THE ELABORATION PROCESS IN THE CONSTRUCTION OF SCIENTIFIC MEANING

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I. Semiotic models

Since Kunh's *The Structure of Scientific Revolution* (1962) was published, scientists have been increasingly using semiotic models to complement their physical and biological models of the universe. In fact many physical, chemical and biological phenomena are being interpreted as semiotic events, as we can see in the following example:

Text 1

<u>Crude oil</u>

There are four significant sources of crude oil: (1) petroleum: (2) coal liquefaction; (3) shale oil; and (4) tar sands. Most of the crude oil used to date has been petroleum derived since what is found in the ground requires little processing before delivery to a refinery. Coal on the other hand, must be treated to increase its hydrogen content and remove undesirable elements such as nitrogen, sulfur, arsenic,

> mercury, cadmium, or phosphorous. Shale oil is difficult to get out of the ground since it is soaked up in rocks. Tar sands contain hydrocarbons mixed with sand and are more difficult to remove from the ground than petroleum. Like coal derivatives and shale oil, oils from tar sands require hydrogenation and removal of undesirable chemicals from the crude before it is delivered to the refinery. As petroleum supplies dwindle, more and more crude oil will be made from alternative sources.

As Halliday has already observed (Halliday, 1992) what is important in this example is not the technical words themselves -*crude oil petroleum, coal liquefaction, shale oil, tar sands*- which can be repeated throughout the disciplines, but the system of meaning that constitutes a scientific theory of communication, that is, of semiotic systems and processes, and the lexicogrammatical resources (the 'wording' as a whole) by which these meanings are construed.

As the prototype of a semiotic system is a natural language the scientific writer has adapted natural language to the construction of experimental science, and in so doing, he has developed powerful new forms of wording in writing.

Written technical language enables scientists to re-classify the world in a different way as to how it is normally done in natural spoken language. In fact, written scientific English has recourses for making meanings that are not generally to be found in spoken language. As Halliday claims (Halliday 1985b) it has only been through developments in written scientific English that lengthly, complex scientific theories have been able to develop. The language of science is, in fact, a language in which theories are being constructed; as Lemke (Lemke, 1990) has expressed it 'a scientific theory is a system of related meanings'. For Halliday a scientific theory is 'a linguistic construal of experience'. However human experience may vary throughout the time and across cultures. Whorf (1.956: 134-159) defined the linguistic relativity principle *"which holds* *that all observers are not led by the same physical evidence to the same picture of the universe, unless their linguistic backgrounds are similar or can, in some way, be calibrated"*. In this construal of experience scientific language has evolved to form a model that not only supports scientific knowledge, but that has also become a universal norm of writing.

We shall examine some of the complexities of scientific language and the elaboration process involved in translating abstract scientific knowledge into words, taking into account both, grammar and lexis.

II. Elaboration: From common sense taxonomies to scientific knowledge

Scientific language is concerned with building up uncommon sense as a starting point and then translating it into specialized knowledge In semiotic terms this process is known as elaboration (Martin,1992).

Following Hjelmslev and Halliday, language is viewed as a stratified system with one, more 'concrete' stratum or plane realizing a second more 'abstract' (the 'content' plane). An example of this in scientific texts is the use of acronyms which compact information on the more concrete plane or stratum. Technical terms, on the other hand, compact information on the content plane (high level abstractions). Defining technical terms means translating common sense into scientific knowledge.

Common sense, like specialized knowledge, makes use of nominal groups and relational clauses ('be' clauses) in order to classify experience. As Halliday and other scholars have observed (Christie, 1988) children are doing it all the time: sorting out the world of living things and organizing them into common sense categories. The main difference between common sense taxonomies and specialized knowledge is that common sense classification is based on what can be directly observed by the senses. In a common sense taxonomy Metals, for example, might be normally classified according to their use; diseases according to their symptoms and effects; chairs as a class of furniture and so on. Science and technology, on the other hand, differs from common-sense taxonomies. Scientific knowledge has been organized around systems of technical concepts arranged in strict hierarchies of wholes and parts or/and classes and subclasses or causes and effect. Thus, metals might be taxonomized according to their different components, or categories; diseases according to viruses or bacterias, classes and sub-classes; chairs according to engineering design or materials, etc. Let us illustrate this point with the following examples:

Common-sense taxonomies:

Copper: is a metal, a good conductor of electricity, and it is frequently mixed with other metals to form alloys.

Epilepsy: a mental disease normally accompanied by loss of conciousness

Scientific taxonomies:

Text 1: *Classification of copper and alloys*

Copper and its alloys may be classified in several ways. One classification is by three categories: (1) tough pitch. (2) oxigen free, (3) deoxidized coppers. Another method classifies copper and its alloys into four general categories: (i) those classified as copper (ii) the brasses, in which zinc is the principal alloy, (iii) the bronzes. in which tin is the principal alloy (also included as bronzes are those metals with alloy silicon or aluminium with copper) and (iv) nickle alloy.

Text 2. *Definitions and classification of epilepsy.*

Afebrile seizure: A paroximal disturbance of conciousness, sensation or movement, primarily cerebral in origen, unassociated with acute febrile episodes

Status epilepticus. A seizure or series of seizures lasting more than 30 minutes.

Remission of seizure· 2 or more years free of seizures before the 10 year follow up, whether or not anticonvulsant drugs were still prescribed.

Active epilepsy. Afebrile seizures in the 2 years before the 10 year follow up in a child with epilepsy.

Idiophatic seizure. Those for which there was no underlying diagnosis or history of neurological insult that could be considered a predisposing cause.

Symptomatic seizures: Those that were not idiopathic.

In the examples above -texts 1 and 2- the terms imply taxonomies which organize reality differently to common sense ones. This has lead to the creation of technical terms which are an essential part in the construction of scientific discourse. However, what is significant in these taxonomies is not only the technical terms themselves, but as Halliday mentions, the potential that lies behind them which contributes to. *both, the possibility of being organized into systematic taxonomic hierarchies, and to being created 'ad infinitum.* For instance from the term 'tensor' a great number of taxonomies may be created:

tensile strength - tensile stress - tensile strain - tensile resilience - tensile stress-strain curve - tensile splitting strength - tensile plastic deformation...

These terms are represented as 'things', but each of them conveys different, and on many occasions a great deal of information. The creation of these taxonomies has been possible through the linguistic resource of nominalisation. Nominalisations are an important tool for generating taxonomies of interrelated terms. They are used to pack together a great number of events and states. Understanding technical discourse means being familiar with these specialized taxonomies and the principles which lead to their construction.

But, as Halliday claims (Halliday, 1992), there is another aspect of scientific language that is just as important as its technical terminology, and that is its technical grammar, since, creating a technical term is, in fact, a grammatical process. The grammatical resources used in scientific written discourse is, as a matter of fact, the construction of nominal groups and clauses deployed in such a way that they can be combined to build a particular form of reasoned argument. This has developed a particular rhetorical structure which is prototypical of the discourse of written science. Halliday has studied the development of scientific writing and has already found this manner of construing a reasoning argument through a particular kind of grammar in the earlier scientists. Priestly, for example, in *The history and present state of electricity, with original experiments,* published in 1760s builds up his argument around 'electricity', by using taxonomies of interrelated terms:

electrical light, electric fire, electric fluid, electric circuits, electrical battery, electrical experiment, excited electricity, medical electricity, conductor of electricity, positive and negative electricity, electric shock.

As scientific knowledge advances and becomes more specialized, the complexity of the information requires the linguistic resource of nominal groups in order to translate into words high level abstraction. Any current scientific article may exemplify it. Consider the following example:

Title "The curvature of material surfaces in isotropic turbulence": This title starts with a nominalisation followed by nominal groups. representing high level of abstraction. The argument is built troughout the article by taxonomies formed from the main concept or argument:

curvature of material surfaces - isotropic turbulence - constant density homogeneous isotropic turbulence - mean-square curvature - large curvatures - cylindrical in shape - nearly straight lines - curvature K...

The translations of these abstract concepts into language has been possible thanks to nominalisations.

This leads us to another consideration: technical terms cannot be separated from the grammar that construes them; both have to be studied together. In doing so, we have to refer to grammatical metaphor.

III. The grammar of abstraction: grammatical metaphor

Halliday defines 'transitivity' as the system which "specifies the different types of process that are recognised in the language, and the structure by which they are expressed. . A process consists potentially of three components: (i) the process itself: (ii) participants in the process; (iii) circumstances associated with the process" (Halliday, 1985 a: 101).

He outlines the concept of grammatical metaphor in *An Introduction to Functional Grammar* (1985a). He suggests that a proposition is associated with a congruent process type -material mental or relational- and that this will control the selection of participants and circumstantial elements and the sequences in which they occur (1985a), that is. in the relationship between semantics and grammar -between meaning and form- there is a natural (congruent) relationship between the two. In other words, actions come out as verbs, descriptions come as adjectives, logical relations as conjunctions and so on. These congruent correspondences are outlined below following Martin: (Martin, 1992)

<u>Semantics</u>	<u>Grammar</u>
participant:	noun
process:	verb
quality:	adjective
logical relation:	conjunction
assessment:	modal verb

However, this is not always so, specially in scientific English. Grammatical metaphor occurs when the process type chosen is different from the congruent one, with a consequent change in transitivity relations. For example the congruent expression:

The temperature	increases	sharply
noun	verb	adverb

where the subject is a noun and the verb a material process, may be expressed as:

The sharp	increasing	of temperature
adjective	noun	noun

where the verb has been 'nominalised' and the adverb has become an adjective in theme position.

Qualities can also be nominalised:

The metal	was	heavy
noun		adjective

becomes:

the heaviness	of	the metal
noun		noun

The most frequent form of grammatical metaphor is the nominalisation of processes, with subsequent change of the verbal element in the clause from a material process type (process of doing) to relational processes (process of being) or circumstantial (process expressing attribute or circumstance) (Halliday, 1985a) For instance:

- an electron	moves	in an orbit
participant/thing	process/event	circumstance/participant/thing

becomes:

- the orbital	motion	of an electron
classifier /thing	thing	qualifier

Halliday suggests that a tendency to pack lexical information in the nominal group is a typical feature of scientific English, and that this is heavily related to written language *"to represent phenomena as product"* (Spoken and Written Language: 1985b: 8), that is, to represent them as things. Nominalisations, then, are used by scientists in order to 'reconstruct' the world as a place 'where things relate to things'. The potential of nominalisations as a linguistic resource is commented by Eggins *et al* (Eggins *et al*, 1987):

Turning doings into things allows us to utilize the full grammatical resources available to Things in English. These include being able to quantify, qualify, classify, act, be acted upon, cause, have attributes and be equated with other things (Eggins et al, 1987: 60).

Definitions

A good example of this is Definitions. Definitions are a special type of relational clause which translate common sense into specialised knowledge. Translating common sense into un-commonsense, specialized knowledge is a semiotic process.

At clause rank this meaning is construed through the relational identifying clause (Halliday, 1985a, pp 112-280) Consider the following example:

> Text 4
>
> Electricity refers to a physical phenomenon arising from the existence and interaction of charged particles.

The technical term *Electricity* is related to its definition *a physical phenomenon arising from the existence and interaction of charged particles* by the relational process 'refers to' Introducing a technical term means -at clause rank- placing a Token in relation to its Value, and this entails relating meanings in the grammar as participants. Electricity is not a thing but has to be presented as one in scientific discourse in order to be defined:

electricity	is (refers to)	a physical phenomenon arising from the existence and interaction on charged particles
Token	process	Value

Like all identifying clauses, this clause is reversible:

A physical phenomenon arising from the existence and interaction of charged particles	is referred to	as electricity".
Value	process	token

Common defining verbs are: be, consist of, call, refer to, mean, represent, express...

Definitions are important in scientific language because they relate known common terms (old information) or already defined technical ones to new technical terms (new information). This relation -common terms to technical ones- is done by means of grammatical metaphor.

The apparently simple definition shown above contains a great deal of information. This information is packed into a grammatically simple equation: "x=y" But underlying the language there are complex processes, actions and events going on. In order to make the definition of electricity appear so simple the resources of written language have been used to pack together a great number of events and states. All the complex processes, conditions and states that define electricity are represented here as a 'thing' by means of nominal groups. The term *electricity* itself is represented to the reader as a thing, but it is not a thing at all; it is the linguistic representation of a complex network of processes, activities and states. If we unpack the nominal groups, the complexities of the written language are shown:

x		y
electricity	is (referred to)	a physical phenomenon arising from the existence and interaction of charged particles

This second complex nominal group is a tightly packed set of activities processes and states, each of them embedded into another. Though represented as things they are in fact actions, processes and qualities that have been turned into things. This means that they are also very abstract in their content as can be seen if we unpack these nominal groups:

physical phenomenon :	occurs in physical nature
charged particles:	there exist particles that are charged and that interact each other
electricity:	the set of the above processes, states, conditions

Such a short definition of electricity, involving so many phenomena, is only made possible thanks to the compact grouping of events and states into complex nominal groups. As can be seen in these examples the relation between grammar and semantics, or meaning and form is not congruent. Processes -*exist, interact, arise charge*- have been realized as nouns or adjectives at the grammatical level -*interaction, existance, charged, raising*-.

Nominalisation is also used in science to represent processes at a high-level abstraction. The vast majority of technical words are nouns, - in fact terms or groups of terms-. Obviously, it is easier to refer to the term electricity than to the whole process which this word stands for.

In the following text, elaboration is done through a link of definitions. Each definition is an elaboration of the previous one, and adds new value to the last token.

Text 5

Reuleaux defines a machine as a "combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinate motions" He also defines a mechanism as an "assemblage of resistant bodies, connected by movable joints, to form a closed kinematic chain with one link fixed and having the purpose of transforming motion".

Some light can be shed on these definitions by contrasting them with the connected by joints, but its purpose is not to do work or to transform motion. A structure (such as a truss) is intended to be rigid. It can perhaps be moved from place to place and is movable in this sense of the word; however, it has no internal mobility, no relative motions between its various members. whereas both machines and mechanisms do. Indeed the whole purpose of a machine or mechanism is to utilize these relative internal motions in transmitting power or transforming motion.

A machine is an arrangement of parts for doing work, a device for applying power or changing its direction. It differs from a mechanism in its purpose. In a machine, terms such as force, torque, work, and power describe the predominant concepts. In a mechanism, though it may transmit power of force, the predominant idea in the mind of the designer is one of achieving a desired motion. There is a direct analogy between the terms structure, mechanisms, and machine, and the three branches of mechanics shown in Fig. 1-2.

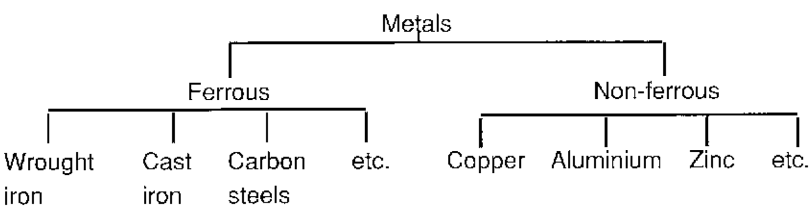
Classification

Similarly technical terms facilitate classification of phenomena as if they were things, since things are easier to be organized into classes and subclasses and as part and wholes. The example below may illustrate this point:

Text 6

Steels are divided into two groups, plain carbon steels and alloy steels. Plain carbon steels consist of alloys of iron and carbon which contain up to 1-5% carbon and up to 1% manganese. Alloy steels consist of steels which contain more than 1% manganese and other metals. Alloy steels include high tensile steels, heat resisting steels, and stainless steels. Carbon steels include dead mild steel, which contains from 0-1% to 0-15% carbon; mild steel, which contains from 0-15% to 0-25% carbon; medium carbon steel, which contains from 0-25% to 0-85% carbon and high carbon steel. which contains from 0-85% to 1-5% carbon (from *Nucleus*).

The elaboration here is classification of steels. In this taxonomy the major subclasses of Steels are defined and established in the field as technical terms. At the same time they construct new, uncommon sense relationships among steels and their alloys to create new meanings. In doing so, they both accumulate and change the nature of the meanings they translate into technical fields. As Martin says (Martin 1989: 229) they "establish new *valeur*". A consideration of the subjects also shows that they reflect a schematic structure which moves from superordinate categories to increasingly specific instances. Thus, the passage is organized in a lexical chain of hyponomy (Davies, 1986). The following diagram shows how the taxonomy in text 6 has been built in order to construct new meanings:



The text shows relational identifying processes to define its technical terms. It follows that technical terms are fundamental to specialize discourse. They should not be considered as a kind of 'jargon' but as a linguistic resource science has developed to reinterpret the world and to put into words very abstract concepts. Along with this, a full range of relational clause resources in terms of participants and processes are used to construct the taxonomy shown in the diagram. This shows that the taxonomy has been built up from superordinate to sub-class. The text begins with 'steels', breaking them into two and then more than four sub-classes. Steels, on the other hand belong to a major class of alloys, which are included in another class of metals. This creates a complex network of technical terms and of relational identifying clauses in order to construct new knowledge.

Explanation

The resources of written language are also important in developing the scientific method of explanation For example, nominalisation is chiefly used in the following examples to construct a cause and effect relationship:

Text 7

The gas turbine engine fires continuously. The engine draws air through the diffuser and into the compressor, raising its temperature. The high pressure air passes into the combustion chamber, where it is mixed with a fuel and produces an intense flame. The gas from the combustion chamber is directed through the turbine, where the pressure of the gas decreases and its velocity increases. The turbine drives the compressor. The gas increases in speed as it passes through the exhaust nozzle before it is finally expelled from the turbine.

Text 8

When the bell push is pressed, electricity flows through the contact into the electromagnet. This attracts the iron arm of the clapper. The arm moves out on a spring and strikes the gong. This movement breaks the electrical contact and the current stops flowing through the electromagnet Without the magnetism, the arm is pulled back by the spring, it returns, touches the contact again and starts the flow of current to the electromagnet again. The cycle repeats itself.

In these texts the explanation is organized through actions ordered in time, so very different discourse patterns arise. As far as relational clauses are concerned, the explanation is formulated as relationships of cause, and subclassification among processes presented as things. Elaboration -i.e. translating common sense into specialized knowledge- is also found at group and word rank. In this elaboration, however, the cause and effect relationship is frequently implicit. In texts 6 and 7 the cause and effect relationship is mostly implicit. Following Halliday and Hasan (1976) these relations are referred to as internal, and they are concerned with what may be referred to as rhetorical relations within the text itself. It means that the causal relations are realized within rather than between clauses. This relation may be explicited by nominalisations :

(Text 6)

Cause	Effect
a) Incoming air from engine	raises its temperature
b) Mixture of h.p air & fuel	produces intense flame
c) The increasing velocity of gas	drives the compressor
-----	expells gas

(Text 7)

Cause	Effect
a)Pressing of bell	electricity flows
b) this	attracts the iron arm
c) The movement of the arm	strikes the gong
d) This movement	breaks the electrical contact : current stops flowing
e) The lack of magnetism	pulls the arm back,
f) (this)	stars the flow of current to the *electromagnet* again

In these examples the cause and effect relationship can only be made possible because the events are represented. not as a process, but as things. It entails nominalising events as participants Because nominalisations turn an event into a noun, it allows us to represent one event as causing another event in a single clause. This results in a compactness which serves to construct cause and effect relationships within a single phase in a causal explanation. As the events are not normally visible to the observer and because they involve abstract entities or properties, nominalisations are chiefly used in cause-effect relationships.

Text organization

Grammatical metaphor is not only a resource for forming terms, defining, classifying or expressing a line of reasoning. Grammatical metaphor is also a tool for organizing a text. As far as the clause itself is concerned. the critical structures are those associated with the systems of Theme (theme-rheme) and Information (given-new) (Halliday, 1985a; Fries, 1981, 1983).

Consider the following example again:

The arm	moves out on a spring and strikes the gong
Theme	Rheme/New
This movement	breaks the electrical contact and the current stops flowing through the electromagnet
Theme	Rheme/New

Theme is realized in first position in English, and in declarative clauses conflates with the subject in the unmarked case. Both systems, Theme and Information, are grammatical resources for relating clauses to their context; therefore they have to be interpreted with respect to the patterns they build throughout texts (Halliday 1985a; Martin, 1992). As Martin notices, the more powerful resource of grammatical metaphor is the possibility of grouping meanings together into Theme and New. It allows for the organization of texts in their contexts. This interaction -Theme New and grammatical metaphor can be seen in text 7. In this text sentences (a) and (e) present a marked structure -realized through the adjunts 'when' and 'without' and the rest are unmarked:

Theme: -unmarked (**bold**)

-marked (***bold italics***)

New : (*italics*)

a) ***When the bell push is pressed,*** *electricity flows through the contact into the electromagnet*

b) **This** *attracts the iron arm of the clapper*

c) **The arm** *moves out on a spring and strikes the gong*

d) **This movement** *breaks the electrical contact and the current stops flowing through the electromagnet*

e) **Without the magnetism**, *the arm is pulled back by the spring*

f) **It** *returns, touches the contact again and returns into the electromagnet*

In this text, grammatical metaphor is strongly associated with Theme. A closer observation of the text will reveal that thematic structure is less numerous than rhematic. However, thematic structure in this example contains several meanings, each theme packing in a single word the new information of the previous rheme. As Fries suggests, (Fries: forthcoming) *"the information contained within the Themes of all the sentences of a paragraph creates the method of development of that paragraph"*. This means that grammatical metaphor is an important tool in the creation of meaning in scientific writing.

Conclusión

The analysis presented in this paper, though limited to a few examples, shows that grammatical metaphor is a semiotic means scientific writers use evently to represent meaning. It also shows that lexis and grammar are interrelated. Furthermore, grammatical metaphor is an important device in the organization of texts giving them coherence, since it interacts with both thematic and informatic structures. It also shows that there is a relationship of lexico-grammatical patterns to the schematic structure of the texts. Understanding these characteristics will help teachers to develop both linguistic and cognitive models to assist students. However, further research is needed that relates lexico-grammar patterns to different disciplines and to different levels of specificity.

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ABSTRACT

This paper examines the role lexis and grammar play in the construction of scientific meanings. It is concerned with the lexicogrammatical mechanisms used to translate common-sense taxonomies into scientific knowledge, or, in other words, with the elaboration process involved to represent abstraction in wording. Such mechanisms have been described in Systemic Functional Grammar (SFG) as the 'grammar of abstraction' or 'grammatical metaphor' (Halliday, 1985a, 1985b, 1988, 1990). With this purpose, some scientific genres have been analysed.

A study of the transitivity system in terms of Halliday's systemic functional grammar shows that the elements of the models studied are frequently not realized congruently (Halliday, 1985a) at the lexicogrammatical level. The most noticeable feature is that the process' element is frequently realised by a nominalisation. Nominalisations appear as participants in relational processes such as 'occur', and 'take place' and as subjects of verbs expressing circumstantial relations, such as 'cause and produce'. They may also appear as agents of other processes. The analysis also shows a strong relationship between lexis and grammar in the construction of scientific meaning and the schematic structure of the text.