 500 pp. (Conversationalist)

1842

Reid, H. Elements of Astronomy. Oliver and Boyd, Edinburgh, 165 pp. (Formalist)

1846

Dick, T. The Christian Philosopher; or, The Connection of Science and Philosophy with Religion. 10th Edition. W. Collins, London, 333 pp. (Formalist; 1824)  
Joyce, J. Scientific Dialogues. Henry G. Bohn, London, 565 pp. (Conversationalist)

1848

Patterson, R. Introduction to Zoology for the Use of Schools. Simms and M'Intyre, London, 198 pp. (Formalist; 1846)

1849

First Steps in General Knowledge: Part IV--The Vegetable Kingdom. Society for Promoting Christian Knowledge, London, 187 pp. (Conversationalist)

1850

British Fish and Fisheries. The Religious Tract Society, London, 192 pp. (Formalist)

1851

Dick, T. The Telescope and Microscope. The Religious Tract Society, London, 192 pp. (Formalist)

1852

Bland J. Grandpa's Tales About Animals. Milner and Sowerby, Halifax, 160 pp. (Conversationalist)

1855

Brewer, Dr. A Guide to the Scientific Knowledge of Things Familiar. Jarrold and Sons, London, 488 pp. (Catechetical)  
Rollo's Philosophy: Air, Fire, Museum, Sky, Water. Phillips, Sampson and Co., Boston. (Conversationalist)

1856

Chambers, W. and Chambers, R. Introduction to the Sciences. W. and R. Chambers, London, 136 pp. (Formalist)  
Owens, J. The Stepping Stones to Natural History. Longmans, London, 198 pp. (Catechetical)

1857

Girtin, T.C. The House I Live In. J.W. Parker, London, 224 pp. (Conversationalist/Monologue)



1858  
Herb of the Field. Mozley, London, 288 pp.  
 (Conversationalist/Monologue)

1860  
 Chambers, W. and Chambers, R. Natural Philosophy: Laws of Matter and Motion. W. and R. Chambers, London, 66 pp.  
 (Formalist)  
 Pepper, J.H. The Boys' Book of Science. George Routledge, London, 506 pp. (Formalist)

1861  
 Lee, R. Anecdotes of the Habits and Instincts of Birds, Reptiles and Fishes. Griffin and Farran, London, 336 pp.  
 (Conversationalist/Monologue)

1862  
 Austin, J.H. The Philosophy of the Earth. Daily Journal, Newcastle, 83 pp. (Formalist)

1870  
 Buckmaster, J.C. and Willis, J.J. The Elementary Principles of Scientific Agriculture. Longmans, London, 199 pp. (Formalist)  
 Tomlinson, C. First Steps in General Knowledge: Part 1--The Starry Heavens. Society for Promoting Christian Knowledge, London, 161 pp. (Conversationalist)

1871  
 Newton, R. Nature's Mighty Wonders. Partridge, London, 185 pp.  
 (Conversationalist/Monologue)  
 Proctor, R.A. Lessons in Elementary Astronomy. Cassell, Petter and Galpin, London, 127 pp. (Formalist)

1872  
 Anderson, William (Ed). Glimpses of Nature, Science, and Art for the Young. Gall and Inglis, Edinburgh, 250 pp.  
 (Formalist)  
The Earth, and its Garment of Water and Air. Jarrold and Sons, London, 212 pp. (Formalist)

1873  
 Balfour, J.H. Second Book of Botany. William Collins, London, 140 pp. (Formalist)  
 Wilson, A. Elements of Zoology. A. and C. Black, Edinburgh, 634 pp. (Formalist)

1874  
 Buckmaster, J.C. The Elements of Inorganic Chemistry. 11th Edition. Longmans, London, 201 pp. (Formalist)  
 Pink, W. and Webster, G. A Course of Analytical Chemistry. Lockwood, London, 180 pp. (Formalist)  
 Roscoe, H.E. Chemistry. Macmillan, London, 104 pp.  
 (Experimentalist; 1872; 32 reprints to 1913)

1876

Odling, W. A Course of Practical Chemistry. 5th Edition. Longmans, London, 262 pp. (Formalist; 1860)  
 Plummer, J.I. Introduction to Astronomy. William Collins, London, 174 pp. (Formalist)

1877

Griffin, J.J. Chemical Handicraft. 2nd Edition. Griffin, London, 479 pp. (Formalist; 1866)

1879

Mackay, A. Physiography and Physical Geography. William Blackwood, Edinburgh, 158 pp. (Formalist)

1880

Chambers, W. Miscellaneous Questions in Science, Literature, Arts, Etc., with Answers. W. and R. Chambers, London, 209 pp. (Catechetical)  
 Clarke, L.L. Objects for the Microscope. 6th Edition. Groombridge and Sons, London, 230 pp. (Formalist)  
 Galbraith, J.A. and Haughton, S. Manual of Hydrostatics. 3rd Edition. Cassell, Petter, and Galpin, London, 105 pp. (Formalist)  
 Lees, W. Acoustics, Light, and Heat. William Collins, London, 299 pp. (Formalist)

1881

Henslow, G. Botany for Children. 3rd Edition. Edward Stanford, London, 103 pp. (Formalist)  
 Reynolds, J.E. Experimental Chemistry for Junior Students: Part I--Introductory. Longmans, London, 144 pp. (Formalist)

1882

Half Hours in the Tiny World. William Isbister, London, 311 pp. (Formalist/Monologue)  
 Reynolds, J.E. Experimental Chemistry for Junior Students: Part II--Non-metals. Longmans, London, 279 pp. (Formalist)

1884

Baker, W.G. Magnetism and Electricity. Blackie and Son, London, 144 pp. (Formalist)  
 Buckley, A.B. Life and Her Children: Glimpses of Animal Life. Edward Stanford, London, 312 pp. (Conversationalist/Monologue)  
 Geikie, A. Geology. Macmillan, London, 154 pp. (Experimentalist; 1873; 20 reprints to 1931)

1885

Gaussen, L. The World's Birthday. Nelson, London, 270 pp. (Formalist/Monologue)  
 Murche, V.T. Elementary Botany for Beginners. Blackie and Sons, London, 234 pp. (Formalist)  
Pictures and Stories of Natural History: Wild Animals. T. Nelson, London, 90 pp. (Conversationalist)

1887

Bert, P. First Year of Scientific Knowledge. 5th Edition. Relfe Brothers, London, 344 pp. (Conversationalist/Monologue)  
 Roscoe, H. Lessons in Elementary Chemistry. Macmillan, London, 459 pp. (Formalist; 1885)  
 Thome, O. and Bennett, A.W. Textbook of Structural and Physiological Botany. 6th Edition. Longmans, London, 480 pp. (Formalist; 1869)

1888

Irving, A. A Short Manual of Heat. 6th Edition. Longmans, London, 128 pp. (Formalist; 1878)

1889

Edmonds, H. Elementary Botany: Theoretical and Practical. Longmans, London, 213 pp. (Formalist; 1882)  
 Huxley, T.H. and Martin, H.N. A Course of Elementary Instruction in Practical Biology. 2nd Edition. Macmillan, London, 512 pp. (Formalist; 1875; 14 reprints)  
 Ripper, W. Steam. Longmans, London, 202 pp. (Formalist)  
 Woods, J.G. Half Hours With a Naturalist. Charles Burnet, London, 340 pp. (Conversationalist/Monologue)

1891

Huxley, T.H. Physiography. Macmillan, London, 384 pp. (Formalist; 1877; 15 reprints)  
 Stewart, B. Physics. Macmillan, London, 170 pp. (Experimentalist; 1872; 19 reprints)  
 Webb, H.J. Elementary Agriculture. Longmans, London, 196 pp. (Formalist)

1892

Marshall, A.M. A Junior Course of Practical Zoology. 3rd Edition. Smith, Elder and Co., London, 478 pp. (Formalist; 1886)  
 Poyser, A. Magnetism and Electricity. 5th Edition. Longmans, London, 255 pp. (Formalist; 1889)

1895

Bastin, E.S. Laboratory Exercises in Botany. W.B. Saunders, Philadelphia, 540 pp. (Formalist)  
 Oliver, J.W. Elementary Botany. 5th Edition. Blackie and Son, London, 208 pp. (Formalist; 1890)

1896

Wood, J.G. Common Objects of the Microscope. G. Routledge, London, 188 pp. (Formalist)  
 Edmonds, H. Elementary Botany. Longmans, London, 241 pp. (Formalist; 1894)

1897

Mill, H.R. The Realm of Nature: An Outline of Physiography. Murray, London, 369 pp. (Formalist; 1892)

1898

Grieve, W.H. Lessons in Elementary Mechanics. Longmans,

London, 156 pp. (Experimentalist/Formalist transitional; 1888)

#### 1900

Dobbin, L. and Walker, J. Chemical Theory for Beginners. Macmillan, London, 240 pp. (Formalist; 1892; 3 reprints)  
 Hackwood, F.W. Chatty Object Lessons in Natural Knowledge for Standard 1. Longmans, London, 106 pp. (Conversationalist)  
 Jones, D.E. Examples in Physics. 2nd Edition. Macmillan, London, 348 pp. (Formalist; 1888; 4 reprints)  
 Lodge, O.J. Elementary Mechanics. W. and R. Chambers, London, 308 pp. (Formalist; 1896)  
 Roscoe, H. and Lunt, J. Inorganic Chemistry for Beginners. Macmillan, London, 254 pp. (Experimentalist; 1893; 6 reprints)

#### 1901

Pilley, J.J. Chemistry of Common Objects. 3rd Edition. G. Gill, London, 336 pp. (Formalist; 1892)  
 Thompson, S.P. Elementary Lessons in Electricity and Magnetism. Macmillan, London, 626 pp. (Formalist; 1881; 23 reprints)

#### 1902

Foster, M. Physiology. Macmillan, London, 132 pp. (Experimentalist; 1874; 17 reprints)  
 Huxley, T.H. Introductory. Macmillan, London, 94 pp. (Experimentalist; 1880; 10 reprints)  
 Huxley, T.H. Lessons in Elementary Physiology. 5th Edition. Macmillan, London, 611 pp. (Formalist; 1866; 27 reprints)  
 Troeger, J.W. and Troeger, E.B. Harold's Discussions: Part V. D. Appleton, New York, 298 pp. (Formalist/Monologue)

#### 1903

Bailey, L.H. Botany: An Elementary Text for Schools. 5th Edition. Macmillan, New York, 355 pp. (Formalist; 1900; 4 reprints)  
 Hawkins, C.C. and Wallis, F. The Dynamo. 3rd Edition. Whittaker, London, 925 pp. (Formalist)  
 Thornton, J. Elementary Biology. 2nd Edition. Longmans, London, 274 pp. (Formalist)

#### 1904

Gillies, W. First Studies in Insect Life in Australasia. 2nd Edition. Whitcombe and Tombs, Melbourne, 178 pp. (Conversationalist/Monologue)  
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