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Epistemic and Dialectic Pathway to Knowledge, Meaning and Language Advancement

Maria Tarantino
Dipartimento Interateneo di Fisica
Bari, Italy

1. Introduction

Over the last decade, pragmatists and language for specific purposes (LSP) researchers have endeavoured to shift the focus of language study from the characterisation of the paradigmatic and syntagmatic potentials of linguistic systems to the analysis of how people communicate in the different domains of knowledge and practice. The debate has provided convincing evidence for the inclusion of cognitive and pragmatic strands in discourse and text analysis. Despite the cogent arguments in favour of a holistic approach to language study, linguistic models of scientific writing which explain the genre as an exercise in grammar mechanics and relate its understanding to questions of competence, in every-day speech, are still influential. The descriptions proposed give little weight to the role that discerning minds, technological inventiveness, mathematical concepts combined with experimental interaction, and operative procedures of specialist communities have in modern science and its discursive practices. Occurrence of nominals, in text fragments, is framed as evidence of a strategy used by scientists to objectify nature, depersonalise speech and impede lay people from understanding their texts (cf. Halliday & Martin, 1993). The critique of specialist writing is admittedly issue oriented. It relies on intra-linguistic observations and constrains epistemic, pragmatic and semantic aspects of text production and interpretation within logocentric theories.

The present paper suggests that the objective nature of specialist prose arises from the fact that it relates to phenomena, and practices external to linguistic-system conventions. The discussion traces the roots of the scientific approach to knowledge and discourse back to Aristotle's philosophy and speech categories. It then frames scientific progress as a cumulative enterprise which advances through the contributions of independent minds, investigation of phenomena, development of instruments and techniques, creation of verbal and non-verbal codes sustained by pondered debates. The account demonstrates that, although grammatical competence is indispensable in discursive acts, the meaning of the propositions occurring in specialist texts is determined by extra-linguistic factors. Moreover, in science, the reliability of the affirmations and claims do not depend on the judgement of one individual, but on the inter-subjective agreement of a community of researchers sharing a number of material and conceptual tools. These common elements are used in the same manner by the community members in order to verify propositions, test claims, repeat experiments, improve and expand existing knowledge.

Successful communication in science depends on the intertwining of all these factors in a dynamic texture. This makes the genre complex, multi-levelled, and permeated with ethnographic strands (cf. Hymes 1974). It is therefore concluded that idealistic framing of scientific communication should be invigorated with principles and suggestions from both applied linguistics and applied pragmatics.

2. The rise and consolidation of scientific discourse

Scientific inquiry has been defined as a dialogue with nature which must follow systematic procedures of investigation and draw on mathematical, geometric and verbal codes. To investigate nature, a researcher must know what questions to ask, how to interpret and verify possible answers and how to present findings to peers for reproduction and verification. These heuristic operations rely on cumulative knowledge and are public (cf. Cooper 1969). Therefore, anyone can contribute to scientific progress provided that s/he has the required capabilities, namely disciplinary knowledge, familiarity with instruments, procedural techniques and verbal and non-verbal codes of communication. Since physical phenomena are complex and can have a multiplicity of causes and effects, a scientist usually investigates only one aspect of nature rather than addressing the whole of reality. Obviously, the subject chosen for investigation and the current state of knowledge on the issue of interest influence the operational criteria adopted, the propositions discussed and the validity of the affirmations made.

Science progresses through a dialectic interaction with many protagonists, namely the researcher, nature, instruments, experts sharing knowledge about the specific and interrelated field of inquiry. Besides theoretical and factual aspects, the members of a specialist community share knowledge of techniques for measuring variables, calculating relations and mapping dynamic aspects of phenomena. They must also be conversant with patterns of representation which rely on verbal, mathematical, geometric and graphic channels. The latter are used to analyse and describe phenomena and to report procedures and findings.

Objectivity in science goes well beyond the arrangement of formal structures. It is a pragmatic approach which, among other things, allows scientists to "... build arguments that coerce, by their cogency, the agreement of all who will attend to them" (Booth 1967: 141). The roots of scientific discourse trace back to the principles which were fathered by Aristotle (384-322 BC) and have contributed to the development of scientific knowledge as well as founded the philosophy, language and practices of science.

Aristotle acknowledged the importance of verbal forms in social, economic and academic interactions. He argued, however, that speech should also be framed in consideration of the cognitive and pragmatic activities devised by mankind to contribute both to the welfare of the people and to the meaning-making process. In *Nicomachean Ethics*, Aristotle explains that it is not words that have meaning, but the speaker and listener who mean something by their use of words. Therefore, he entrusts people with the epistemic and semiotic processes underlying communication. The philosopher-scientist argues against theories which give verbal symbols permanent grammatical categories and attribute them ideal values. He demonstrates that the grammatical class of a lexical item is relative to its position and function in a sentence, whereas the significance of each linguistic form depends on speech situation, concrete evidence, crafts and disciplinary domains (cf. Aristotle 1998). In the same treatise, Aristotle draws attention to the different uses and aims of language. He distinguishes 'apophantic' propositions, based on probative statements, from 'emotive' and 'rhetorical' speech forms which rely on emotions and commentary. Through his discussions, Aristotle shifts the focus of language study from form to content and relates speech events to context and interactants. Thus, he anticipates notions of speech act, semantic and pragmatic principles, which have been debated and developed in depth in the last decades.

In *Posterior Analytics*, a treatise devoted to science, Aristotle states that "every method and every knowledge starts from previous knowledge" (Aristotle 1924:I-18, 81[a], 35). He defines scientific research as a journey from what is more obscure by nature towards what is more clear and knowable through investigation. Thereafter, he roots this process of discovery in the intertwining of experience, sensation and observation of natural phenomena with inductive and deductive reasoning. Aristotle then states that scientific explanations of natural processes should be filtered through a discussion among people sharing concepts and know-how in the particular area of knowledge or craft. He explains that the dialectic process will ensure that the claim made be validated either by everyone or by the majority of the wise. In this framework, the members of a task-based community transform, convert and develop existing knowledge through a dialogic approach. The latter involves the researcher-reporter, systematic analysis of physical events, considerations and contributions of other experts in the field of knowledge. The debate will, thus, result in epistemic, dialectic and pragmatic expansion for all the participants.

Aristotle names the discourse of scientific inquiry **Episthemonikos**, i.e., knowledge making discourse. He associates this speech type with the purpose of understanding, explaining, classifying natural processes as well as establishing inter-relations between phenomena, objects and organisms observable in the physical world (cf. Adler 2002).

In Aristotle's framework, Episthemonikos has the following protagonists:

Users	Field-experts discussing evidence and exchanging opinions;
Ends	Discovering causes and properties of physical phenomena;
Proofs	Observation and comparison of different views on a specific subject drawing on evidence, reasoning, analogy and concrete examples;
Time	Present related to stative and ergative categories and propositions.

Episthemonikos differs from the discourse types described by Aristotle in his *Rhetoric* (cf. Tarantino 1998), in so far as both the reporter and the reader have an active role in the meaning-making process; the topic is external to the interlocutors; and the evidence is based on observation of concrete facts supported by logical inference and reasoning. These elements allow for the content of this variety to be in constant evolution.

Aristotle applied the method of investigation and discourse he had theorised in a series of books that form the foundation of biology. The most well known is his *Historia Animalium* which describes the life style of hundreds of species of animals "… how they breed and reproduce, where they are found, and how they interact" (Adler 2002:22). He based his descriptions on direct observation of living creatures and dissection of cadavers as well as on discussions "… with philosophers, fishermen, farmers, travelers and other people with first hand-knowledge of animals" (Adler 2002:23).

Aristotle's empirical treatise on natural philosophy and discourse were seminal for the scientific revolution in the Renaissance. The enlightened men who, in the seventeenth century, gave course to modern science wanted to organise knowledge on logical bases and to explain natural phenomena and their relations drawing on systematic and factual evidence. Thus, they adopted and adapted the speech genre which could best help them: "... to apply Reason to Imagination for the better moving of the will" (Bacon 1955:X).

Through their empirical work and discussions, Bacon (1561-1626), Galileo (1564-1642), Descartes (1596-1650) and Newton (1642-1727) innovated Aristotle's approach to knowledge. They fused philosophic and empirical strategies with techniques from mathematics and geometry. They argued that investigation and discussions of natural phenomena could be improved, firstly, with the use of technical tools, which could extend the senses; secondly, with the reproduction of phenomena under study in experimental conditions; and, thirdly, with the validation of results through further experiments enriched with reasoning and discussions with peers (cf. Galileo 1938).

Galileo is recognised as the first scientist who actually added perspective to Episthemonikos or rational speech and adapted it for the needs of modern science. He stated that the purpose of scientific work and argumentation is not to make man virtuous, but wise. He argued that, in order to understand natural phenomena, one should not confront the opinion of authorities, but observe nature directly and reproduce the process through experimental means, measure its physical properties and open the argumentation, results and claims for public discussion. Galileo defended the right of science to investigate, explain, order and classify the phenomena and laws which govern nature. He ventured into this enterprise by observing physical events and establishing their properties in relation to space-time co-ordinates which he established through the use of appropriate instruments. Thus, he introduced a new method for doing and discussing science (cf. Tarantino 1999).

In the Galilean method, intellectual and manual faculties have a primary role. The main elements of the dialogic interaction which frames scientific research, are in fact the inquiring mind, the acting individual, nature and a method of investigation shared by the disciplinary community members. The latter will ascertain the reliability of the propositions and claims reported by the follow researcher. In addition, they will judge whether the task has been conducted according to accepted rules so that the investigation can be successfully repeated (cf. Galileo 1938). Over time, the systematic working-model originated by Galileo has been improved and its current guiding elements are shown in Fig. 1.

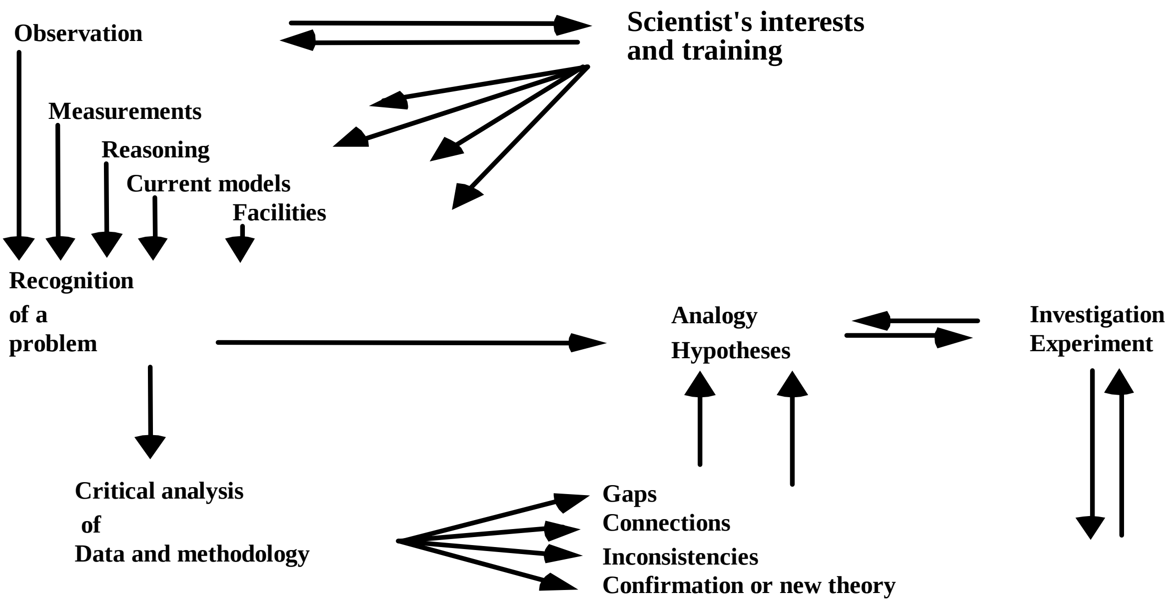


Fig. 1: Observation strategy in science

The heuristic activities reported in the diagram, or more precisely the epistemic, semantic and pragmatic content embodied by the various elements of the decisional course, highlight the dialectic process which establish between mental, dialogic and experimental tasks in the various phases of a scientific inquiry. Obviously, the current status of each element will influence the thematic and functional units of a specialist report as well as modulate the researcher's stance. Following Galileo's teachings, the discussion of scientific findings must be enriched with visual representations of the process investigated and of the instruments used. Consequently, these elements add other thematisation foci to the text (cf. Lemke 1998).

3. From shadows to light

Human kind has always been keen to understand natural phenomena and to employ the information obtained through experience and observation for useful purposes. A telling example of these characteristics is related to phenomena produced by sunlight. Primitive societies learned to use the shadow cast by the sun at different times of the day to establish both the parts of the day and the season of the year. This information was then used to organise daily-work routine and to plan migration and agricultural schedules. In order to have more objective information, they devised the gnomon or sundial which is considered the earliest instrument found in almost every culture (Fig 2.).

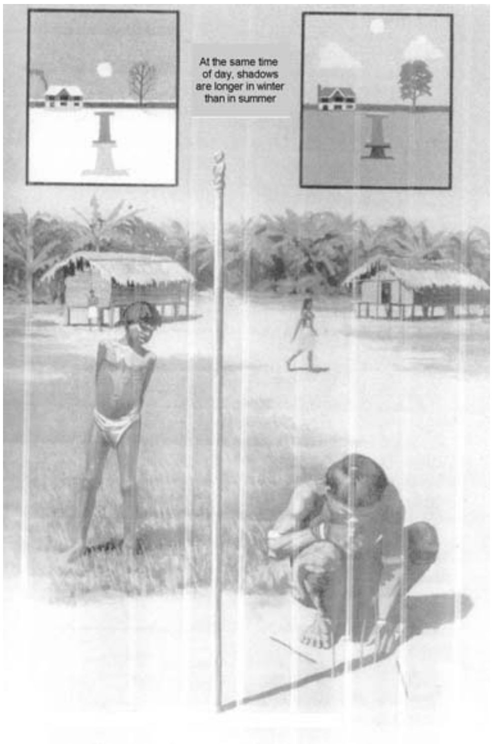


Fig. 2: Primitive tribesman measuring the shadow of a gnomon

Although very simple, the gnomon was a useful tool in the development of scientific knowledge. In ancient Egypt, Eratosthenes (220–140 BC) used the device to gauge the angle of the shadow cast by the sun in different locations and at different times of the day. With the help of a human ***pacer*** - a man who was trained to pace out distances by walking in steps of equal length, counting as he went -

Eratosthenes then calculated the difference in the shadow cast at the same time of day in two different locations and the distance between the two places.

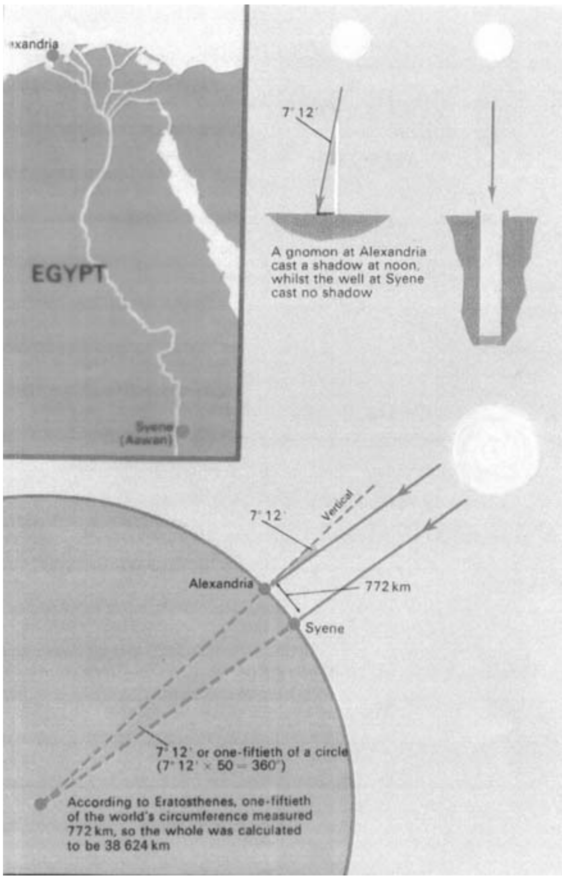
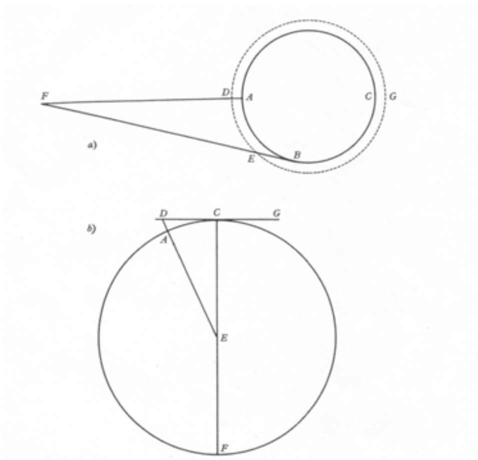


Fig 3: Eratosthenes' experiment

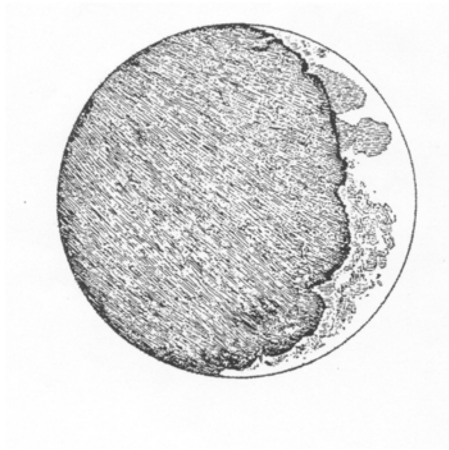
He used the information collected in geometric projections which led him to compute the circumference of the earth, with surprising precision considering the simple method used, and to speculate about the planet spherical shape and other properties.

In 1610, Galileo observed shadows on the moon surface by means of his telescope. Drawing on the teaching of Arab astronomers and Euclidean geometry, he projected the shadows through geometrical figures and calculated their dimensions (Fig. 4). From the results, he postulated that the 'heavenly body', whose surface was believed to be smooth as a mirror, was covered by mountains and craters similar to those existing on the earth. With admirable art, he mapped the moon surface (Fig. 5). He then extended his research to other planets and defended his discoveries and claims with considerable rhetorical and argumentative skills. Through his discoveries, Galileo started the Copernican revolution which influenced changes in human perception and in every branch of knowledge and discourse (cf. Adler 2002).



Galileo’s projections of the shadows detected on the moon surface

Fig. 4



Galileo’s map of the moon surface

Fig. 5

Following the Galilean method and using the information and diagrams found in the *Dialogue Concerning the Two Chief World Systems*, Newton conceived his *Principia*, the treatise in which he developed the law of universal gravitation (cf. Drake 1980). Then, he brought about one of the most fruitful innovations in philosophic and scientific thought. Newton was curious about the nature of light and colour, thus, in a series of brilliant experiments, he passed a ray of white light through a glass prism and detected shadows of different colours projected onto a screen. Through geometric representations and mathematical measurements, he identified the properties of each shade and defined the colour spectrum (Fig. 6). Newton confirmed his findings by recombining the colours of the dispersed light through an inverted prism whereby he obtained white light again. Thus, he hypothesised that white light is composed of all the colours in the spectrum (cf. Newton 1952).

The technique devised by Newton and the conclusions he reached opened science to infinite horizons. The development of spectroscopy and the application of its principles and techniques in investigating the macro- and micro-world has changed knowledge about sidereal bodies, living organisms and minerals and has greatly changed as well as expanded linguistic repertoires.

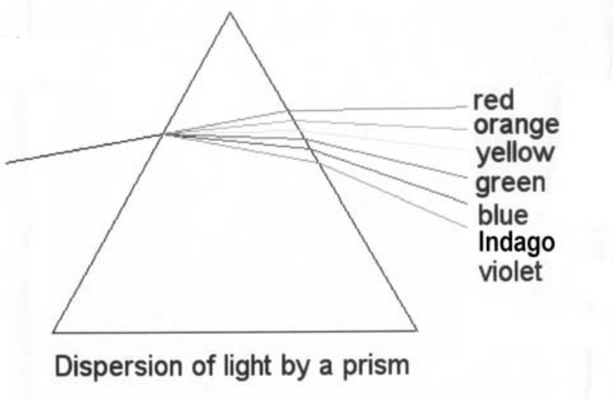


Fig. 6

Following the procedures suggested by Galileo, Newton and Bacon, scientists have devised complex instruments, concepts, and terms and brought their inquiry into:

- … the realm of the directly accessible material world of objects and properties that can be sensed unaided.
- … the realm of those things which can be accessed through instrumentation. These are initially proposed through logical reasoning.
- … the realm of those things which are beyond sensory experience and instrumentation but are accessed through logical reasoning alone.

(Monk 1994:131)

Information has accumulated on the bodies that populate the universe, on physical phenomena which occur on our planet, on the constituents of life and matter, on the causes of diseases, and on their treatment. The most spectacular contributions have been made in the subatomic realm. Even in this enterprise, shadows have had a major role in shedding light on fundamental questions about the cosmos, matter, life, and evolution.

The blotches left by uranium salt on a photographic plate, first observed by Henry Becquerel (1852-1908), led Marie Curie (1867-1934) to speculate about the possible release of energy from the metal. To verify her suppositions, she carried out experiments which confirmed her hypothesis and opened new avenues of thought, research and applications. The scientist's creative mind not only contributed to the discovery of subatomic particles and their interactions thus establishing nuclear physics as a new discipline, but also enriched the scientific vocabulary and language in general. M. Curie coined terms such as 'radioactive', 'radioactivity', 'disintegration' and 'transmutation' to describe the phenomena she had observed through her experiments and applications (cf. Adler 2002). In their turn, these concepts have led to the generation of other semantic fields.

The episodes which led to the detection, identification and determination of the deoxyribose nucleic acid (DNA) molecule can offer a striking example of how scientific knowledge advances as well as of how new verbal and non-verbal codes are generated. A brief reflection on the step by step contributions which brought about the characterization of the DNA molecular configuration can also give stringent evidence that science is a cumulative and cooperative enterprise.

3.1 Dialogic journey to the origin of life

The first step in the definition of the basic elements of life came with the finding by Hooke (1635-1703) that the structure of cork was composed by walled cavities which he termed 'cells' (cf. Nurse 2000). With the development of more powerful microscopes, biologists and botanists gathered evidence on the similarities between the basic constituents of plants and animals and became more and more convinced that all organisms are composed of cells. Then, in 1859 the physiologist Virchow (1821-1902) postulated the now famous: '*Omnis cellula e cellula*' that is,' every cell comes from cells' thus establishing cells at the core of all vital processes. This launched researchers into a relentless quest to understand and reveal the cell mechanism and features.

The nucleic acid, now termed DNA, was first detected in puss cells in 1869. However, at the time, biochemistry was in its infancy, crystallography had not been incorporated into the life sciences and no microscope powerful enough had been devised to identify the structural conformation of the acid. The 'tetranucleotide' structure or chain structure of the organic compounds constituting the molecule was tentatively proposed in 1919. Then, with advancements in biochemistry, the acid influence on heritable changes was hypothesised in 1928. The chemical composition and genetic properties of the molecule were finally identified in 1944 (cf. Adler 2002). However, the structural characteristic of the molecule remained a mystery until 1952 when Rosalind E. Franklin identified two forms of DNA which she termed *A* and *B*. The skilful use of X-ray diffraction techniques and principles helped the young scientist to obtain an excellent X-ray diffraction pattern of structure *B* (cf. Franklin 1953:740). It was the interpretation of the shadows, found on the photographic plates obtained by Franklin (Fig. 7), sustained by geometric intuition, that led Watson and Crick to devise the double helix structure in 1953 (Fig. 8) and to postulate other characteristics of the molecule (cf. Watson & Crick 1953).

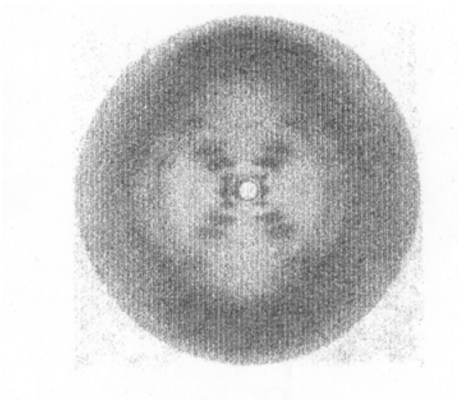


Fig. 7

R. Franklin: X-ray diffraction image of the deoxyribose nucleic acid molecule

Fig. 8

Watson & Crick: diagrammatic representation of the double-helix DNA structure

Nature, April, 25th 1953

The pattern they suggested drew on mathematical and geometric representation and on chemical descriptions of the acid which had tentatively been proposed by members of the research community through the previous decades. Watson and Crick refined the model, suggested the double helix structure and focused on some convincing implications of their representation. Yet the double helix proposal remained speculative until 1961 when the DNA molecule was sequenced and reproduced in laboratory experiments and the characteristics of its genetic material were determined (cf. Olby 2003). Since then, molecular biology and genetics have broken new grounds in the understanding of biological molecules, their influences and control with consequent changes and advancements in most fields of research. The discovery and description of the DNA structure show that science progresses through gradual approximation, partial understanding and evolving definitions.

The tentative nature of scientific claims and discourse is well exemplified by Watson and Crick's speculative statement about their model:

> It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.
>
> (cf. Watson & Crick 1953:737)

More than demonstrating humbleness on the part of the authors, the statement intends to signal to the community both the tentative hypothesis they were working on and the possibilities for future developments it implied. The expression also suggests that, in writing scientific reports, researchers obey Grice's cooperative principles. To this purpose, the morphosyntactic, semantic and rhetorical choices they make are in accordance with the categories of **quantity**, **quality**, **relation** and **manner** (cf. Grice 1975).

The degree to which Grice's maxims hold in a particular community and in relation to particular sphere of knowledge is thus important for the understanding and description of discourse patterns. In scientific writing, the category of **quality**: "Try to make your contribution one that is true …" and its maxim "Do not say that for which you lack adequate evidence." (Grice 1975:46) appear to have a relevant role. The importance of this maxim is highlighted by Franklin's comment about the effective knowledge of the DNA structure in 1953:

> …the X-ray evidence cannot be taken, at present, as direct proof that the structure is helical, other considerations discussed below make the existence of a helical structure highly probable.
>
> (Franklin 1953:740)

The scientific community was aware that many problems needed to be solved before the helical structure could be accepted as a fact. Scientists learn the principles of the scientific method through their academic training. At the same time, they become aware both of the probabilistic nature of scientific claims and of the need to use concrete arguments in describing findings and procedures. They are also taught that floundering the cooperative principle maxims can bring about loss of credibility for the individual researcher as well as cause a waste of time for the community.

The researcher-author knows who his/her interlocutors will be and writes with specific purposes in mind. S/he is aware that the fate of his/her work depends on the fruitfulness of the findings, or better, that the audience is more interested in facts and ideas which can improve methods of analysis and instruments than in 'empty words'. In discussing his/her research, the researcher, tries thus to avoid ambiguity and aid comprehension by defining technical terms carefully, by using examples, analogies and imaginative expressions. Besides appropriate language scientific communication relies on illustrations which can clarify techniques, tools and images which are too complex to be conveyed by linguistic structures alone (cf. Alley 1987).

4. Toiling for terms and discourse adequacy

Scientists are aware of the importance that the written and oral modes have in their work. Thus, they toil to find precise verbal forms to express their thoughts and describe their findings. They also know that appropriate use of language forms is fundamental for effective communication as well as a means for knowledge development. Lavoisier (1743-1794) states this clearly:

> Languages are intended, not only to express by signs, as is commonly supposed, the ideas and images of the mind; but are also analytical methods, by means of which, we advance from the known to the unknown, and to a certain degree in the manner of mathematicians…
>
> (Lavoisier 1788:4-5)

This awareness about the importance of language makes scientists particularly attentive in naming physical entities and in organizing explanations about the nature, causes, effects and consequences of physical phenomena (cf. Hacking 1997). In every branch of science, the choice and/or creation of technical terms to refer to either to concrete objects and their properties, or to theoretical entities is a slow, complex intellectual and semiotic process which may build on the contribution of experts in different fields as well as draw on discussions which may extend over centuries (cf. Duhem 1989). For instance, the coining of the term 'oxygen' by Lavoisier evolved from discussions and experiments. The gas which had attracted the attention of many scholar, had first been named 'fat earth', then re-termed 'phlogistone' and finally 'dephlogisticated air'. The debate had engaged scientists from different linguistic background for over two centuries when through appropriate experimentation, measurements and verification was satisfactory defined and given the appropriate name (cf. Tarantino 1999).

In scientific domains, the choice of terms is founded on Aristotle's categories and relates to meaning which depends on physical visual, tactile, motor and other properties of objects or entities referred to. The term may reflect:

> what (or Substance), how large (that is Quantity), what sort of thing (that is Quality), related to what (or Relation), where (that is Place), when (or Time), in what attitude (Posture, Position), how circumstances (state of Condition), how active, what doing (or Action), how passive, what suffering (Affection).
>
> (Aristotle's *Categories IV*)

The Greek philosopher applied these categories in deciding the names for the over six hundred animals and plants that he studied and classified. Thus, he started both biology and systematics. With the subdivision of science into many branches, scientists have devised systematic approaches of nomenclature and terminology which reflect observed morphologic aspects and/or physico chemical- properties of the entities studied and classified.

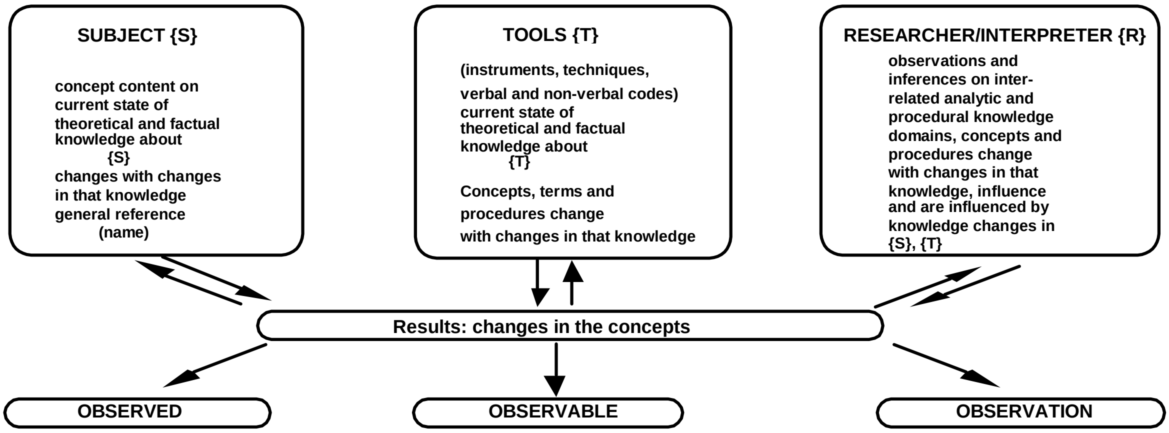


Fig. 9: Components: semantic interaction and conceptual change

The meaning refinement and term definition, besides direct observation and verification of the phenomenon studied, rests on a dialectic exchange between the components of the knowledge advancement effort (Fig. 9). The Subject (S) is the object of study for example 'common salt', in technical expressions, sodium chloride (NaCl). The Tools (T) are the intellectual strategies, operative steps and instruments used to establish and verify the properties of the chemical compound. The Researcher/Interpreter (R) is the generator of the evolutionary process. In the investigation and description of the substance, R draws on knowledge from interrelated disciplinary domains as chemistry, crystallography, physics, mathematics and geometry as well as from X-ray diffraction techniques, previous and on-going discussions about the substance.

The state of knowledge of each component will influence discourse production and interpretation by governing the cognitive aspects of communication which are responsible for non-linguistic factors of coding and de-coding, such as implicature, entailment, presuppositions, speech acts and text structures (cf. Levinson 1987). Clearly, scientific progress builds on existing disciplinary knowledge and relies on the researcher's mental and manual abilities. Through problem posing and solution-seeking strategies, the scientist aims at discovering new data which prove or disprove the adequacy of existing patterns of analysis and/or theories regarding specific aspects of nature, and when possible improve data and models.

In the quest for a better understanding of reality, however, the scientist must always bear in mind "... that the ground of our opinion is far more custom and example than any certain knowledge" (Descartes 1967:703). Consequently, to avoid discrepancies and errors due to subjective influences, the researcher has to adhere closely to the model of analysis accepted by the scientific community, back up his/her perceptions with quantitative and qualitative data and support his/her inferences by factual proofs. In other words, to provide grounds for the claim advanced, s/he must separate feelings and desires from the findings reported and present the discussion in "...an environment that he objectifies in the third-person attitude of an observer" (Habermas 1979:66).

In this effort, scientists must also take into account that 'the observed system' and 'the observer' are interdependent entities. To avoid covert influences, they must abide by the principles of science and report exact quantitative measurements and true to fact claims. At the same time, they must adhere to the principles of rhetoric which demand that "…the audience be informed as efficiently as possible, and that the reporters stay honest" (Alley 1987:15). In this perspective, the researcher will communicate his/her findings through: "Constative speech acts (which) contain the offer to recur if necessary to the 'experiential source' from which the speaker draws the 'certainty' that his statement is true" (Habermas 1979:63-64, original italics). In order to reflect 'tacit knowledge' and to display evidence, the propositions must be related to one another and to the world they represent. Hence, through factual or content- and language-true statements, (cf. Preti, 1953) the researcher tries to secure transparency to the investigation and cognitive validity to each step of his/her presentation.

Even though touching on a limited number of scientific innovations, the considerations proposed above demonstrate that scientific progress builds on shared knowledge, intelligible information and repeatable experiments. The Galilean method has actually established scientific research as a 'public activity' as well as strengthened the role of the audience in the communication process. It is the audience that will provide validation for the evidence presented and accord consensus to the claim. Through further investigation and discussion, the disciplinary community will then endeavour to improve the findings and/or change them (cf. Toulmin, 1972). The discussants can contribute to the improvement of a report by offering informed criticism since they have a thorough understanding of the subject matter and of the material and instruments used for the investigation. At the same time, they can acquire knowledge and be guided to setting new problems and making new discoveries. This combination of activities makes scientific discourse a heuristic enterprise where all the protagonists can participate to meaning, knowledge and language evolution. Each member of a scientific community can partake in the ongoing discussion and open new paths of thought, research and communication.

5. Issue-oriented frames of scientific discourse

In recent decades the language of science has interested researchers of different disciplines among which theoretical and applied linguists. The latter have attempted to provide models of analysis and description which have tended to emphasise the role of formal structures in text organisation while neglecting the contribution of extra-linguistic strands in the process of discourse construction and interpretation. A most singular description of scientific discourse is the one proposed by the systemic functional linguistic (SFL) school, admittedly "… evolved as a tool for participating in political processes" (Halliday & Martin 1993:22). The purpose of the linguistic investigation is "not just to remaking science as a humane endeavour, but also developing new analytic perspectives for critiquing science"(Halliday & Martin 1993:*x*). The idealistic approach suggested relies on the deconstruction of fragments of scientific texts:

> … deliberately sidestepping the question of the role of mental organs in human behaviour—but with semiosis as the resolution of engagement of physical biological and social resources (i.e., consciousness) in our species.
>
> (Halliday & Martin 1993:23, original parentheses)

The analysis proposed is presented as a means both to disambiguate the meaning of terms and to understand "how the patterns relate to what the scientists were trying to achieve" (Halliday & Martin 1993:82). In the descriptions elaborated, the role that independent minds, inventiveness and manual skills have had in the development of scientific discourse is underplayed while the occurrence of targeted nominals is emphasised and considered as a mark of elitism. The 'syndrome' which characterises scientific discourse is localised in the occurrence of terms such as *radiation*, *transmutation* and *refraction*, which are classed as derivational nouns in theoretical grammars. On the basis of this classification, these terms are described as deviations from everyday language structures and then defined as 'virtual entities', 'dummy things' used for taxonomic purposes (cf. Halliday & Martin 1993).

The definition is elaborated in absence of ethnographic considerations and with little reference to the scientific and linguistic principles which govern lexical choices and determine meaning in science. According to Lavoisier, the scientist who systematised chemical concepts and terminology in reference to evidence, in scientific contexts terms as *sublimation, crystallization, distillation, condensation*, signify both the transformation of a substance and the end products of a process (cf. Lavoisier 1788). Such expressions should thus be classified grammatically as nouns which refer to ongoing processes having observable causes and effects or better as 'second order entities' which, as explained by Lyons, have observable results and temporal duration (cf. Lyons 1994:445). To categorise the concepts embodied in terms which have visible effects as "grammatical metaphors" or virtual items used by the scientist to construe reality as an edifice of 'static things' seems not to be adequate to improve understanding either of the terms or the discourse genre.

Good scientists are usually very accurate in choosing word which can depict better the phenomenon or process they are describing and in forming propositions which can clearly represent perceptual strategies and conceptual relations woven in their texts. They are aware of the importance that words have in representing the sequence of a phenomenon, in calling forth concepts and in expressing them. At the same time, they know that in writing, interpreting and validating research reports:

> "It is impossible to dissociate language from science and science from language…"
>
> (Lavoisier 1788:288).

As explained above, in science, the creation of terms and the organisation of texts is a dialectic game involving many partners: natural processes, the researcher-inquirer, other members of a research community, and instruments used to investigate physical objects. Scientific discourse relies on the solutions of mathematical equations which can only be approached through the written mode. The discourse of science should be framed not as a monologue, or assimilated to oral speech, but as a debate which, through the written mode, takes place between experts who share know-how, interests, and purposes of their disciplinary area and who may belong to different generations and cultures. Scientists do not create knowledge ex-novo, they reflect on what is known and through intellectual and manual activities they transform, convert, and develop information. In so doing, they enrich the epistemic, semantic, and pragmatic dimensions of language and communication. To make effective understanding of the genre solely dependent on grammar mechanics trivialises the efforts made by humankind to develop language structures adequate to refer to the external world and to respond to their intent and purposes.

Scientific discourse, as any discourse type linked to a profession or trade, should not be equated to everyday speech or popular-science prose. The content matter of specialist reports builds on different sources of knowledge, hence, it cannot be properly understood by people not trained in the specific field of research and application. Lay people can repeat technical terms in speech or writing. However, since they are unaware of the non-verbal dimensions which technical expressions embody, they lack the knowledge required to evaluate the reliability of a scientific text, criticise or expand its content. In other words, they will not be able to appreciate the specific information that the text builds on and the expectations it implies. The objectivity of scientific reports does not depend on idiosyncratic choices on the part of the writers, it arises instead from the philosophy and method of science and from the purposes shared by members of disciplinary communities.
Logocentric descriptions of scientific discourse which constrain science within abstract linguistic rules and ideological frames miss accounting for the endeavours that, through the ages, generations of researchers, from different cultural backgrounds, have made to liberate human thought and knowledge from such constrains in order to better understand nature and society and to improve work and living conditions.

6. Conclusions

The study has demonstrated that advancement in science is driven by reasoning, doing, making, arguing and intervening (cf. Hacking 1997). Researchers intervene in setting conditions to recreate phenomena, in determining their properties, in mapping their structure through geometric representations and in naming them. They make observations, draw inferences, carry out experiments, manipulate materials, take measurements, create conditions, set-up situations, and construct instruments with varying degrees of precision. Their quest to better understand nature is a never ending enterprise which builds on approximation and partial explanations. Each researcher is aware that scientific truth is never final; what s/he aspires for is 'moral truth', a truth which is relative to the status of the research components (cf. Newton 1952). As a consequence, scientific activities, findings and claims are represented through verbal and non-verbal codes that are tentative and in constant evolution.

Science is universal for its method is independent of the idiosyncrasies of the individual inquirer; objective since it tries to be in agreement with the facts of nature; intersubjective since its claims rest on consensus by disciplinary communities; progressive since subsequent development of scientific knowledge builds on accumulated knowledge.

More reliable models of scientific discourse cannot be based solely on the morpho-syntactic forms featured in sample texts, they should be in light of suggestions coming from philosophers of language, pragmatists, relevance theorists and LSP researchers. These scholars have shifted the attention of language studies from grammar forms to the people who use them for actual interactions. They have opened linguistic studies to aspects of meaning which arise from extra-linguistic strands of discourse. To this purpose, they have separated 'mere speech' from informative discourse practises. On the one hand, their discussions emphasise the prevalent social function of everyday conversation and its feeble links to truth-conditional requirements. On the other, they attribute discursive events propositional and heuristic propensities and link the process of communication to observable phenomena, epistemic, cultural and operative worlds. These variables should be included in discourse analysis so that the contribution of humans who think, act and discuss in order to understand nature, improve living and work condition and facilitate communication may have the attention it deserves in the language sciences.

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ABSTRACT

Epistemic and dialectic pathways to knowledge, meaning and language advancement

Maria Tarantino
Dipartimento Interateneo di Fisica, Bari, Italy

The paper emphasises the propositional and heuristic nature of scientific discourse and relates the meaning-making process to epistemic, procedural and dialogic strategies shared by members of disciplinary communities. It suggests that this sphere of communication is in constant evolution due to the informative and innovative thrust that each contribution provides to a common explanatory endeavour.

The discussion traces the foundation of the knowledge-making approach to discourse in Aristotle's work. The Greek philosopher defines scientific research as a journey from what is more obscure by nature towards what is more clear and knowable through investigation. He roots the process of discovery in the intertwining of experience and observation of phenomena with actions, cognitive and verbal strands internal to disciplinary worlds. Moreover, Aristotle maintains that advancement in any field should be filtered through a discussion among people sharing concepts and know-how in the particular area of knowledge or craft. In this framework, the members of a task-based community transform, convert and develop existent knowledge through a dialogic approach which involves the individual researcher, systematic analysis of physical events, considerations and contributions of other experts in the field.

The study then explains that since the Renaissance, scientists have followed and expanded Aristotle's approach to knowledge and discourse. The advancement has thriven on the fusion of empirical and scientific research sustained by mathematics, geometry, technical props and systematic experiments. This method has rendered the investigation, modelling and description of natural phenomena more reliable and open to verification by the expert-community. At the same time, it has enriched scientific terms, texts and language with disciplinary semantic and pragmatic dimensions, thus, making the genre universal, objective, rational, true and open ended.

Through reference to actual scientific discoveries, the paper demonstrates that technical concepts, terms and texts build on accumulated knowledge, independent thinking, principles, theories, practices, verbal and non-verbal codes of research domains. It indicates that scientific writing has its own goals, problems and constraints which rule questions of precision, clarity, truthfulness, familiarity, imagery and fluidity of expression. The discussions provide support for models of language study which challenge linguistic determinism and argue for descriptive approaches which include humans who think, act and discuss in order to understand nature, improve living and work conditions and facilitate communication.

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