'Snakes aren't animals, they're worms': technical taxonomies and their effect on examination performance

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Unless close attention is paid to the particular demands of the scientific register within an examination paper the greater challenge for candidates will be the interpretation of the questions

Science, like many other areas of human activity, has a unique way of talking about the topics with which it is concerned and just as one can talk about mathematical language, political language or the language of art, so too one can talk about scientific language. If this form of language use were sufficiently different from other forms then it follows that a pupil would need to learn this language along with the things and concepts that it expresses. This will have serious implications for assessment since in any science examination one would never know what was being assessed. Do candidates give an incorrect answer because they do not understand the topic or because they do not understand the language in which the question is framed? In order to address this question one would first need to explain the difference in language use. What makes the language of science different? Why does the difference arise? Such an explanation does in fact exist and it has been worked out according to the principles of 'systemic functional grammar', a model developed by the British linguist M. A. K. Halliday (Halliday and Martin, 1993). According to analysts who work within this discipline, specialised languages (called *registers*) arise because of differences in the subject matter (the *field*), differences in the relationship between the reader and author (the *tenor*) and differences in the way in which the information is presented (the *mode*).

With these influences in mind, it is relatively easy to explain the way in which the scientific register differs from other registers. As far as the field is concerned, scientific language is constantly required to relate new discoveries and new concepts, a demand which is rarely placed, to quite the same extent, on the authors of other texts. The mode too must be significant because the ideas and things to be related often demand different methods of communication (graphs, symbolic language, diagrams, etc). It could also be argued that the tenor of many scientific texts also makes significant demands because the author must not only relate the content of his work to his peers but also persuade them of its validity, reliability and significance. Given that scientific authors are faced with a wide range of special demands, it follows that they will adapt their texts in a correspondingly wide range of ways. In particular, one would expect to see specialised terminologies and specialised methods of organising information, and it follows that this organisation would be reflected in distinct syntactic structures. Yet the extent of this specialisation does not appear to be acknowledged in school science as the following extract from a QCA scheme of work illustrates.

ABSTRACT
Science has a particular way of using language, called its register. One feature of this register is technical taxonomy, a specialised way of defining things and processes. Although the purpose of these taxonomies is to make scientific texts clearer and less prone to ambiguity, they can be confusing to novice readers. The effect of these taxonomies on the performance of examination candidates is discussed, as are the implications for teaching and assessment.

> ***Language for Learning***
> *Through the activities in this unit pupils will be able to understand, use and spell correctly:*
> - *words and phrases relating to dissolving, e.g. solution, solute, solvent, soluble, insoluble, saturated solution*
> - *words and phrases relating to the separation of mixtures, e.g. filtration, distillation, chromatography, chromatogram*
> - *words and phrases relating to explanations using the particle model, e.g. prediction, evaluate, interpret*
> - *words with similar spelling but different meanings, and use them in a consistently correct way, e.g. affect, effect*

Here it can be seen that the only linguistic element accounted for is the lexicology (that is the role of individual words). Moreover, in the first three requirements listed in this extract, it not so much the language that is regarded as a challenge to the pupil as the ideas and processes that this language represents. Thus the word *solution* does not by itself present difficulties so much as the conceptual model that is used to describe and explain solutions. Yet, the meaning of a word does not exclusively arise from the thing that it represents. Words also have meaning because they have unique relationships to other words. Take the term *man* for example. One can define this term by reference to the thing that it represents (perhaps by pointing to a man and, at the same time, saying the word *man*) or one could define the term by explaining its relationship to other words (the opposite of *woman* or *boy*, for example). In all, there are three such relationships: *synonyms*, where two words share the same reference (e.g. ‘Venus is the Morning Star’ or ‘the trachea is the windpipe’); *antonyms*, where the word is defined by opposition (e.g. ‘dark is the opposite of light’ or ‘acids are the opposite of alkalis’) and *hyponyms,* where the term is defined as a kind or type of another word (e.g. ‘a puffin is a kind of bird’). It is in this last set of relationships that scientific language tends to differ from common language. Halliday calls these specialised word relationships ‘technical taxonomies’ and argues that these lexical structures form one of the most significant challenges to any inexperienced reader of scientific texts.

Technical taxonomies

Normally the way in which words are defined by hyponyms can be rather idiosyncratic, but in scientific texts the criteria for this kind of definition is rather more explicit and less dependent on circumstance. It may, in certain situations, be acceptable to call a spider a kind of insect (and here one might imagine that a mother, on instructing her son not to drop insects down his sister’s back, would not smile indulgently if he dropped spiders instead). Yet this hyponym would not be accepted in a piece of scientific writing. In this discourse there are rules to determine the organisms that can be defined in this way. These rules are rigid and they apply in almost every case regardless of the context. Thus, if an animal is to be described as an insect then the taxonomic rules of scientific register demand that it possesses three pairs of legs, an exoskeleton, a head, thorax and abdomen.

In addition to these strict rules, scientific hyponyms also tend to be more complex than the hyponyms of everyday language. Each term has a super-ordinate which itself has another super-ordinate, and so on. The word *duck*, for example can be defined as a member of the family *Anatidae*, while the *Anatidae*, in turn, belong to a larger group called the *Anseriformes* (or waterfowl). Accordingly, an *Anseriform* can be defined as a kind of *bird*, and, of course, birds belong to the subphylum *Vertebrata*. Now this succession of super-ordinates is by no means restricted to biology and it would be fair to say that technical taxonomy is universally employed throughout scientific literature, for example in the classification of organic compounds or the classification of forces.

Taxonomic ambiguity

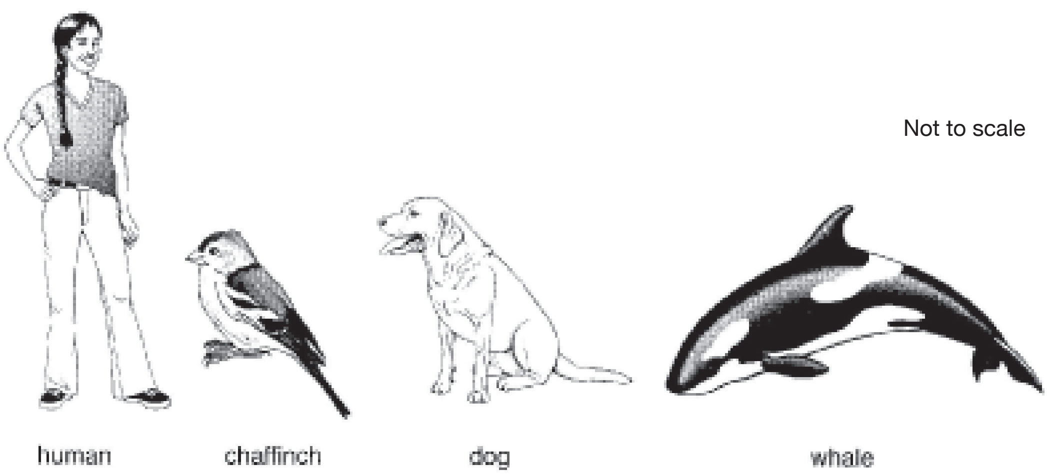
Without a doubt, the function of these nomenclatures is to aid the clarity of the text and to reduce ambiguity. However, as Halliday points out, they do not always achieve this and, moreover, they often present particular problems for school science. These problems lie in the fact that as people become more practised in a form of language use, they become less explicit and tend to rely more on cultural cues and assumptions about what the listener already knows (Cheng and Warren, 1999). Halliday argues that scientists are no different and that as they become more experienced with their register, their language loses some of its clarity. This would not present any significant difficulty to someone with equal experience, but to a novice or to an outsider this can cause confusion. In meteorology, for example, showers are defined by cloud shape. Yet in non-meteorological language, a shower is usually thought of as a short spell of rain. Inevitably, this means that the predictions of a weather-forecaster and the actual conditions experienced by his audience are at odds, even though the forecast may be perfectly accurate.

This goes some way to explain Halliday's belief that technical taxonomies can often create misunderstanding rather than circumvent it, for where a technical term is used a pupil would have to know the rules by which it was defined, along with its location within the appropriate taxonomy. This would mean that a pupil would either need a prior knowledge of the taxonomy, or the taxonomy would need to be made explicit at the time that the term was used. Several years ago, at the end of a year 7 lesson on vertebrates and invertebrates, a pupil pointed to the group of reptiles that had been drawn on the board and said '*You've got that wrong*. *Snakes aren't animals, they're worms!*' At the time, this seemed to be a rather strange or even stupid thing to say. But, on reflection, it is probable that the problem was caused by the fact that words such as *animal*, *reptile* and *snake* were being defined according to a process that the pupils may not have encountered before and that this process should have been made much more explicit.

Technical taxonomies and examination questions

Analysis of the key stage 3 National Curriculum for England tests shows that two types of question seem to be particularly prone to problems involving technical taxonomies and these questions either concern the classification of living things or the nomenclature of forces. A typical question of this type, from the 2003 paper, is shown in Figure 1. In this case, the problem lies in the fact that the required level of the taxonomy is not made explicit and the question author assumes that the candidate will understand that the 'group' being asked for is the immediate super-ordinate of the two classes represented in the diagram. As a result of this, many pupils chose super-ordinates that were several steps above this. *Animals* was one common choice, while *living things* was another. Interestingly, another frequent answer was *warm blooded* and this gives further weight to the argument that the term *group*, as used in this question, is rather ambiguous as the animals shown in the diagram may be grouped in a number of different ways.

The drawings show a human, a chaffinch, a dog and a whale.



One of these animals is a bird. The other three are mammals.

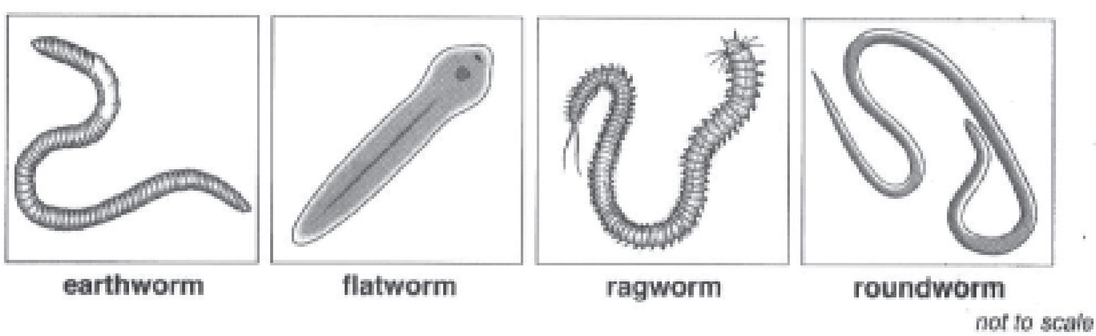
Which group do all four animals belong to?

Figure 1 Question 11 from the 2003 key stage 3 National Curriculum test. Many candidates gave *animals* as an answer. *Living things* and *warm blooded* were also common answers. (QCA, 2003)

A similar problem can be seen in Figure 2. Here again, the level of the taxonomy appears to create a problem for a number of candidates; in this case many of them gave '*They are both invertebrates*' as an answer. It can be seen, of course, that *all* the animals shown in the diagram are invertebrates, but the need to distinguish the ragworms and earthworms from the other given organisms is not made explicit. Therefore, it could be argued that, according to the logic of the question, the answer *invertebrates* is correct. In addition to this, many pupils failed to understand that in order to answer the question correctly it was necessary to choose a specific defining feature (which in the case of the annelids is a segmented body). As a consequence, many candidates focused on the similarity in length of the earthworm and ragworm as compared to the roundworm and flatworm. In this case, it might be argued, however, that the question does make it clear that the drawings are not to scale and so, unlike the *invertebrates* answer, it does not agree with the question's internal logic. Yet, if one compares the relative proportions of width and length, it can be seen that the earthworm and ragworm are quite similar, while the roundworm is long and thin and the flatworm is short and fat. Thus, where the candidates wrote *length*, it is possible that they are referring to the proportionate length. This would also explain why so many candidates gave *shape* as an answer, since this could also refer to the relative proportions of width and length. As a counter-argument, it could be suggested that the taxonomic rule that distinguishes annelids by their body segments is, or should have been, taught prior to the examination and the failure to group the earthworm and the ragworm accordingly reflects a lack of knowledge on the part of the candidate rather than a problem with the construction of the question. This argument would certainly be valid if it were clear that the question related to the scientific taxonomy of invertebrates but this was not the case; in fact, the section occurs midway through a question on food chains.

It is likely then that, in this case, the context of the question had an important influence on the ability of a candidate to handle the demands created by the taxonomy; it would also be reasonable to assume that the effect of the context is likely to be as great in similar questions. Yet, an important part of becoming a scientist must be developing the ability to take abstract ideas away from their contexts and apply them in new situations (as one does with the formulae of physics). When, for example, the speed formula is taught the teacher typically explains the way in which this equation is derived and then provides a number of different examples in which the formula can be applied. By making the contexts of these examples as different as possible the teacher would aim, not only to equip pupils with an abstract

(c) The drawings below show an earthworm and three other worms.



The ragworm belongs to the same group as the earthworm.

How can you tell this from the drawings?

Figure 2 Question 9c from the 2005 National Curriculum test, paper 1 level 3–6. The correct answer should have referred to the fact that the earthworm and ragworm have segments. Many candidates gave **'***They are both invertebrates***'** as an answer. *Length* and *shape* were also common answers. (QCA, 2005) tool but to train them to recognise the situations in which the formula might be applied. Consequently, in order to prepare pupils for questions such as the one above, it would be necessary to treat technical taxonomies in a similar way. However, these linguistic principles are rarely expressly taught in a classroom, and where technical taxonomic terms are used, the principles that define these terms are only referred to vaguely. One of the consequences of this omission can be seen in Figure 3. Here, confusion has arisen between the categories of the taxonomy and the rules that apply to these categories. In the normal course of events, the topic of forces would be introduced by explaining to a class that a force can push, pull, change the shape of an object or change the direction of an object. These, however, are not forces in their own right: they are criteria that tell us where the term *force* may be used. (In the same way, the possession of three pairs of legs, an exoskeleton, a head, thorax and abdomen are some of the criteria that determine where the term insect may be used.) The actual categories, at least as far as key stage 3 science is concerned, are *friction*, *gravity*, *upthrust*, *magnetic force*, *surface tension* and *electrostatic force*. Unfortunately, unlike other technical taxonomies, the criteria that are used to assign the term *force* in these cases also appear to form a taxonomic structure of their own. In fact, it may even be the case that, in the earlier stages of teaching, the terms *push* and *pull* are used in this way. How then can a pupil know which of these taxonomies is the appropriate one? Here again, the linguistic demands of the question seem to indicate that the principles of technical taxonomy and their

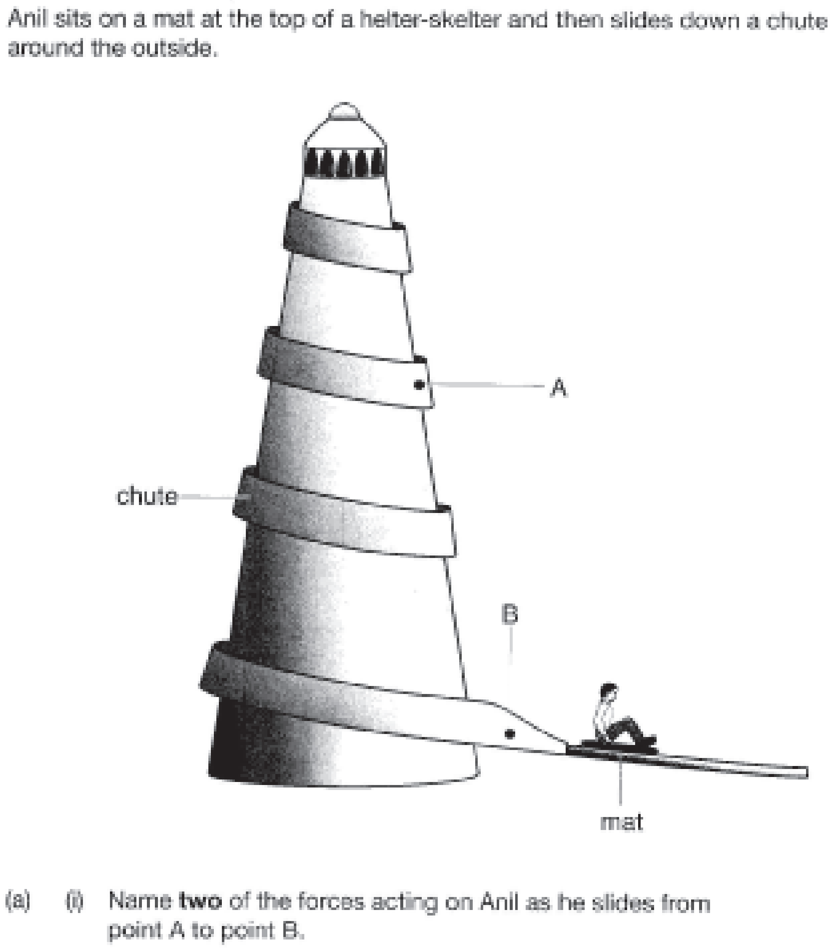


Figure 3 Question 12 from the 2003 National Curriculum test, paper 2 level 3–6. *Gravity*, *weight*, *friction* and *air resistance* were all possible correct answers. Many candidates answered *push* and *pull*. (QCA, 2003)

applications should be specifically taught as a topic in its own right.

The case for further study

As far as examinations are concerned, it is clear that Halliday's argument about the inclusion of technical taxonomies within texts written for readers outside the scientific community is both valid and relevant. However, in this discussion, Halliday's argument has been justified almost exclusively in terms of marks lost or gained as a result of these structures. Yet the implications of his argument must be much greater than this, since a pupil who consistently fails to appreciate the lexical principles behind the technical terms within a topic will in all probability misunderstand much of the topic's content. So, the actual effect on understanding, motivation and confidence is likely to extend far beyond the criteria used in this discussion.

Although technical taxonomy has been the main focus of this discussion, Halliday identifies a number of grammatical features that consistently cause confusion amongst uninitiated readers and these features can be just as problematic as technical taxonomies. It follows from this that unless close attention is paid to the particular demands of the scientific register within an examination paper the greater challenge for candidates will be the interpretation of the questions rather than their understanding and knowledge.

However important these implications are, it would be quite unreasonable to demand of an examination board that they should immediately take account of Halliday's lexico-grammatical features. Not enough is known about the way in which these features influence candidate performance, the significance of these influences or how to address the problems that they create. Furthermore, it should be borne in mind that examinations themselves tend to employ specialised linguistic forms and so anyone attempting to understand the linguistic challenge of scientific examinations is really dealing with a kind of hybrid register formed from scientific English and examination English.

One of the strengths of systemic functional linguistics is its capacity to analyse and describe a very wide range of texts, including political speeches, science fiction and advertising. It should therefore be well within the capacity of this discipline to create a practical description of the lexicology and grammar of examination–scientific registers. With this description one would then be in a position to study the effects of its structures on the performance of candidates. It would then be possible for examining organisations to make informed decisions about the way in which to construct assessment material. Teachers too would benefit from such a lexico-grammatical model. As has been seen with technical taxonomies, there are elements of the scientific register that should be given rather more attention than is currently the case and this has been revealed by a study of the way in which pupils respond to questions that contain these structures. In this light, just as examinations can show which scientific concepts are well taught and which are not, so too can they show which linguistic structures require more attention.

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