Evaluating the language of different types of explanations in junior high school science texts

Dr. Len Unsworth,
Faculty of Education,
University of Sydney, Sydney, 2006, AUSTRALIA.
email: l.unsworth@edfac.usyd.edu.au

Evaluating the language of different types of explanations in junior high school science texts

Abstract

Since 'it is written texts - and the talk around them - that provide the discursive means for the development of the 'higher mental functions' (Wells 1994), the quality of writing and explicit use of texts in teaching warrant close attention. This is not to diminish the importance of 'hands on' investigations, observation and negotiation of understanding through talk. However, the complementary use of effective texts has a significant role. This article demonstrates how functional language analyses differentiate explanation types and specify language features relevant to the effectiveness of texts in apprenticing students to the language forms of scientific English. Key differences between different types of explanations are illustrated, then sample text analyses show how language features index variation in explanation quality. Implications are drawn for the selection and use of texts and the role of knowledge about language in teaching critical comprehension and composition of science explanations.

Evaluating the language of different types of explanations in junior high school science texts

Introduction

Explaining is obviously central to science education and, as well as studies of explanatory strategies such as analogy (Treagust *et al.* 1992, 1996, Dagher 1995), research has addressed different explanation types and problematic aspects of teachers' classroom explanations (Martin 1972, Dagher and Cossman 1992, Nott and Smith 1995). Echoing earlier concerns about the inconsistent conceptualisation of explanation in science teaching and science texts (Horwood 1988) and the need 'to teach explicitly about the different forms of explanation' (Solomon 1986), Gilbert *et al.* (1998a, 1998b) developed a typology of explanations and emphasised that

> Students will be able to generate explanations which meet their own needs from the explanations with which they are provided only if they know what an explanation is (Gilbert *et al.* 1998b:194).

However, to date 'relatively few studies of explanation per se have actually been carried out in science classrooms' (Gilbert *et al.* 1998b:190). Some studies have investigated the oral language of teachers' classroom explanations (Lemke 1990, Ogborn *et al.* 1996), but scant attention has been paid to the nature and use of explanations in science books. This may, in part, be due to the very slight use made of science books in classroom teaching as indicated by Ogborn et al (1996:142). Ogborn and his colleagues acknowledged the importance of 'looking at the ways in which books and material from books play a role in explanation', but did not pursue this line in their study. It is, of course, important from a number of perspectives that this line of investigation is pursued. Part of knowing what an explanation is involves knowing how the resources of language (and images) are used to construct different types of explanations.

The development of students' science learning throughout their schooling entails a gradual apprenticeship to the characteristic language structures of scientific English (Lemke 1989, 1990, Halliday 1993a). These extend well beyond the obvious issue of technical vocabulary to include distinctive grammatical forms that characterise written rather than spoken language (Lemke 1990, Halliday 1993a). As Martin and Halliday have shown, these distinctive forms are crucial in actually constructing scientific understanding rather than simply expressing it, and hence cannot simply be replaced by more familiar grammatical patterns of everyday language use (Martin 1993a, 1993b, 1993c, Halliday 1993a). However, the language experience of many students does not include a strong orientation to these 'written' grammatical forms and so explicit pedagogic support is required in developing students' familiarity with them (Lemke 1990, Wells 1994).

The significance of this kind of explicit teaching in the context of students' engagement with written texts in curriculum area learning, has been particularly emphasised by Wells (1994: 81-82):

> Through engaging with written texts in relation to the topics that they study in school, therefore, children gradually reconstitute their lexicogrammar in the more abstract written mode....
>
> Thus, in learning to reconstrue experience in terms of the semantic structures of written language, children construct what Vygotsky refers to as 'scientific concepts'. That is to say, it is written texts - and the talk about them - that provide the discursive means for the development of the 'higher mental functions'...

Wells goes on to argue that 'the reorganisation of the grammar and the concomitant reconstrual of experience that is required in order to use written text as a tool for thinking

and communicating does not occur spontaneously for most children' (Wells 1994: 82). Hence developing students' knowledge and understanding in school science, and developing their knowledge of the language forms that construct and communicate that understanding, is one and the same thing. Whilst the importance of 'hands on' investigative work, observation and negotiation of understanding through associated talk, cannot be underestimated in science teaching, it is also clear, according to Wells, that effective use of science texts and the development of students' writing have a very significant role. The quality of the writing in science textbooks in terms of supporting students in 'gradually reconstituting their lexicogrammar in the more abstract written mode' is therefore a crucial factor in enhancing science teaching.

This paper is concerned with the quality of written texts students encounter in junior high school science. Its focus is on explanatory texts. The intention is to show how a comparison of the language features of these explanations can indicate their relative quality as 'apprenticing' texts to the language of scientific English. It is further intended to indicate how knowledge about these language features can be used as a practical resource for teaching and learning about written explanations. Firstly, we need to show that different types of written explanation in school science each have their characteristic language features. Then we can compare the language of different examples of the same explanation type dealing with the same phenomenon and intended for students at the same level of schooling. To do this we will use material derived from an extensive study (Unsworth 1996) in which a large sample of texts was analysed using concepts from systemic functional

linguistics (Halliday 1994a, Martin 1992, Matthiessen 1995). Three aspects of the language analyses in the original study are used here.

- The first level of analysis, based on 'genre' theory (Martin 1992, 1997), identifies the functional stages in the complete text of the explanation. This involves specifying the part played by each text segment in the overall explanation.

- The second level of analysis is concerned with the ways in which the reasoning in the explanation is achieved through conjunctive relations. This involves, for example, the use of temporal and causal conjunctions like 'as', 'when', 'so' and 'hence' as well as phrases like 'at the same time' and 'due to this'.

- The third level of analysis examines the nature and extent to which written explanations use noun forms derived from verbs to "nominalise" events and relations, for example "The rapid movement of the particles..." instead of "The particles moved rapidly..."

In the next section I will briefly describe each of these three analyses, indicating their significance for explicating the characteristic nature of the language of school science explanations. The subsequent three sections of the paper will apply each level of analysis to explanations of how coal is formed and how sound travels. In each section I will show how the particular analysis distinguishes these examples as different types of explanation, then I will compare two explanations of the same topic, evaluating the relative effectiveness of the textual features under consideration. On the basis of the analysis described in each section I will outline some practical implications for classroom work with explanatory texts.

Analysing the language of science explanations

Genre or text type and schematic structure

The explanation is a genre or text type that can be distinguished from other genres or text types (e.g. 'report'; 'procedure'; 'exposition') by the characteristic functional stages constituted by successive segments of the text. Martin (1992, 1997) has referred to these functional stages as the text's 'schematic structure'. The schematic structure of a procedure, for example, includes the stages Goal, Materials and Steps (by convention in systemic functional linguistics functional parts of any structure are given an initial capital letter), while the schematic structure of an exposition includes the stages of Thesis, Arguments, and Reiteration of Thesis. Early descriptions of explanation texts indicated the stages of schematic structure as Phenomenon Identification and Implication Sequences. However, it soon became clear that in order to account for the characteristic language forms of different types of explanations, an elaborated account of the stages of schematic structure was necessary (Unsworth 1996, Veel 1997, 1998). In the subsequent section of this paper I will provide such an elaborated account for the 'coal' and 'sound' explanations. I will also suggest that once teachers and students become aware of the typical and distinctive schematic structuring of different types of explanation, this meta textual knowledge can be a productive resource in critically reading and effectively producing such explanations.

Reasoning and the deployment of conjunctive relations

The types of conjunctive relations identified, the notational conventions used, and an example of each of the types of conjunctive relation are shown in table 1. These categories and examples from Unsworth (1996) are based on the account of conjunctive relations in Martin (1992).

[insert table 1 about here]

Conjunctive relations are sometimes implicit. This occurs when the meanings unambiguously include a logical relation, of sequence or causality for example, but the writer has chosen not to make this explicit in the language. This is illustrated in the following example where the temporal relation of simultaneity between the first clause and the second clause is made explicit by the conjunction 'as', but the relation of temporal succession between clauses two and three remains implicit. It would, of course, be possible to make the temporal succession explicit by inserting 'then' at the beginning of clause three:

1 As the object moves to the right

2 it pushes or compresses the air particles next to it.

3 The compressed air particles push on the particles to their right...

(Chapman *et al*. 1989: 281)

One additional dimension to conjunctive relations is that they may refer to external (material world) logical relations, or to the writer's internal (rhetorical) organization of the text. You can see this is the following constructed examples:

Example 1:

Coal is formed from the remains of plant material buried for millions of years. <u>First</u> the plant material turns into peat. <u>Next</u> the peat turns into brown coal. <u>Finally</u> the brown coal turns into black coal.

Example 2:

Coal cannot be relied upon as an energy source for the future. <u>First</u> the burning of coal is highly polluting. <u>Next</u> the world's supplies are finite. <u>Finally</u> the extraction of coal is becoming more and more expensive.

In Example 1 the underlined words refer to the unfolding of the events in real time, so to the temporal sequencing of the formation of black coal. However, in Example 2, the same underlined words refer not to temporal sequence, but to the writer's rhetorical organization of the information: 'First' is 'first in the sequence in which I choose to write', 'next' is 'what I have chosen to write next' etc. When conjunctions are used to relate sentences in this way we refer to the relation as <u>internal</u> conjunction.

Consequential relations can also be external or internal. In the following constructed example the cause/effect relationship is between events in the material world and 'so' expresses an external conjunctive relation:

The plant remains were covered with water containing very little oxygen, <u>so</u> they did not rot.

9

However, the nature of the cause/effect relation is quite different when the following clause occurs at the end of an explanation of how coal is formed:

Thus coal is merely carbonized plant remains (Chapman *et al*. 1989:127).

Here the consequential relation is internal. The writer's use of 'thus' expresses a rhetorical cause/effect relation. This sentence could be glossed as: "Because of the foregoing explanation of coal formation you can now accept the proposition that coal is carbonized plant remains."

Nominalisation: Grammaticalizing events and relations as 'things'

The third analysis deals with a grammatical feature that is clearly indexical of the difference between the grammar of written text (especially technical texts) and the grammar of spoken language (especially everyday talk). This feature is known as 'grammatical metaphor' and involves

...a substitution of one grammatical class, or one grammatical structure by another; for example, *his departure* instead of *he departed*. Here the words (lexical items) are the same; what has changed is their place in the grammar. Instead of the pronoun *he* + verb *departed*, functioning as Actor + Process in a clause, we have determiner *his* + noun *departure*, functioning as Deictic + Thing in a nominal group (Halliday 1993: 79).

The functionality of grammatical metaphor in scientific English has been well established by Halliday (1993b) and Martin (1993a, 1993c). Martin (1993a) for example, shows how this is a key resource in constructing technicality:

| The process of conversion of food in the stomach and bowels to be used by the body | is called | digestion |

In this example the meanings to be 'compacted' and 'distilled' must be in a nominalised form ('The process of conversion...') so that they can be grammatically equated with the nominal form of the single technical term ('digestion').

As well as facilitating the construction of technicality, grammatical metaphor is also functional in the development of a chain of reasoning. In order to lead on to the next step, it is useful to be able to summarise what has gone before as the point of departure. Halliday (1993:131) illustrates the simplest form of this:

...both ethyne and nitrogen oxide are kinetically stable ...

The kinetic stability of nitrogen oxide shows...

The noun group (nitrogen oxide) + verb (are) + the adverbally modified adjective (kinetically stable), forming a clause structure, are compacted into a single noun group ('The kinetic stability of nitrogen oxide') as the starting point for the next clause. This involves turning the adjective 'stable' into the noun 'stability' and hence using grammatical metaphor to create an abstract 'thing' in order to be able to progress in the explanation.

Grammatical metaphor also occurs when a verb ('results in') or a noun ('the result') substitutes for a conjunction (because). For example, instead of 'He failed because he was lazy', this could be expressed metaphorically as 'His failure was the result of his laziness' or 'His laziness resulted in his failure'. So in a science text we may have, 'The effect of the

11

addition of lubricant was a decrease in friction' instead of 'Lubricant was added, <u>so</u> the friction was reduced.'

Genre analysis: Different types of explanation with distinctive text structures

In this section I will first compare the schematic structure of explanations of coal formation with the structure of explanations of how sound travels. I will then evaluate two examples of explanations of coal formation and two examples of explanations of sound waves, indicating the implications of these textual evaluations for teaching practice.

Figure 1 shows the schematic structure of Coal Text 1 (DeVreeze *et al*. 1992:131).

[insert figure 1 about here]

The schematic structure for written explanations of how sound travels is exemplified using Sound Text 1 (Chapman *et al*. 1989: 280-281) in figure 2.

[insert figure 2 about here]

The possible schematic structures for explanations of coal formation and sound travel are compared in figure 3 (There is no Phenomenon Contextualisation Coal Text 1, but it does occur in Coal Text 2 (see figure 4)). Two layers of staging are indicated. The first layer is in upper case and the second in lower case with initial capitalisation. Iterative elements are

indicated by the superscript n; optional elements by parentheses (...); and the caret $\wedge$ indicates that the subsequent element must follow the preceding element.

[insert figure 3 about here]

It can be seen that both types of explanations have some elements of schematic structure in common, however some clear differences are also evident. For example, no instances of PHENOMENON EXEMPLIFICATION and no use of Analogic Accounts within the ORIENTATION were found in the explanations of coal formation surveyed as part of a major study of explanations in primary/elementary and junior high school science books (Unsworth 1996). Nor have any instances of these stages of schematic structure been found subsequently in informal observations by the author of textbook explanations of coal formation used in classroom work. Correspondingly, none of the textbook explanations of sound waves encountered (Unsworth 1996) have used a Phenomenon Contextualisation or Explanation Summary in their ORIENTATION.

Even at this stage of analysis there are immediate implications for developing students' comprehension and composition of different types of written explanation. Students can be taught explicitly that in negotiating explanations like 'how sound travels' the common practice is to make strategic use of analogy and a specific, concrete exemplar of the phenomenon. On the other hand with 'sequential' explanations like 'how coal is formed' common practice is the use of an Explanation Summary stage in the schematic structure. When reading, this Explanation Summary is likely to preview the development of the IMPLICATION SEQUENCES and can be used to predict the elements of this stage in the

explanation. When writing, students can be taught to formulate an Explanation Summary as a plan or overview of the IMPLICATION SEQUENCES they will then construct. Familiarity with the functions of the stages of written explanations can also be used to promote critical literacy. For example, students could discuss the value position that is taken in Phenomenon Contextualizations like ' Coal is another very important biochemical sedimentary rock' (Chapman *et al.* 1989:127) compared with 'Coal deposits are very common in many areas of Australia' (Heffernan and Learmonth 1990a: 70).

Once we know how schematic structure varies across explanation types, it is useful to explore the variation of schematic structure within an explanation type in texts dealing with the same phenomena. We can then use these comparisons to begin to specify differences in explanation quality. The schematic structures of Coal Text 1 (DeVreeze *et al.* 1992:131) and Coal Text 2 (Heffernan and Learmonth 1990:70) are compared in figure 4.

[insert figure 4 about here]

The main difference is that the second text does not include an Explanation Summary in its ORIENTATION and also does not include the Trigger in its IMPLICATION SEQUENCES. The consequence of the latter omission is that agency is not specified in the events in the subsequent Transformation elements of the IMPLICATION SEQUENCES, so a key aspect of what causes coal to form is not dealt with.

14

As well as providing a starting point in evaluating explanatory texts, the stages of schematic structure can be further deployed directly in classroom work. Students can be given a schematic structure template with the text of some stages omitted and be asked to construct the missing information. Groups can be given templates with different stages omitted. The members of each group can collaborate on the construction of their assigned stage and then 'regroup' so that the new groups have some members of original groups assigned to each of the omitted stages. Members of these new groups then discuss their efforts. Templates can also be used for student comparison of explanations of coal formation and discussion of issues such as:

- Which stages can be omitted and which cannot?

- How do texts vary in their expression of the content of particular stages?

- How can the transformation stages be 'collapsed'?

The schematic structures of Sound Text 1 (Chapman *et al.* 1989: 280-281) and Sound Text 2 (Heffernan and Learmonth 1990b: 145) are compared in figure 5.

[insert figure 5 about here]

The schematic structure of the second text differs from that of the first in that Sound Text 2 does not include an Analogic Account in its ORIENTATION stage and does not include any Extension, Generalisation or Application in its CLOSURE stage. Although these stages are not essential elements in the schematic structure of explanations of sound waves, the inclusion of the Analogic Account in the first text is part of a strategy of gradually moving the reader from a commonsense to a more technical account of how sound travels. At the

15

same time this strategy introduces, in the context of more familiar events, the nominalised forms of language that will ultimately be necessary for this technical account.

An important function of the Analogic Account in Sound Text 1 is the bridging between nominalised grammar and more everyday forms. In the Analogic Account (extending from clauses 05-14) the nominalised forms of the Agent ('Vibrating materials') and the object ('sound waves') in clause 05 are to be reformulated as the more iconic subject + verb + object structures in the subsequent clauses.

05   Vibrating materials send sound waves through the air.

06   As the materials vibrate

07   they disturb the air particles near them.

08   These air particles disturb other air particles and so on.

09   Just like a long chain or dominoes, the disturbance or sound wave is passed on from air particle to air particle.

10   Unlike the dominoes, the air particles spring back to their original position.

11   Sound waves travel through gases, liquids and solids

12   because they all contain particles [[which will carry or transmit disturbances]].

13   However, sound waves will not travel through a vacuum

13.1 which is an empty space:

14   without particles [[to transmit the disturbance from a vibrating object]], sound waves cannot be formed.

Here we are introduced to the kind of 'unpacking' of grammatical metaphor that will be used in the more technical account in the IMPLICATION SEQUENCES . In this Analogic Account stage the nominalisation as Agent in clause 05 is unpacked as clause 06 -

16

05 Vibrating materials ⟶ 06 As the materials vibrate

Then we have an invisible technical event in which 'the materials' from clause 06 becomes the Agent acting upon air particles:

07 they disturb the air particles near them.

and the 'air particles' which are acted upon in clause 07 become the Agent in the next clause:

08 These air particles disturb other air particles and so on.

These events are then nominalised (disturb → the disturbance). So actual events are made into virtual things in the language by being expressed in this nominalised form. It is in this grammatically metaphorical form that they act as participants in a macro event at a higher level of abstraction:

09 ...... the disturbance or sound wave is passed on .....
12 ....which (particles) will carry or transmit disturbances.

We can see then that the changes in language form in the Analogic Account (unpacking the initial nominalised form to the subject + verb + object structures, and then turning these back into the nominalisation 'disturbance'), is a foreshadowing of the deployment of these resources in the next more technical treatment of the process, which will follow in the IMPLICATION SEQUENCES. In this stage the shift to grammatical metaphor involves the use of the technical descriptions (compress → compression) for which the non-technical nominalisation (disturb → the disturbance) in the Analogic Account was preparatory.

What is being provided here at the level of genre is a sequence of 'advance organisers' to scaffold the progressive increase in technicality. These 'graduated shifts' from the more familiar commonsense perspectives towards a more systematic scientific view are not matched in Sound Text 2, where, within the IMPLICATION SEQUENCES, there is more of a 'melding' of commonsense and scientific orientations through selection of commonsense vocabulary ('slightly squashed together air') and the use of (frequently anthropomorphic) images like 'crowding against and bashing into their neighbours'.

Again, a schematic structure template can be used as a scaffold for students to rework explanations such as Sound Text 2, including an Analogic Account and obviating the need for anthropomorphic metaphors in the main explanation. It would be useful for high school students to undertake some reworking of explanations of sound waves in information books for younger children. In many of these texts there is no PHENOMENON EXEMPLIFICATION stage, which results in an inadequate explanatory text (Unsworth 1996).

The language of reasoning: comparing the use of conjunctive relations

<u>Distinctive patterns of reasoning in different explanation types</u>

The deployment of conjunctive relations in the explanation of coal formation is shown in figure 6. Internal conjunction is indicated on the left-hand side of the text and external conjunction on the right-hand side.

[insert figure 6 about here]

It can be seen in figure 6 that internal conjunction in the coal explanation is minimal. The only occurrence is internal reformulation linking the Explanation Summary to the IMPLICATION SEQUENCES. The text is then organized by external temporal:successive relations linking each stage of schematic structure (Conditions, Trigger and Transformations).

The major difference in conjunctive relations between Coal Text 1 and Coal Text 2 is the lack of the internal reformulation due to the fact that there is no Explanation Summary in the latter text. Apart from this, these texts exemplify the common pattern of conjunctive relations constructing reasoning and scaffolding schematic structure across what can be called 'sequential' explanatory texts. These sequentially organized explanations are characterised by external temporal relations linking elements of schematic structure in the IMPLICATION SEQUENCES stage, and if external consequential relations do occur, they occur within and not between elements of schematic structure. This reflects the simple serial structure of the sequential explanation as indicated in figure 7.

19

[insert figure 7 about here]

The deployment of conjunctive relations in the explanation of how sound travels is shown in figure 8.

[insert figure 8 about here]

In contrast to the coal text (figure 6), it can be seen in figure 8 that internal conjunction is a major feature in the explanation of sound waves. Here there is a kind of 'sandwich' structure of internal reformulation (i.e.) and internal consequence (Thus) relating the IMPLICATION SEQUENCES as simultaneously the reformulation of the Phenomenon Exemplification and the rhetorical means for the Conclusion. Internal consequence is also used both in linking elements within the IMPLICATION SEQUENCES and linking events within those elements. These internal conjunctive relations have a major role because the explanation of sound waves is concerned with progressively reconstruing the component technical events of sound transmission as more abstract macro events i.e. air particles pushing on the particles next to them → a compression travels through the air. The reasoning required for this kind of reconstrual is not concerned with the external relations among material events but the internal logic of rhetoric which allows a conclusion to be drawn from the account of material evidence. This can be seen in figure 8 within both the compression and rarefaction elements. Then, in the same way, at the next level of abstraction, the successive relations among the compression and rarefaction elements are the rhetorical means for progression to the

20

Seriation element. Hence, as shown in figure 9, we have a 'nested' serial structure essential to this kind of causal explanation involving the progressive reconstrual of events at higher levels of abstraction.

[insert figure 9 about here]

Comparing explanations of sound waves

As noted earlier, the explanation of sound waves relies on reconstruing technical events at greater and greater levels of abstraction and this reconstrual in turn relies on the deployment of internal conjunctive relations. The reasoning required in the reconstrual of the Phenomenon Exemplification as technical implication sequences and then as a nominalised technical 'meta' event, is much more elaborated through internal conjunction in Sound Text 1 than in Sound Text 2.

The conjunctive relations in Sound Text 1 are shown in figure 8. The pattern is a 'sandwich' structure in which units 16-27 are simultaneously the specification of unit 15 and the rhetorical means for units 28-29. However, this double function of units 16-27 is staged by further internal consequential relations so that 16-19 is the rhetorical means for 20-21 and 22-25 is the means for 26-27, then, taken together, 16-27 is the means for 28-29. It is this cumulation of previous reasoning that makes it possible to establish the consequential relation between the recursion of the observable implication sequence (the vibration of the object - unit 28) and the recursion of the macro-event complex of the compression and rarefaction (established by the logical metaphor 'series' in unit 29). This recursive macro-event complex is then reconstrued nominally as the meta event of the sound wave in the Conclusion in clause 30:

21

30 These compressions and stretchings make up a sound wave.

In Sound Text 2 there are only two internal conjunctive relations forming the 'sandwich' structure in which units 07 - 22 are simultaneously the specification of 05-06 and the rhetorical means for 23, as shown in figure 10.
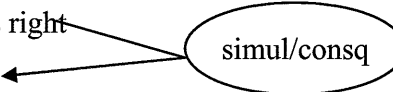

[insert figure 10 about here]

It is significant to note that unit 16 is not conjunctively related to the prior or following text. It is this unit that confronts the reconstrual of technical events as a macro technical event:

16 This region of slightly squashed together air moving out from the prong is called a
     compression.

This corresponds to the following units from Sound Text 1:

20 As each particle pushes on the next one to its right
21 the compression travels through the air.

simul/consq

The simultaneous/(consequential) logical relation which constructs the equivalence relationship between the technical event sequence in 20 and the macro technical event in 21 in Sound Text 1, is not included in Sound Text 2. Furthermore in Sound Text 1, it is the recursion of the technical event sequence in 20 which is reconstrued as a macro event in 21 and the internal consequential relation linking 20-21 with 16-19 is the rhetorical means for this. Now this recursion is realised in Sound Text 2:

14 The neighbouring air particles are then pushed out

15 to hit the next air particles and so on.

But the recursion is not linked logically to the event in 16, which is only realised metaphorically in the extended nominal group - 'This region of slightly squashed together air moving out from the prong'.   The inadequate realisation of this 'dynamic constituency' in the language of Sound Text 2 necessitates the explicit 'repair strategy' in units 21 and 22:

21 The particles of air move to and fro in the same direction in which the wave moves

22 and do not move along with the compression.

Analyses of the subsequent sections of the text (Unsworth 1997d) have shown that the absence of internal conjunction in the explanation of the rarefaction means that there is no reasoning to show how the rarefaction 'moves outwards' (unit 20). Furthermore, in view of the logical gaps in the rhetorical development of units 07-22, it is difficult to see how the text's only internal consequential relation ('Thus') could legitimately signal that the Conclusion in unit 23 is actually derived from the previous sequence of clauses 07-22. On the bases of these analyses it can be shown (Unsworth 1997d) that the more extensive use of internal conjunction in constructing the elaborated reasoning in Sound Text 1 contributes to a more effective explanation than Sound Text 2.

As well as providing a basis for the critical selection of explanation texts to be used as exemplars in classroom work, a key practical implication of this kind of analysis of the language of reasoning is its use as a resource for the explicit teaching of how such explanatory sequences are constructed (For detailed examples of classroom learning activities involving text annotation and diagramming strategies see Unsworth 1997a, 1997b).

Grammatical metaphor: constructing abstraction through nominalisation

The main categories of grammatical metaphor discussed here are those involving the formation of noun structures from verb structures (e.g. compress → compression) and those where a noun or a verb is used instead of a conjunction (e.g. so → the effect). The ratio of the number of occurrences of each of these categories of grammatical metaphor to the total number of clauses in the sample texts dealing with each phenomenon was calculated for eighteen explanatory texts (Unsworth 1996). The comparison of these ratios (expressed as a percentage) for the coal and sound texts discussed here are shown in figure 11.

[insert figure 11 about here]

The graph indicates that the density of grammatical metaphor as a whole in the sound texts is more than one instance per clause, whereas in the coal texts the density is less than half of this. Not only is there relatively little use of grammatical metaphor in the coal texts, but also there is little variation in its use across texts, so our focus here will be on the use of grammatical metaphor in the sound texts. In these texts the density of grammatical metaphor means that the language is very different from the grammatical structures students encounter in oral language. The use of grammatical metaphor is functional and necessary in constructing the explanation of how sound travels, but Sound Text 1 deploys grammatical metaphor much more effectively to this end than does Sound Text 2.

The use of grammatical metaphor in the two sound texts differs markedly for categories of Verb → Noun (compress → compression) and Verb → Adjective (vibrate → vibrating (air particles)). These differences reflect the different ways in which these two texts use language to reconstrue the technical events involved in sound travel (air particles compress

24

adjacent air particles) as macro events (a compression travels ...) and ultimately as a meta event (a series of compressions and stretchings ... sound wave).

In Sound Text 1 different types of grammatical metaphor are used at the technical event, macro event, and meta event levels along a cline of technicality representing the events of sound travel in progressively more abstract terms. Initially, at the technical event level, grammatical metaphor involves the shift to quality (Verb → Adjective). Examples of grammatical metaphor of this kind include: 'vibrating object', 'vibrating materials' and 'compressed air particles'. The next level of abstraction, reconstruing these technical events as macro events, then necessitates the shift to Thing (Verb → Noun). Hence structures like 'compresses air particles' (clause 17) and 'compress them' (clause 19) become the metaphorical Thing, 'compression' (clause 21). This Thing is actually a nominalised form of constituent technical event sequences, but as a Thing it can be a participant in the more abstract macro-event: 'the compression travels through the air' (clause 26) . The concomitant movement back of the air particles when the object moves back to the left is also metaphorized as a Thing ('the stretching apart of air particles'), but avoids the technical nominalisation, 'rarefaction'. The shift to the next level of abstraction, the meta event, involves further reconstrual of the macro events. This also necessitates the resources of grammatical metaphor because it is the recursive macro-event complex (compression and rarefaction) which needs to be reconstrued as a metaphorical Thing so that it can be a participant in the technical meta-event (the sound wave moving). It is therefore the logical relation involved in recursion i.e. temporal succession, which is metaphorized to construct the metaphorical Thing 'a series of compressions and stretchings of air particles' (clause 29). Through presuming demonstrative reference ('These') in clause 30 , this metaphorical Thing is equated with the more familiar 'sound wave'. The development of the grammatical metaphor in Sound Text 1 and the cline of technicality are shown in figure 12.

[insert figure 12 about here]

In Sound Text 2 there are significant problems in the deployment of grammatical metaphor involving shift to Thing to effect reconstrual of technical events as macro events, and there is no use of logical metaphor in their further reconstrual as a meta technical event.

The deployment of grammatical metaphor involving shift to Thing (Verb → Noun), which is necessary to the reconstrual of technical events as macro-events, is not well managed. The first clause relevant to this shift to the macro event is 16:

16 This region of slightly squashed together air moving out from the prong is called a compression.

The metaphorical form 'This region of slightly squashed together air moving out from the prong' causes a good deal of confusion, especially the Qualifier 'moving out from the prong', because, in fact, there is no actual movement of air. There is no concrete participant which is actually transferred away from the prong. This is an abstraction from a series of event sequences which occur contiguously at fixed locations radiating from the vibrating object.   It is the technical event of air particles compressing adjacent air particles which is appropriately condensed metaphorically as the Thing 'compression'. At the next level of abstraction then, this metaphorical Thing can be a participant in a macro technical event i.e. moving out from the prong. Part of the problem with this text is that 'compression' does not function as a participant in a macro-event.   'Rarefaction' does function as an ellipsed participant in clause 20:

19 This region where the air goes thinner is called a rarefaction

20 and also moves outwards.

But again the problem is that the technical term 'rarefaction' is equated with what seems to be a concrete participant ('The region where the air goes thinner') rather than a technical event sequence. Hence 20 seems to realise the actual transference of a concrete participant ('This region') rather than the occurrence of an abstract event - and the notion of the reconstrual of technical events as macro-events at a higher level of abstraction is lost.

In Sound Text 2 there is no realisation of a macro-event complex and no use of the logical metaphor which reconstrues the recursive macro-event complex as a Thing as in the following clause from Sound Text 1:

29 a series of compressions and stretchings is sent out from the object

So, in Sound Text 2, this recursive macro-event complex is not reconstrued as a participant in an event at a higher level of abstraction i.e. sound wave. Instead sound is defined as 'a compression wave that can be heard' (23). Now, if the abstract participant 'wave' is actually constituted by a series of alternating compressions <u>and</u> rarefactions, it is difficult to understand the use of the metaphorical Thing 'compression' as a Classifier of 'wave'. At this stage of the explanation of the phenomenon this Classifier^Thing structure seems to be an inappropriate conflation of two different levels of abstraction. The deployment of grammatical metaphor does not support the reconstrual of unobservable events at progressively greater levels of abstraction along a cline of technicality as was achieved in Sound Text 1.

Science educators have supported the need for students to learn to control the distinctive grammatical forms of scientific discourse (Lemke 1989, Prain and Hand 1996) and the kind of analysis used here can indicate the relative effectiveness of different science texts as

resources for this kind of apprenticeship. But again this kind of textual understanding can be used to generate explicit teaching activities. These can involve 'talking out' the highly nominalised text into the more familiar and iconic noun + verb structures and correspondingly modelling the transformation of these back into nominalised forms in explicit classroom demonstrations of the writing of explanations. Once teachers are familiar with the role of nominalisation, they can support students learning how to deploy such resources in their own writing through scaffolding strategies such as the type of progressive cloze task illustrated in figure 13.

[insert figure 13 about here]

This kind of short cloze task can be used very easily and quickly to consolidate learning and deal explicitly with the written grammar required for such explanations. It can be implemented differentially depending on the level of support needed by different groups of students. Different stages of this cloze task might be introduced in successive lessons with a further consolidating stage repeating stage three but using a different text, before students write their own explanations independently (For further examples of classroom learning activities see Unsworth 1997, 1999).

Conclusion

Despite the very clear differences in the effective co-ordination of a range of textual resources in the construction of the examples of these two types of explanations (all intended for the same general audience of twelve to fourteen year old Australian science students) it is no doubt the case that all of these texts meet the needs of some students for at least some of the purposes for which they are reading. Efficient readers are, after all, active interpreters of texts and good teachers mediate learning from textbooks in the context of a strategic range of

learning activities involving interactive talk and exploratory writing. Nevertheless, the identification of problematic aspects of texts does improve the basis on which teachers can make discriminating selections of books for classroom use and does provide a focus for encouraging critical, resistant readings of these texts when they are used in teaching.

On the basis of the three analyses described here, it can be argued that Sound Text 1 provides a more systematic and clearer textual bridging from the language of commonsense towards the language of scientific English than does Sound Text 2. This is achieved through the inclusion of the Analogic Account in the ORIENTATION stage of the text's schematic structure; the deployment of internal conjunction to clarify the reasoning involved in reconstruing technical events at higher levels of abstraction; and the progressive linguistic construction of the grammatical metaphor needed to describe this technical abstraction. Although structurally there are basic similarities in the two explanations of coal formation, Coal Text 2 compares poorly with Coal Text 1 since Coal Text 2 omits the Trigger element in the IMPLICATION SEQUENCES, and this is an essential element because it deals with the events that initiate the process of coal formation.

It would also seem that specification of the kinds of linguistic differences among the texts discussed here, makes use of basic linguistic descriptions that could be made more generally accessible to science teachers through teacher preparation and professional development activities (for examples of explicit use of functional grammar and discourse in school science teaching materials see Christie *et al*. 1992, Polias 1998 and Veel in press). Functional knowledge about language of this kind would facilitate teachers taking practical account of the interconnectedness of science learning and learning to control the distinctively 'written' characteristics of the language of science. Such shared knowledge among literacy and science educators would enhance collaborative applied educational research and the development of teaching and learning practices.

The analyses discussed in this paper indicate that effective writing of explanations in school science books is identifiable and amenable to specification. Further interdisciplinary research identifying the nature of the effectiveness of an extended range of such texts in combination with studies of their use by different groups of science students for a variety of purposes, may well lead to a practical agenda for the reform of science explanations in school texts in the direction of greater functionality as resources for apprenticing students to the discourse forms of scientific English.

References

Chapman, B., Perry, L. and Stead, K. (1989) Science 9. (Milton, Queensland: Brooks Waterloo), 280-281.

Christie, F., Gray, P., Gray, B., Macken, M., Martin, J., and Rothery, J. (1992) Language: A Resource for Meaning - Exploring Explanations (Teachers' Book) (Sydney: Harcourt Brace Jovanovich).

Dagher, Z. (1995) Review of studies on the effectiveness of instructional analogies in science education. Science Education, 79(2), 295-312.

Dagher, Z. and Cossman, G. (1992) Verbal explanations given by science teachers: their nature and implications. Journal of Research in Science Teaching, 29(4), 361-374.

DeVreeze, D., Lofts, G., Preuss, P. and Gilbert, K. (1992) Jacaranda Science and Technology (vol. 1) (Brisbane: Jacaranda Press), p.131.

Gilbert, J., Boulter, C. and Rutherford, M. (1998a) Models in explanations, Part 1: Horses for courses. International Journal of Science Education, 20(1), 83-97.

Gilbert, J., Boulter, C. and Rutherford, M. (1998b) Models in explanations, Part 2: Whose voice? Whose ears? International Journal of Science Education, 20(2), 187-203.

Halliday, M.A.K. (1993a) Some grammatical problems in scientific English. In M.A.K. Halliday and J.R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer Press), 69-85.

Halliday, M. A. K. (1993b) The analysis of scientific texts in English and Chinese. In M. A. K. Halliday and J. R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer), 124-132.

Halliday, M. A. K. (1993c). Language in a changing world. Applied Linguistics Association of Australia Occasional Paper(13), 62-81.

Halliday, M. A. K. (1993d) New ways of meaning: A Challenge to applied linguistics. Applied Linguistics Association of Australia Occasional Paper (13), 1-41.

Halliday, M. A. K. (1994a) An introduction to functional grammar 2nd edn (London: Edward Arnold).

Halliday, M. A. K. (1994b) Metaphor as semogenic process. Paper presented to the *Workshop on scientific discourse*, University of Sydney.

Halliday, M.A.K. (1995) The grammatical construction of scientific knowledge: The framing of the   English clause. Paper presented to the International Conference 'Languages of Science', Bologna, 25-27 October, 1995.

Halliday, M. A. K. and Martin, J. R. (1993). General Orientation. In M. A. K. Halliday and J.R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer), 2-21.

Halliday, M. A. K.and Hasan, R. (1976) Cohesion in English (London: Longman).

Heffernan, D. and Learmonth, M. (1990a) The World of Science 2nd edn Vol. 1. (Melbourne:Longman Cheshire) p.70.

Heffernan, D. and Learmonth, M. (1990b) The World of science 2nd edn Vol. 3. (Melbourne:Longman   Cheshire) p. 127.

Horwood, R. H. (1988) Explanation and description in science teaching. Science Education, 72, 41-49.

Lemke, J. (1989) Making text talk. Theory into Practice, 28, 136-141.

Lemke, J. (1990) Talking Science: Language, Learning and Values (Norwood, New Jersey: Ablex).

Martin, J. R. (1992) English Text: System and Structure (Amsterdam: Benjamins).

Martin, J. R. (1993a) Literacy in science: Learning to handle text as technology. In M. A. K. Halliday and J. R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer), 166-202.

Martin, J. R. (1993b) Technicality and abstraction: Language for the creation of specialised text. In M. A. K. Halliday and J. R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer), 203-220.

Martin, J. R. (1993c) Technology, bureaucracy and schooling: Discourse resources and control. Cultural Dynamics, 6(1), 84-130.

Martin, J. R. (1993d) Life as a noun: Arresting the universe in science and humanities. In M. A. K. Halliday and J. R. Martin (eds), Writing Science: Literacy and Discursive Power (London: Falmer), 221-267.

Martin, J.R. (1997) Analysing genre: functional parameters. In F. Christie and J.R. Martin (eds) Genre and Institutions: Social Processes in the Workplace and School (London: Cassell), 3-39.

Martin, M. (1972) Concepts of Science Education: A Philosophical Analysis (London: Scott, Foresman).

Matthiessen, C. (1995) Lexicogrammatical Cartography: English Systems (Tokyo: International Languages Sciences Publishers).

Nott, M. and Smith, R. (1995) 'Talking your way out of it', 'rigging' and 'conjuring': what science teachers do when practicals go wrong. International Journal of Science Education, 17(3), 399-410.

Ogborn, J., Kress, G., Martins, I., and McGillicuddy, K. (1996) Explaining Science in the Classroom (Buckingham: Open University Press).

Polias, J. (1998) Teaching ESL Through Science (Adelaide: Department of Education Training and Employment).

Prain, V. and Hand, B. (1996) Writing for learning in secondary science: Rethinking practices. Teaching and Teacher Education, 12(6), 609-626.

Solomon, K. (1986) Children's explanations. Oxford Review of Education, 12, 41-51.

Treagust, D., Duit, R., Joslin, P. and Lindauer, I. (1992) Science teachers' use of analogies: observations from classroom practice. International Journal of Science Education, 14(4), 413-422.

Treagust, D., Harrison, A. and Venville, G. (1996) Using an analogical teaching approach to engender conceptual change. International Journal of Science Education, 18(2), 213-229.

Unsworth, L. (1996) How and Why: Recontextualizing Science Explanations in School Science Books. Ph.D. Department of Linguistics, University of Sydney.

Unsworth, L. (1997a) Explaining explanations: Enhancing science learning and literacy development. Australian Science Teachers' Journal, 43(1), 34-49.

Unsworth, L. (1997b) Scaffolding reading of science explanations: Accessing the grammatical and visual forms of specialized knowledge. Reading, 31(3), 30-42.

Unsworth, L. (1997c) Some practicalities of a language-based theory of learning. Australian Journal of Language and Literacy, 20(1), 36-52.

Unsworth, L.(1997d) 'Sound' explanations in school science: A functional linguistic perspective on effective apprenticing texts. Linguistics and Education, 9(2), 199-226

Unsworth, L. (1999) Teaching about explanations: Talking out the grammar of written language. In A. Watson and L. Giorcelli (eds) Accepting the literacy challenge (Sydney: Scholastic), 189-204.

Veel, R. (1992) Engaging with scientific language: A functional approach to the language of school science. The Australian Science Teachers Journal, 38(2), 31-35.

Veel, R. (1997) Learning how to mean - scientifically speaking: Aprenticeship into scientific discourse in the secondary school. In Christie, F. and J.R. Martin (eds) Genre and Institutions: Social Processes in the Workplace and School (London: Cassell), 161-195.

Veel, R. (1998) The greening of school science: Ecogenesis in secondary classrooms. In J.R. Martin and R. Veel. (eds) Reading Science: Critical and Functional Perspectives on Discourses of Science (London: Routledge), 114-151.

Veel, R. (in press) Write it right: Science Inservice Materials (Erskineville, Sydney: New South Wales Department of Education Disadvantaged Schools Program).

Wells, G. (1994) The complementary contributions of Halliday and Vygotsky to a 'Language-based Theory of Learning'. Linguistics and Education, 6(1), 41-90.

Table 1. Types of conjunctive relations, notation and examples

temporal	simultaneous successive	**simul** **succ**	<u>As</u> the prong moves outwards, it squashes or compresses the surrounding air. ..layers of dead trees and other plants built up on the forest floor <u>before</u> they could rot.
consequential	manner	**man**	<u>By</u> looking closely at one of the prongs, you can see that it is moving to and fro (vibrating).
	consequence	**consq**	Sound waves travel through gases, liquids and solids <u>because</u> they all contain particles which will carry or transmit disturbances
	condition	**cond**	<u>If</u> we look at how a tuning fork produces sound, we can learn just what sound is
	concession	**conc**	This is what happens in a rainforest or in the compost heap of your garden,. <u>However</u>, decomposition is prevented if the plant material accumulates...
	purpose	**purp**	..in each case a vibration was needed <u>(in order) to</u> produce the sound
comparative	similarity	**simil**	<u>Similarly</u>, the Earth's surface is most brightly lit where the sun's rays strike the surface perpendicularly.
	reformulation	**i.e.**	when they strike the Earth's surface perpendicularly <u>i.e.</u> when the sun is directly overhead
	exemplification	**e.g.**	Normally if plant material is left on the ground surface in contact with the air (oxygen) it decomposes. <u>(For example)</u> This is what happens in a rain forest.....
	contrast	**contr**	Large vibrations cause loud sounds. <u>Conversely</u>, small vibrations cause soft sounds.
additive	addition	**add**	when they fall to the ground <u>and</u> become part of the soil humus
locative	location	**loc**	the Earth's surface is most brightly lit <u>where</u> the sun's rays strike the surface perpendicularly.

FUNCTIONAL STAGES	Coal Text 1
ORIENTATION Phenomenon Identification	Coal
Phenomenon Contextualization	
Explanation Summary	1 Coal was formed from the remains of plants buried by sediments.
IMPLICATION SEQUENCES Conditions	2 In ancient forests, which were warm and humid, layers of dead trees and other plants built up on the forest floor 3 before they could rot.
Trigger	4 As the land sank 5 these layers of vegetation were covered with water 6 which deposited sediments of gravel, sand, mud and silt.
Transformation	7 Over millions of years the weight of the sediments and high temperatures removed much of the water from the plant remains. 8 These plant remains are known as peat.
Transformation	9 As the peat was compressed 10 and became warmer 11 moisture was driven out 12 and it became brown coal, or lignite.
Transformation	13 In some places, more layers of sediment built up on top of the brown coal. 14 This caused more and more moisture to be driven out 15 and black coal was formed.
CLOSURE Comment	16 Anthracite has the lowest moisture content of all types 17 but it is rarely found in Australia.

Figure 1. Schematic structure of Coal Text 1(DeVreeze *et al.* 1992:131)

FUNCTIONAL STAGES	Sound Text 1
ORIENTATION Phenomenon Identification	What causes and transmits sounds?
Link	01 To make sounds requires vibrations which disturb the air. 02 Small vibrations cause soft sounds. 03 Large vibrations disturb the air more 04 to produce loud sounds.
Analogic Account	Vibrating materials produce sound 05 Vibrating materials send sound waves through the air. 06 As the materials vibrate 07 they disturb the air particles near them. 08 These air particles disturb other air particles and so on. 09 Just like a long chain or dominoes, the disturbance or sound wave is passed on from air particle to air particle. 10 Unlike the dominoes, the air particles spring back to their original position. 11 Sound waves travel through gases, liquids and solids 12 because they all contain particles [[which will carry or transmit disturbances]]. 13 However, sound waves will not travel through a vacuum 14 which is an empty space: 15 without particles to transmit the disturbance from a vibrating object, sound waves cannot be formed.
PHENOMENON EXEMPLIFICATION	16 Figure 15.1 shows a vibrating object producing sound waves.
IMPLICATION SEQUENCES Compression	17 As the object moves to the right 18 it pushes or compresses the air particles next to it. 19 The compressed air particles then push on the particles to their right 20 and compress them. 21 As each air particle pushes on the next one to its right 22 the compression travels through the air.
Rarefaction	23 When the vibrating object moves back to its left 24 the air particles next to it are no longer being pushed. 25 They spread out 26 or are stretched apart. 27 As a compression travels through the air 28 it is followed by the stretching apart of air particles.
Seriation	29 Because the vibrating object continually moves back and forth 30 a series of compressions and stretchings of air particles is sent out from the object.
CLOSURE Conclusion	31 These compressions and stretchings make up a sound wave.
Extension	32 The vibrating object focuses most of the sound waves in the general direction of its vibrations. 33 However, bending of the edges of the sound waves has the effect of sending them out in all directions around the vibrating object. 34 This is shown by the top view of the vibrating object in figure 15.1.
Generalisation/ Application	35 The same process can occur with the particles in a liquid or a solid 36 so that they will also transmit sound.

Figure 2. Schematic structure of Sound Text 1 (Chapman *et al.* 1989: 280-281)

COAL	SOUND
ORIENTATION	**ORIENTATION**
Phenomenon Identification	Phenomenon Identification
^ (Link)	^ (Link)
^ (Phenomenon Contextualization)	
^ (Explanation Summary)	
	^ (Analogic Account)
	^ PHENOMENON EXEMPLIFICATION
^ IMPLICATION SEQUENCES	**^ IMPLICATION SEQUENCES**
Conditions	Compression
^ Trigger	Rarefaction
^Transformation^n	Seriation
^ (CLOSURE)	**^ CLOSURE**
(Conclusion)	Conclusion
	^ [(Extension)
	· (Generalisation/ Application)
^ (Comment)	

Figure 3. Schematic structures of explanations of coal formation and sound waves

	Coal Text 1 (DeVreeze et al. 1992:131)	Coal Text 2 (Heffernan and Learmonth 1990: 70)
ORIENTATION Phenomenon Identification	Coal	Coal and the Future
Phenomenon Contextualization		1 Coal deposits are very common in many areas of Australia.
Explanation Summary	1 Coal was formed from the remains of plants buried by sediments.	
IMPLICATION SEQUENCES Conditions	2 In ancient forests, which were warm and humid, layers of dead trees and other plants built up on the forest floor 3 before they could rot.	2 They all start as plant remains [[that are not fully broken down and put back into the soil.]]
Trigger	4 As the land sank 5 these layers of vegetation were covered with water 6 which deposited sediments of gravel, sand, mud and silt.	
Transformation	7 Over millions of years the weight of the sediments and high temperatures removed much of the water from the plant remains. 8 These plant remains are known as peat.	3 The first stage of the change to coal is peat, 3.1 which is a watery, spongy black mass of plant material. 4 (Peat can be dried and burnt in the same way as coal, 5 but it does not give out nearly as much heat.) 6 Large areas of peat 'bogs' may take millions of years 7 to form.
Transformation	9 As the peat was compressed 10 and became warmer 11 moisture was driven out 12 and it became brown coal, or lignite.	8 As other layers of rock are laid on top 9 the weight of these sediments squeezes the peat into brown coal,
Transformation	13 In some places, more layers of sediment built up on top of the brown coal. 14 This caused more and more moisture to be driven out 15 and black coal was formed.	10 then into black coal.
CLOSURE Comment	16 Anthracite has the lowest moisture content of all types 17 but it is rarely found in Australia.	11 These two types of coal make better fuels.

Figure 4. Comparison of the schematic structures of Coal Text 1 and Coal Text 2

	Sound Text 1 (Chapman et al. 1989: 280-281)	Sound Text 2 (Heffernan and Learmonth 1990b:145)
ORIENTATION Phenomenon Identification	What causes and transmits sounds?	Sound waves
Link	01 [[To make sounds]] requires vibrations [[which disturb the air]]. 02 Small vibrations cause soft sounds. 03 Large vibrations disturb the air more 04 to produce loud sounds. 04a Vibrating materials produce sound	01 You have just seen a number of sources of sound, 02 many being produced in a way similar to musical instruments. 03 in each case a vibration was needed 04 to produce the sound
Analogic Account	05 Vibrating materials send sound waves through the air 06 As the materials vibrate 07 they disturb the air particles near them. 08 These air particles disturb other air particles and so on. 09 Just like a long chain of dominoes, the disturbance or sound wave is passed on from air particle to air particle. 10 Unlike the dominoes, the air particles spring back to their original position. 11 Sound waves travel through gases, liquids and solids 12 because they all contain particles [[which will carry or transmit disturbances]]. 13 However, sound waves will not travel through a vacuum 13.1 which is an empty space: 14 without particles [[to transmit the disturbance from a vibrating object]], sound waves cannot be formed.	
PHENOMENON EXEMPLIFICATION	15 Figure 15.1 shows a vibrating object [[producing sound waves]].	05 If we look at how a tuning fork produces sound 06 we can learn just what sound is.
IMPLICATION SEQUENCES	16 As the object moves to the right 17 it pushes or compresses the air particles next to it. 18 The compressed air particles then push on the particles to their right 19 and compress them. 20 As each air particle pushes on the next one to its right 21 the compression travels through the air. 22 When the vibrating object moves back to its left 23 the air particles next to it are no longer being pushed. 24 They spread out 25 or are stretched apart. 26 As a compression travels through the air 27 it is followed by the stretching apart of air particles. 28 Because the vibrating object continually moves back and forth 29 a series of compressions and stretchings of air particles is sent out from the object. .	07 By looking closely at one of the prongs 08 you can see that it is moving to and fro (vibrating). 09 As the prong moves outwards 10 it squashes, or compresses the surrounding air. 11 The particles of air are pushed outwards 12 crowding against and bashing into their neighbours 13 before they bounce back. 14 The neighbouring air particles are then pushed out 15 to hit the next air particles and so on. 16 This region of slightly squashed together air moving out from the prong is called a compression. 17 When the prong of the tuning fork moves back again 18 the rebounding air particles move back into the space that is left. 19 This region where the air goes thinner is called a rarefaction 20 and also moves outwards. 21 The particles of air move to and fro in the same direction in which the wave moves 22 and do not move along with the compression.
CLOSURE Conclusion	30 These compressions and stretchings make up a sound wave	23 Thus sound is a compression wave that can be heard.
Extension	31 The vibrating object focuses most of the sound waves in the general direction of its vibrations. 32 However, bending of the edges of the sound waves has the effect of sending them out in all directions around the vibrating object. 33 This is shown by the top view of the vibrating object in figure 15.1.	
Generalisation /Application	34 The same process can occur with the particles in a liquid or a solid 35 so that they will also transmit sound.	

Figure 5. Schematic structure of two explanations of sound waves in high school textbooks
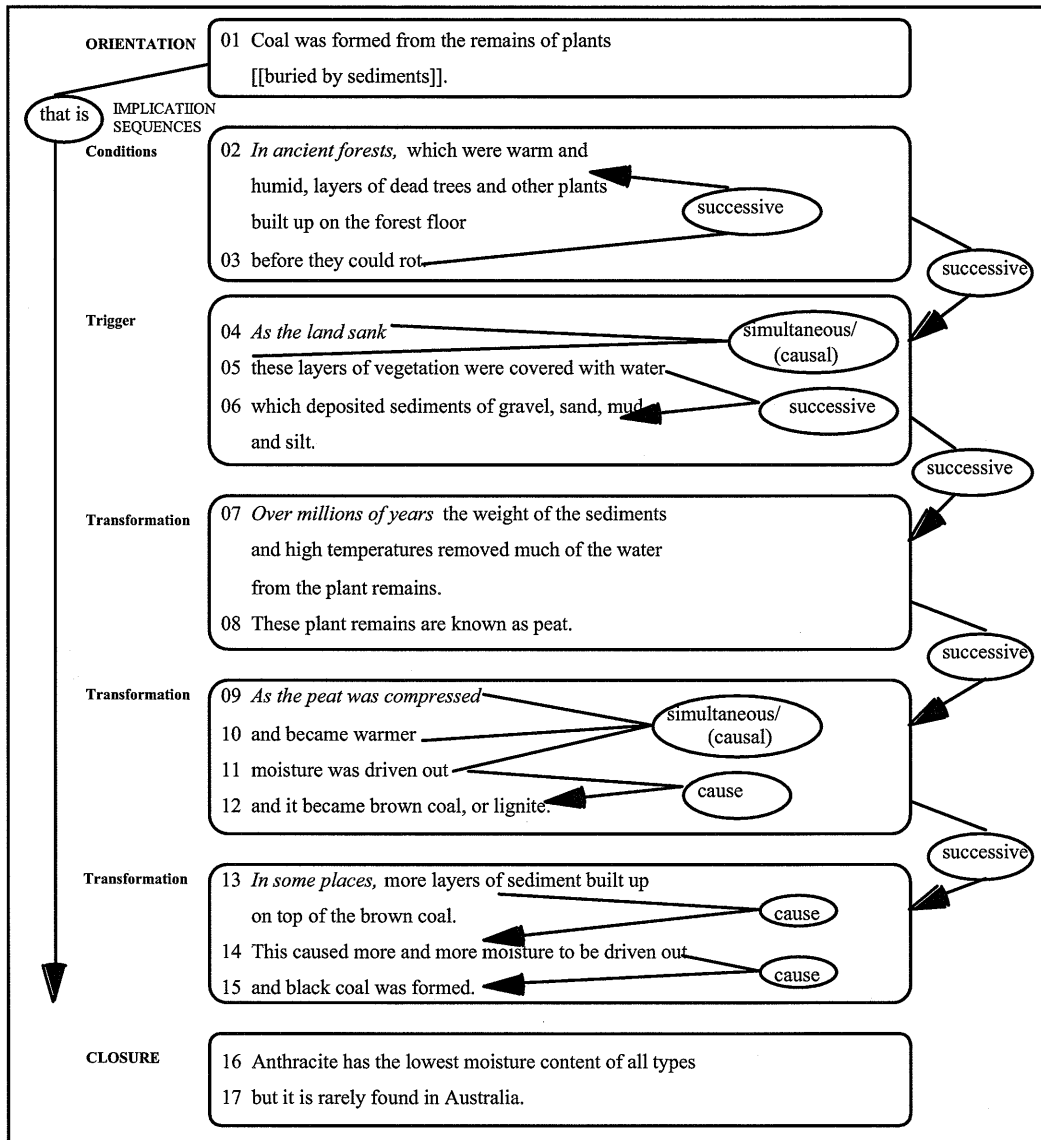
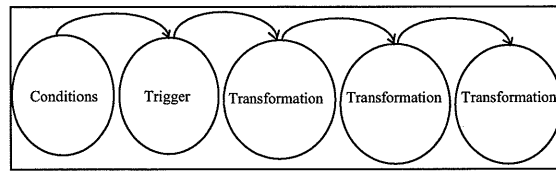**Figure 6. Conjunctive relations in Coal Text 1**
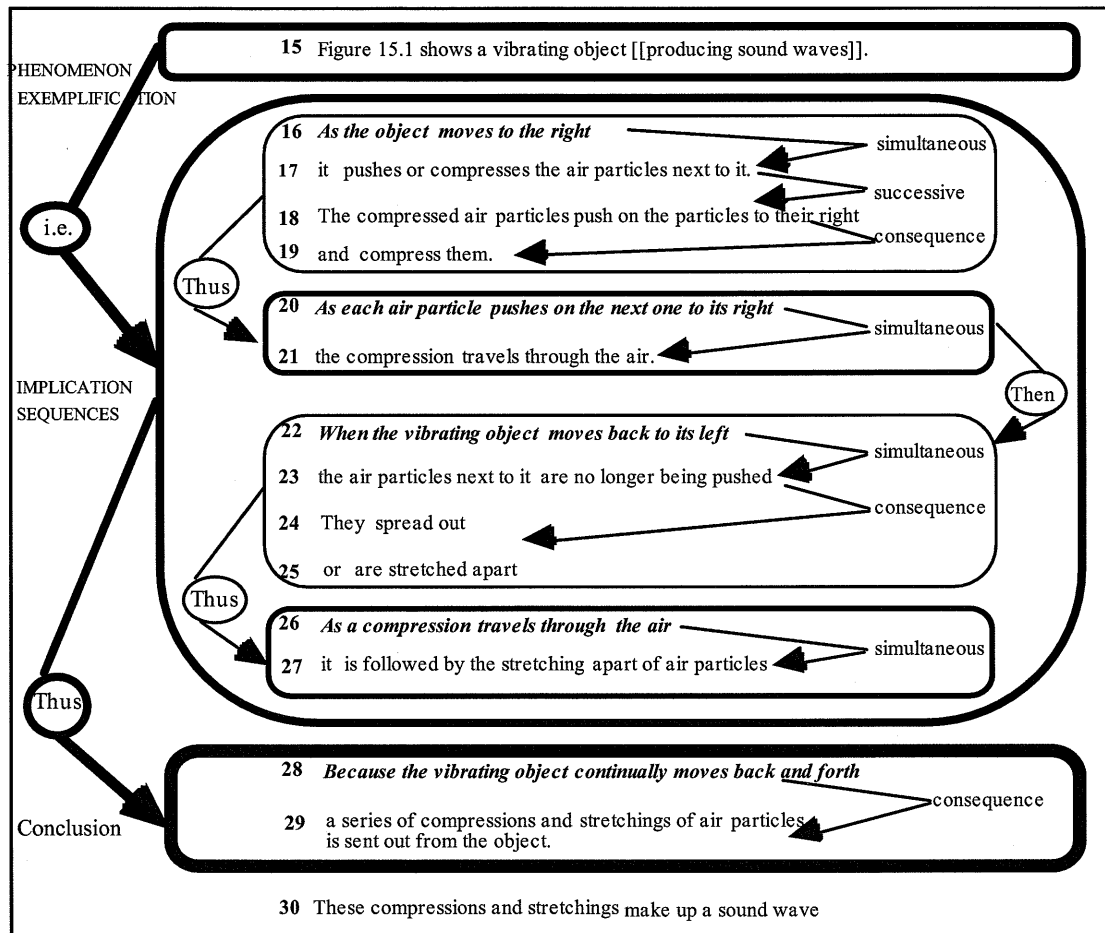
Figure 7. Serial structure of sequential explanations
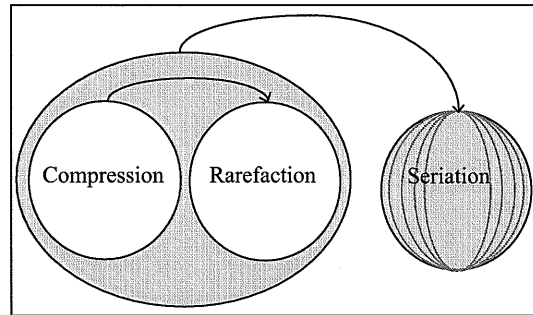
Figure 8. Conjunctive relations in Sound Text 1

44

Figure 9. Nested serial structure of IMPLICATION SEQUENCES in an explanation of sound waves

05 If we look at how a tuning fork produces sound
  condition
06 we can learn just what sound is.

i.e.

07 By looking closely at one of the prongs
  manner
08 you can see that it is moving to and fro (vibrating).

09 As the prong moves outwards
  simultaneous
10 it squashes, or compresses the surrounding air.

consequence

11 The particles of air are pushed outwards
  simultaneous
12 crowding against and bashing into their neighbours
  successive
13 before they bounce back.
  successive
14 The neighbouring air particles are then pushed out
  purpose
15 to hit the next air particles and so on.

16 This region of slightly squashed together air moving out
    from the prong is called a compression.

successive

17 When the prong of the tuning fork moves back again
  simultaneous
18 the rebounding air particles move back into the space
    that is left.

19 This region where the air goes thinner is called a rarefaction

20 and also moves outwards.

21 The particles of air move to and fro in the same direction
    in which the wave moves

22 and do not move along with the compression.

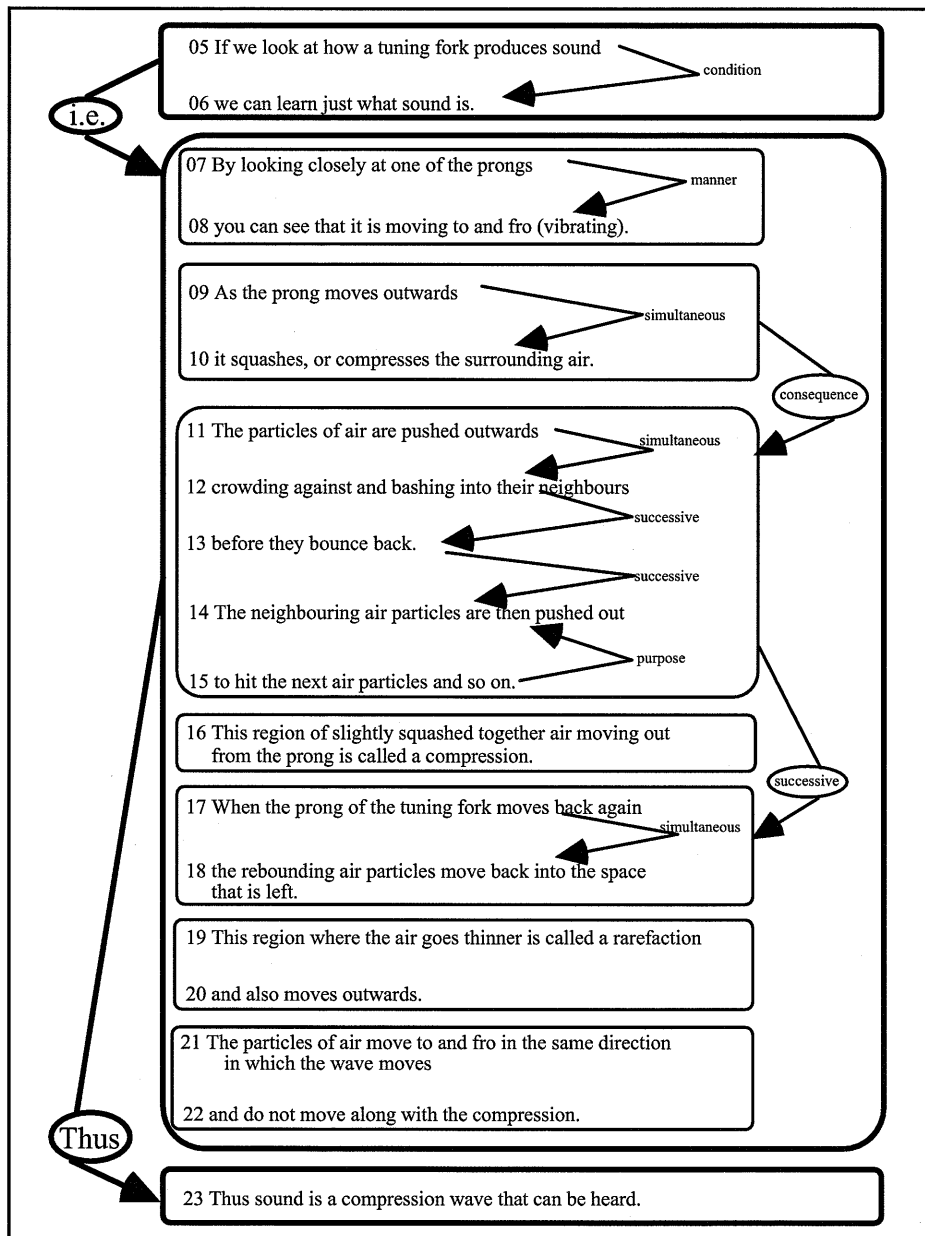Thus

23 Thus sound is a compression wave that can be heard.

Figure 10. Conjunctive relations in Sound Text 2
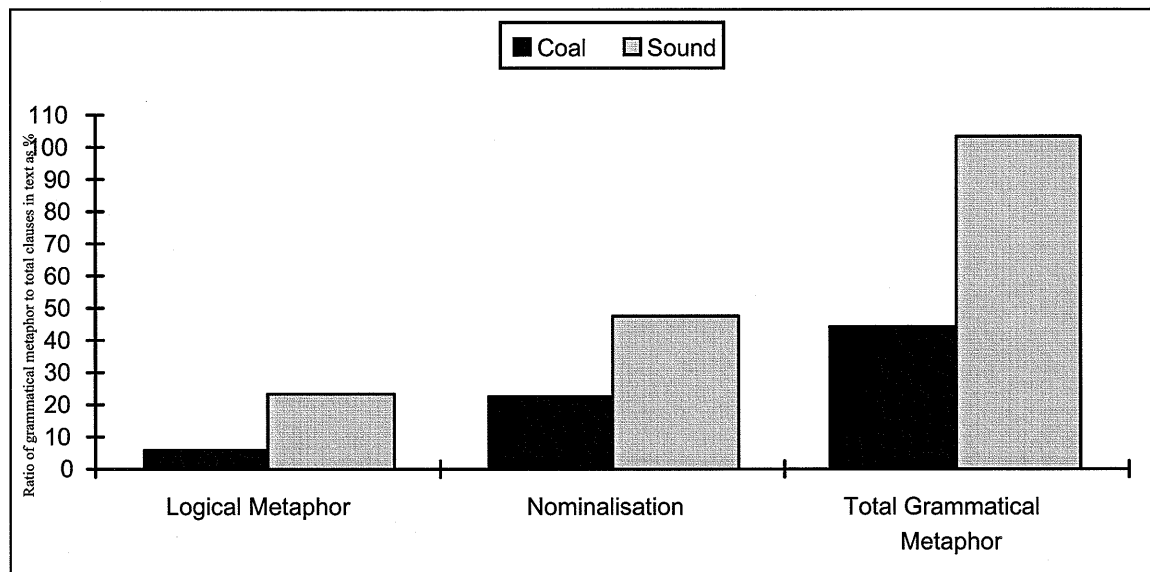
Figure 11. Comparison of density of grammatical metaphor in the coal and sound explanations

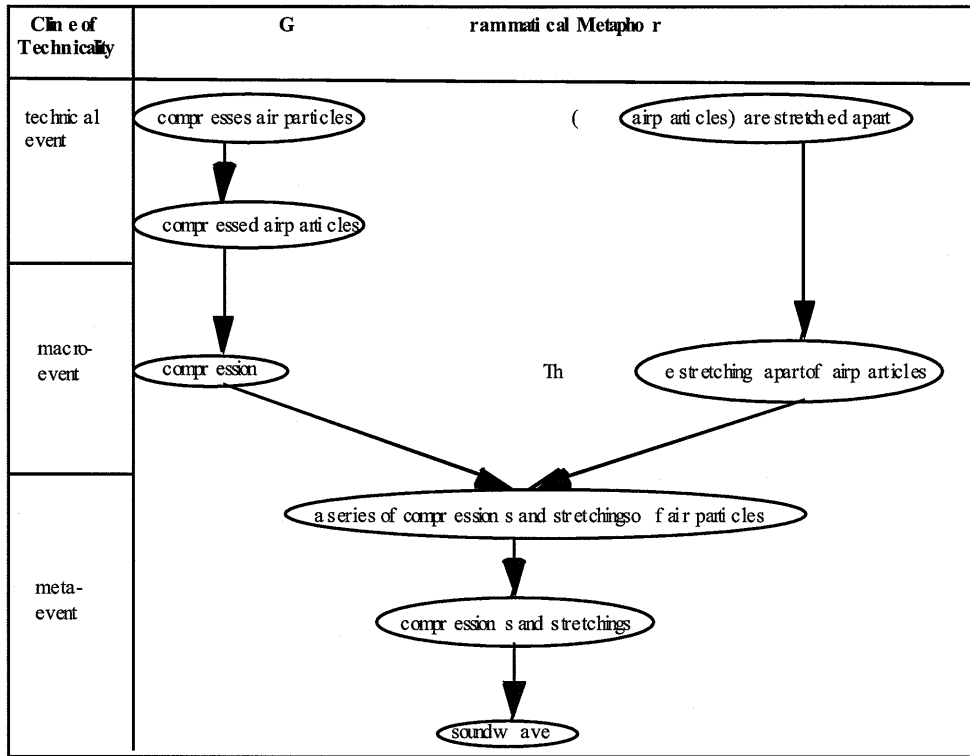| Clin e of Technicality	G rammati cal Metapho r
technic al event	
mac ro-event	
meta-event	

Figure 12. The development of grammatical metaphor in Sound Text 1

① 16 As the object moves to the right
17 it pushes or compresses the air particles next to it,
18 The compressed air particles then push on the particles to their right
19 and compress them.
20 As each particle pushes on the next one to its right
21 the compression travels through the air.

② 16 As the object moves to the right
17 it pushes or compresses the air particles next to it,
18 The c--------d air particles then push on the particles to their right
19 and c------s them.
20 As each particle pushes on the next one to its right
21 the c---------n travels through the air.

③ 16 As the object moves to the right
17 it pushes or ---------- the air particles next to it,
18 The ---------- air particles then push on the particles to their right
19 and -------- them.
20 As each particle ---------- the next one to its right
21 the ----------- travels through the air.

Figure 13. Progressive cloze task targeting grammatical metaphor