Chapter 4
Towards a More Epistemologically Valid Image of School Science: Revealing the Textuality of School Science Textbooks

Kostas Dimopoulos and Christina Karamanidou

School Science and Science in the Public Field

Science as a body of knowledge transported from the initial context of its production to other contexts, such as that of school or the public field, is subject to selective transformations which substantially changes its epistemological image so much so that we can essentially talk about two discrete bodies of knowledge rather than a modified body of knowledge (Tsatsaroni & Koulaidis, 2001).

Many years of research (e.g., Knain, 2001; Matthews, 1994; McComas, 1998) concerning the epistemological image of school science have resulted in certain basic conclusions. According to these conclusions, school science as presented in science textbooks is static and final. Also, in many cases, it is presented as ahistoric, beyond doubt, universally applied knowledge, discovered[1] by intelligent, individual scientists with no self-interest, after painful efforts, which are ultimately crowned with success.

As mentioned by Kuhn (1970), school textbooks present the 'paradigm' of each scientific area. In the majority of cases, using the concept categories that Masterman (1970) identified as attributable to the term "paradigm," what dominates is the philosophical paradigm, i.e., the basic ontological perceptions such as the certainty of the existence of fields, electrons, and other entities constituting the scientific universe.

Conversely, what seems to be absent from school textbooks is the notion of artifact paradigm, i.e., the paradigm corresponding to legitimate models of solving

[1]The term "discovery" is of great epistemological significance as it implies that scientific truths preexist and are waiting to be discovered. Conversely, terms such as "invention" or "results" openly imply the involvement and contribution of the scientific community and the construction of scientific knowledge.

K. Dimopoulos (✉) • C. Karamanidou
University of Peloponnese, Damaskinou & Kololotroni Str, Korinthos, Greece
e-mail: dimop@uop.gr; ckaramanidou@gmail.com

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Table 4.1 The most important epistemological differences between school science and science in the public domain

School science	Science in the public domain
Static – final	Dynamic – in the making
Ahistorical	Evolutionary/innovative
Beyond doubt/above controversy	Under negotiation/controversial
Free from conflicts of interest/insulated from motives – a product of cognitive effort exclusively	Under the influence of interests
Universally applied	Locally applied/depending on the context
Linear – deterministic	Nonlinear – reflective
Generated by individual scientists	Generated by multidisciplinary teams of collaborating experts
Linear path to a successful conclusion	Regressions between successes and failures

scientific problems. This is due to the fact that scientific knowledge is presented as a "ready-made solution" rather than "an open question to be answered." Also absent is the sociological paradigm, i.e., the whole of commonly accepted rules of social negotiation of knowledge within the scientific community since as it has already been mentioned school science is presented as unquestionable.

In conclusion, the basic characteristic of school science is its transcendency and, consequently, the concealment of evidence which can corroborate the idea that it is a "construction" or a product resulting from processes taking place in the context of specific epistemic, cultural, political, financial, or other influences.

On the other hand, science in the public sphere is mainly presented due to its adhesion to other areas of human activity and culture such as politics, economy, and ethics or due to its innovative character (new scientific theories, technological innovations). Moreover, science usually enters the public domain due to controversies that occur both within the scientific community as well as between the scientific community and representatives of other social institutions or finally due to the challenge and/or the protection from modern risks (Dimopoulos, 2001).

The aforementioned reasons dictate the epistemological image of science in public. Science in public constitutes a complex, dynamic body of knowledge which is frequently in question, under constant social negotiation, dependent on the specific circumstances of its implementation framework and is formed based on the collaboration of multidisciplinary groups of specialists and a number of regressions between successes and a multitude of failures.

In the public domain, the influence on science of various interests coming from different actors or pressure groups, e.g., industry, governments, international organizations, citizens' societies (civil society organizations), and nongovernmental organizations, is more than evident.

In Table 4.1, the most important epistemological differences of school science with science in the public domain are presented.

The characteristics listed in the above table are possibly not the only ones, but they suffice to establish the view that school science and science in public constitute two discrete and divergent bodies of knowledge.

Based on the conclusions of a series of modern ethnomethodological studies deriving from the current sociology of scientific knowledge (SSK) (e.g., Knorr-Cetina, 1999; Latour & Woolgar, 1979; Pickering, 1984) and focusing on how the scientific community practices the formation of techno-scientific knowledge, it seems that the image of science in the public sphere is more representative of the way techno-scientific knowledge is really produced within the context of the current social conditions than the image of school science.

In order to further illustrate this point, the theory of Gibbons et al. (1994) concerning the contemporary way of production of techno-scientific knowledge should be mentioned. According to this theory, after the end of World War II, a dramatic change occurred in the way of production of techno-scientific knowledge. This change is described as a simple transition from Mode 1 to Mode 2 (the terms are introduced by Gibbons et al.). Mode 1 corresponds to what traditionally is called *academic science and technology*, the main characteristics of which are (Ziman, 2000):

- The search of universal laws in favor of the objective truth
- The handling of techno-scientific problems by individual expert scientists
- The restriction of techno-scientific work to academic-type institutions (e.g., universities, academies)
- The relative autonomy of techno-scientific research from its duty to be accountable to various social agents

Conversely, Mode 2 corresponds to what is called *post-academic science and technology* (Gibbons et al., 1994; Ziman, 2000) which refers to a new way of production of the equivalent knowledge. This way is gaining ground during the last decades against the *academic science and technology* to such an extent that currently it is considered dominant. The main characteristics of Mode 2 are:

- The search for practical solutions to real-life problems of limited scope
- The handling of problems by numerous scientific groups which are comprised by experts from various techno-scientific fields
- The conduct of techno-scientific work within the context of nonacademic organizations and especially organizations which relate to state and business interests
- The requirement of the techno-scientific research to handle available resources with effectiveness and be accountable for its results to various social agents (public, governments, private interests, etc.)

It is evident from the above analysis that the description of science in public (e.g., as presented in the mass media) is closer to the "post-academic" mode rather than the traditional academic one. Equivalently, school science (as it is presented in school science textbooks) seems to be more compatible with the "academic" mode.

This epistemological image in school science textbooks is constructed through the frequent use of certain rhetorical means. The term "rhetoric" in this case refers to the means of persuasion and building consensus which are used by school textbooks in order to establish the truth of the allegations projected through them (Gross, 1996).

The aforementioned are linguistic means used for the formation of equivalent concepts. Their effectiveness lies in the fact that through frequent use, the means are internalized by the students as the canonical language of natural sciences and are normalized, thus, making their "rhetoric" function invisible.

Consequently, a substantial move towards the direction of changing the epistemological image of school science so that it becomes more compatible with the nature of science in public would require the drastic refutation of this "rhetoric" and the adoption of alternatives in its place.

The Concealment of Textuality of School Science Textbooks

The image of the natural sciences in school, as described in the previous section, is constructed based on a series of "rhetoric" means which converge into an effort to present the relevant school texts as self-referential, a monologue which conceals its textuality and, thus, its constructed nature. These means enhance the absolutization of school knowledge and the conversion of the school textbook into a "symbol of knowledge."

The most important of these means are:

(a) The *concealment of the subjects of scientific action* via the frequent use of verbs in passive voice, in third person singular or in plural form, using physical entities or their relationships between them as subjects. Furthermore, declaratory statements as well as the lack of references to parallel texts, sources, or alternative views.

These means attempt to withdraw subjects' (e.g., scientists) actions from the scene and therefore the contribution of scientists in the process of formation of scientific knowledge.

Conversely, emphasis is put on the specific given, ahistorical, and realistic character of physical entities and the deterministic laws that govern their behavior. According to Woolgar (1988a, p. 69), the impression given is "as if scientists simply stumble upon eternally pre-existing truths which have until now not been discovered."

In fact, it is an attempt to form a belief of metaphysical realism, a belief according to which natural-scientific entities and laws correspond to entities and structures of the natural world.

For example, in the excerpt that follows, the impression that is given is that there is an anonymous narrator which can be identified in the minds of the reader as the "voice of the textbook" or "the voice of the whole scientific community" which describes the

way in which the natural world works. The use of third person singular decisively contributes to this rhetoric result, which brings references to entities and the relationships described to the foreground (e.g., a planet which has potential energy, a revolving electron, a taut string which has potential energy, bodies regaining their original state), as well as the use of passive voice (e.g., exercised, subjected):

Example 1

A planet revolving around the sun has gravitational potential energy because of the gravitational force that the sun exercises on the planet. But an electron which revolves around the nucleus of an atom has electrical potential energy because of the pulling electrical force that the nucleus exercises on it.

Potential energy is also evident in a taut string, a compressed spring or a deformed ball. On all the above cases the deformation is elastic which means that the bodies fall back to their original condition when the force which deformed them is no longer exercised. Every body which has been subjected to elastic deformation has potential energy which depends on the extent of its deformation. *The potential energy of each body equals the work that resulted from the force that was exercised to deform them*.

Source: Antoniou, N., Demetriades, P., Kampouris, K., Papamichalis, K., Papatsimpa, L. (2007). Physics year 9, Athens OEDB, p. 94.

(b) *The reinforcement of faith in the objective realities of entities and laws of natural science* through the rhetoric of iconicity or experiential iconism (Enkvist, 1981), the use of the present tense, and the almost complete lack of modality of formalities. Iconicity or experiential iconism corresponds to figures of speech in accordance to which the structure of language has an isomorphic relationship with the structure of empirical reality. In other words, the order of textual data corresponds to the order of the incoming data of the sensory experience (temporal, spatial, causal, etc.).

For example, in the following excerpt from a chemistry school textbook, temporal determinations and actions are represented in an isomorphic manner evident by their linear order in the text:

Example 2

In the first test tube a white blur is formed, in the second a whitish-yellowish blur is formed and in the third a yellow blur is formed which is due to the formation of insoluble grains of chloride silver, bromide silver and iodide silver respectively. After some time the insoluble grains will sink to the bottom of the test tubes.

Source: Theodoropoulos, P., Theofanous, P., Sideri, F. (2007). Chemistry year 10, Athens, OEDB, p. 76.

Furthermore, the use of verbs in the present tense facilitates the emergence of scientific knowledge as timeless or "eternal truth" that has no specific time frame of validity.

(c) *The emphasis on scientific knowledge as a final product and the degradation of the scientific process* through the excessive use of reports and a lesser use of experimental and historical accounts (Koulaidis, Dimopoulos, Sklaveniti, & Christidou, 2002).

Firstly, "report" is a type of text that describes how things are, presents information by building up generalizations, classifies various entities, and explains processes in natural phenomena or explains how a technological artifact works.

"Experimental account" is a type of text that usually contains a series of sequenced steps, which show how a specific experimental task should be carried out, and/or presents the results of this task. Finally, "historical account" is a type of text that presents either episodes from the history of science and technology or biographical information about famous scientists and engineers.

According to Sklaveniti (2003) in the Greek school textbooks of the natural sciences of primary and secondary school, 80 % of text units can be classified as reports, 13.2 % as experiments, and 6.8 % as historical accounts.

Summarizing, the aforementioned three rhetorical strategies are complementary and work towards the common direction of consolidating and strengthening the objective nature of scientific knowledge, while attempting a systematic concealment of its fabricated nature from the reader's view.

In this manner, language as a means of representation, while shaping the epistemological image of science, tends to impose a certain kind of amnesia with regards to its own role (Serres, 2001).

It is attempted to convince student-readers that there is no effort of persuasion in the text. The written language is in this case internalized as an inert channel of an "objective" description of the natural world.

According to Collins and Pinch (1998), this mode of written language functions towards the "hardening of facts" and the hiding of the textuality of scientific knowledge. Furthermore, this becomes much more intense as the context of transmission becomes more remote (socially and/or time-wise) from the context of primary production.

A characteristic example of this trend is the evolution of wording used to describe the quark. In 1969, the Dutch physicist J. J. Kokkedee, one of the pioneers in research on the particle in question, talked about it in the following way: "At this moment the quark model should not be considered anything more than what it is: a trial or a simplistic expression of a still unclear underlying dynamic within the context of the world of hadrons" (as reported by Pickering, 1984, p. 91).

In 1974, only 5 years later, Feynman considers the quark as almost real reporting that: "There is a considerable body of evidence, and no experimental evidence against the idea that hadrons consist of quarks…let's assume then therefore that quarks exist in reality."

By 1982, the formalities had advanced further towards the objective existence of quarks. The renowned physicist George Zweig reported "The quark model admirably describes half of the natural world" (as reported by Pickering, 1984, pp. 114, 147). Thus, in less than a few decades, the quark from a convenient agreement of

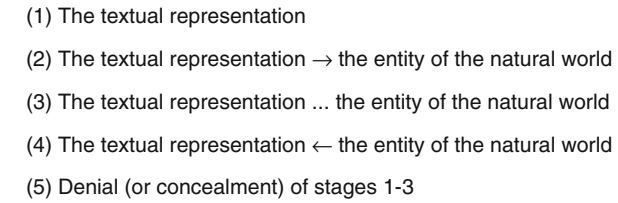

Fig. 4.1 The splitting and inversion model

theoretical physicists became a real entity which explains the causal structure of a large part of the natural world.

A similar course has been followed in the development of other scientific advances. A typical case is the introduction and establishment of the "Big Bang" theory which competes on an equal basis with two other theories with regard to the birth and evolution of the universe, namely, the "Steady State Universe"[2] proposed by Fred Hoyle, Thomas Gold, and Hermann Bondi and the "Inflationary Universe"[3] theory proposed by Alan Guth (Bucchi, 1998).

The supporters of the "Big Bang" theory using basic rhetorical means[4] tried and largely succeeded to establish this theory in education (today, in the vast majority of school textbooks, the "Big Bang" theory is undeniable) as well as in the public domain marginalizing the other two competing theories.

The trend of gradual concealment of the constructed and, thus, of the textual nature of scientific knowledge is described by the model of "splitting and inversion". This model attempts to shape the process of scientific knowledge production based on the case study of the discovery of pulsars by Hewish, Bell, and other three members of the amateur astronomy society in the late 1960s (Woolgar, 1988a). The model which foregrounds the textual and thus constructed nature of scientific knowledge includes the five stages presented in Fig. 4.1.

During the first phase, scientists handle textual data representations in the form of recording instruments (e.g., graphs as output of recording instruments), articles published in academic journals, and tables of empirical results of previous research efforts.

[2] According to the theory of the "Steady State Universe" which was introduced in 1948, the universe is always in a state of constant density as the constantly emerging new material is balanced out by the process of cosmic expansion.

[3] According to the theory of the "Inflationary Universe" introduced in 1981, the universe at the initial stage of its evolution spent a brief period of accelerated expansion during which the light had the opportunity to spread throughout the forming universe. This theory addresses the weakness of the "Big Bang" theory (which paradoxically is also its experimental confirmation) to explain the uniformity of the cosmic radiation background in the universe as according to the latter, the light did not have the time to spread across all the areas of the universe which were formed. The "Inflationary Universe" theory includes the additional theoretical difficulty of predicting the existence of negative gravity during the first phase of the accelerated expansion of the universe.

[4] In the context of this strategy came the publication of the Stephen Hawking's "Chronicles of Time," an avid supporter of this theory. The book attracted the public's interest in techno-scientific issues and revived editions of popularized scientific works and sold, according to Rodgers (1992), four and a half million copies worldwide.

During the second stage, scientists through an intense process of discussions and debates select or combine some of these textual representations in order to infer the existence of an entity of the natural world. Thus, at this stage, the textuality of scientific knowledge is very visible. During the third stage, a schism occurs between the entity and the textual representations from which it derived. In other words, the entity acquires status commencing its autonomous existence. During the fourth stage, the relationship between the entity and the textual representations is reversed. Thus, during this phase, an assumption is created that a text refers to an entity that has always existed. This phase corresponds to the phase of scientific publication during which the rhetoric goal is to convince peers for the truth of the allegations. However, at this stage, the rhetoric means and therefore the textual nature of scientific knowledge are still visible. Finally, a critical fifth stage follows which involves minimization, denial, and degradation of all the previous stages of the procedure. In this final stage, the story of the scientific discovery is rewritten so as to fully establish the objective ontological status of the scientific terms and relationships. According to our previous analysis, this phase corresponds to the image presented in school textbooks.

Towards a Proposal for the Disclosure of Textuality of Educational Materials for the Teaching of Natural Sciences

As it has been previously mentioned, a more realistic image of science corresponds to a form of knowledge which is being formulated. The problem that arises is the following: Which rhetorical means can be used to highlight the textual and therefore constructed nature of this knowledge as shown in the first four stages of its construction according to the "splitting and inversion" model?

After all, we should not forget the very etymology of the word "text" in the Latin version (the current English word comes from the Latin noun *textum* (verb *texo*) which means "textile" or "construction based on interwoven sections of wood" and refers to an artifact with complicated construction characteristics which is made from a combination of several components) (Lehtonen, 2000).

In a figurative level, we would say that the aim is the dismantling (tearing down) of the individual threads that make up this "construction" called *text* so as to highlight the formulation process, in other words its textuality. Such a process treats the textual representation of scientific knowledge more as a process rather than a final and static product (Barthes, 1986).

In this case, certain textual elements are required in order to bring to the foreground the following:

(a) The actors of the scientific process (scientists, authors of the school textbook, other stakeholders)
(b) The activities of these actors (claims, formulations of hypotheses, collection of experimental measurements)
(c) The antecedent conditions that lead to relevant activities (motives, interests, etc.) (Woolgar, 1988a)

Such elements, however, are necessary to put the validity of those rhetorical means through a critical test which in accordance with our previous analysis tend to increase belief in a metaphysical type of realism cultivated through school textbooks. The critical test of conventional rhetoric means, which tends to be used in the context of teaching of the natural sciences, arises from the effort to avoid a futile attempt to escape the constructed nature of every type of representation.

With regard to the question as to which are the most appropriate textual techniques to create the conditions to challenge the dominant rhetoric practice of hiding textuality of natural-scientific knowledge, the sociology of scientific knowledge (Ashmore, Myers, & Potter, 1995; Cooper, 1997; Woolgar, 1988b) in response has proposed all those forms of speech which, through their non-conventionality, highlight the mutual relationship between form and content (new literary forms).

These forms of speech are characterized by the celebration of heterogeneity, the introduction of textual instability, and the placement of the text construction procedure in the foreground, in other words the very idea of textuality.

Such texts, which make educational materials seem less self-referential and less like a monologue, tend to develop reflexivity and therefore control to the student-reader (Cooper, 1997). Lawson (1985, p. 363) characteristically states that: "the move toward reflexivity allows the text to indicate that there is something more than the meaning already mentioned."

The trend of moving towards texts which enhance reflexivity originates from the principle of symmetry (Bloor, 1976) according to which the various conflicting and controversial versions of natural-scientific knowledge (contemporary or previous historical phases) should be treated (even retrospectively if it concerns theories now established) as phases (1) and (2) of the "splitting and inversion" model.

The aim, therefore, of the use of non-conventional forms of discourse is to question tacit commitment to an orthodox epistemology governing natural-scientific texts in the field of education (perhaps not solely) while at the same time opening up to any type of challenge based on the claims made.

This can be achieved in two ways: firstly, by introducing textual types to the educational material which bring to the foreground multiple "voices" with regard to the same issue.

Secondly, the same literary effect can be produced with the creative use of figures of speech which through surprise and intensity of expression make the constructed nature of the text more visible while leaving the content open to interpretations on the part of the reader.[5]

Indeed, regarding the introduction of non-conventional figures of speech as a reinforcement of the reflexivity of the text, Gross (1996) reports that the avoidance of these figures of speech in standard scientific writing has as an aim to cultivate

[5] See the difference between "closed" i.e., stylized and formalistic, and "open," i.e., not as standardized in terms of expression texts according to Eco (1979), or the corresponding focus on form rather than content of abstract art which creates the conditions for more open-ended interpretations according to Gombrich (1960).

(or foster) the impression that science describes reality without the need to refer to the mediation of expressive means, in other words, a perception according to which scientific truth speaks for itself without the need for rhetoric tricks (décor).

Characteristic examples of the first of two types of functions (i.e., the introduction of multiple voices) are dialogue, plays, attribution of human voice to entities (real or imagined), diary, review of the literature, description of conditions behind the authorship of a text, and verbatim quotes from someone (i.e., quotations).

Examples of figures of speech, which, through the surprise they cause, contribute towards a more reflective attitude of the student-reader, are irony, paradox, hyperbole, rhetorical questions, and self-reference (Cooper, 1997) as well as enhanced modality formalities (Latour & Woolgar, 1979). Each of these forms will be analyzed in greater detail below.

Textual Types Revealing Textuality and Thus Enhancing Reflexivity

Dialogue

Dialogue is a textual type which allows the positions of the author to be questioned by those voicing alternative approaches to these positions. In other words, dialogue, as a text type, allows the introduction of "multiple voices" into the educational material. It is a simulation of a discussion or debate, and of course if the style is closer to spoken language, then it differs dramatically from the formal style of scientific writing in the sense that it invites the reflexivity on the part of the reader.

Apart from its direct form, dialogue can be introduced in the educational material indirectly as well by quoting opposing views in the format of a table or parallel texts. A typical example of such writing is the famous dialogue in which Galileo presents his views in his works primarily through the voices of Salviati and secondarily Sagredo while expressing the Aristotelian and counterargument to them through the voice of Simplicio.[6]

Theatrical Script (Play)

Apart from the dialogues included in theatrical writing, whose value has already been analyzed, there are also stage descriptions as well as description of the psychological state of the protagonists. These are elements which allow a viewer to reflect upon the

[6] According to Shamos (1987), the reasons which led Galileo to adopt this model of writing was his effort to appear attentive and less absolute in the formulation of his positions because of the expected response these would generate but also due to his admiration for the work of Plato (out of 36 works of Plato, all but "Apology" are written in dialogue).

context of the positions additionally to the positions themselves. A characteristic example of this case is the play Copenhagen by Michael Frayn. The play is about a meeting which takes place in September 1941 in Copenhagen, under German occupation at the time, between Heisenberg and Bohr, and uses as a background the construction of the atomic bomb.

Similar cases include the *Life of Galileo* by Brecht, *The Physicists* by Durrenmatt which addresses the issue of moral responsibility of scientists with regard to the use of their research findings, or the comedy *Picasso at the Lapin Agile* by Martin which describes a meeting between Picasso and Einstein in a coffee shop one afternoon in 1904, 1 year before the theory of relativity was formulated. Yoon (2004) indeed categorizes plays relating to the natural sciences into those that (a) describe (give, contain) content with regard to the natural sciences, (b) describe the lives of certain scientists, (c) relate to episodes (defining moments) in the history of science, (d) refer to the social dimensions of science, and (e) use natural sciences as a pretext in order to let the dramatic plot unfold.

The Attribution of Human Voice to Entities

This approach draws its inspiration from the Actor Network Theory by Latour (1987) according to which the formulation of scientific knowledge is a process which is characterized by the creation of networks comprising of heterogeneous elements such as texts, references, artifacts, technologies, people, and institutions. This position suggests that in order to study science in the making and the creation of these networks, we have to abandon all the a priori distinctions between human and nonhuman actors. A characteristic example of the way various researchers in the field of sociology of scientific knowledge have used the technique of attribution of a human voice to entities in order to handle the procedures of socio-technical systems is that of Mulkay (1991a) which gave a voice to dolphins and fetuses in the womb (Mulkay, 1991b) and that of Law (1992) who gave a voice to the text itself which conversed in dialogue with the author and other voices.

The attribution of human voice to entities in the form of animism can only be found in the educational material used in the first years of primary education. In this case, the reflective effect does not seem to be achieved. In older ages, the use of this technique could create the conditions required for reflexivity (e.g., see cases of voice attribution to the planet Earth or animal species in ecology texts).

The Diary

This genre allows the recording of the evolution of a scientist's thinking over time as well as the recording of the social and historical contexts within which this evolution takes place or at least as the scientist perceives them. This very

description of the evolutionary process demonstrates in the eyes of the student-reader that the scientific thought goes through multiple stages of formulation and is influenced by many circumstances or even random incidents. Autobiography could also be included in this textual type. Typical examples of this kind are the autobiographical chronicle of the discovery of the double helix structure of DNA as presented by one of the two scientists who made the discovery, James Watson (the other scientist was Francis Crick), entitled *The Double Helix* (Watson, 1966), and extracts from the *Red Notebook* in which Darwin kept all the notes regarding his observations and his thoughts during the 55 months of voyage on the Beagle.

Review of the Literature

The use of references from and commentary of the existing literature on a certain scientific issue is an established practice in the scientific literature but usually absent from educational material. The adoption of such a textual practice in educational material would undermine the absolute nature of what is being said and thus would enhance reflexivity. Moreover, the very nature of this practice would indicate clearly that the formation of scientific knowledge is a result of social interaction within the scientific community and thus refers to its textual nature.

Description of Conditions Behind the Authorship of Educational Material Texts

This textual practice is quite often met in prologues to various texts whereby the authors adopt a style resembling a confession or an evaluation and describe the conditions under which they produced their text (Genette, 2001). In this way, student-readers can more easily understand the constructed nature of the text they are exposed to, as well as understand the special circumstances under which it was written (e.g., influence from peers, communicating with reviewers and editors, and psychological or emotional state of the author at the time).

Quotations

Citing verbatim quotes constitutes a crack in the usual monologue of natural sciences educational texts, as it allows the introduction of additional "voices" beyond the voice of the author. Indeed, the reflective function in this case is especially strengthened when the citations listed are in conflict with the main arguments of the material.

Figures of Speech

Irony

In this figure of speech, the author seems to say something, but actually, he means something else. In this way, this figure of speech contains contradictory meanings out of which the student-reader must choose the right one and thus becomes more reflective. The reflective function of irony is further enhanced by the fact that in order to communicate its meaning, it must refer to the common interpretative resources of the author transmitter and the student-reader. In this way, these two agents come into play, and the text is revealed as a product of the author's activity and is therefore constructed. According to Giannakoppulos (1991), irony constitutes an antiphrase. In other words, irony is a figure of speech "with which an expression of a concept or a judgment is made with words that mean exactly the opposite" (p. 517). Similar to the rhetorical function of irony are euphemism and humor. All these figures of speech are, by their very nature, attempts to undermine meaning delivered and thus represent a direct criticism of their objectivity.

Paradox

The paradox is a figure of speech which while at first glance appears not true and/or not feasible, a second reading can make it appear to the student-reader compatible with reality (e.g., the paradox of the Hare and Tortoise by Zeno and the paradox of Einstein's Gemini). One could say that the reflective nature of the paradox is the very fact that emphasizes that certain claims which initially seem to be untrue could under certain circumstances or conditions become true. A similar function to the paradox is also performed by the figure of speech "oxymoron."

Hyperbole

According to Pantidos (2008) in the figure of speech of hyperbole, formalities differ a lot from the usual (or mainstream) in order to cause a sensation. It is this deviation which invites the student-reader to consider the accuracy or otherwise of the claim and thus makes him/her more reflective.

Rhetorical Questions

These questions are put as a pretext with an aim to lead immediately after to their response. However, the mere fact that they are posed clearly suggests that scientific claims do not emerge directly from nature but constitute answers to questions posed

by scientists. In this sense, a rhetorical question brings the scientific community to the forefront and helps scientists to be seen not as passive readers of the "book of nature" but as active actors who shape the actual scope of their quests. The technique of rhetorical questions has been used by Newton in his work *Optics*. Specifically in this work, Newton has included over 31 such questions, in order to refute the criticism of other scientists and specifically Hooke, with regard to the particle nature of light which he advocated (Gross, 1996).

Self-Reference

The voice of the author is expressed through the use of first person singular (or first person plural in the case of multiple authors). The corresponding formulations can concern either the epistemic (degree of effect, certainty, innovativeness, generality, compatibility, probability, possibility) or the emotional (usefulness, utility, elegance, morality, acceptability) or the evaluative attitude of the author in relation either to its own claims or the claims of others. The self-references in the educational material relativize the value of arguments presented, leaving the student-reader free to agree or disagree with the explicit position of the author.

Reinforcing the Modality of Formalities

The epistemic attitude of the author is possible to be delivered indirectly through the modality of formalities used. The modality in this case refers to the degree of certainty attached to each formality. Moreover, the modality of expression constitutes "one of the most important means of showing the attitude of the transmitter towards the content of an utterance" (Lekka, 2005 p. 77). Adding expressions that indicate modality (e.g., may, under certain circumstances it may apply, scientist X argues that) results in gradual devaluation or degradation of the objectivity of the claims raised.

Latour and Woolgar (1979) distinguish five levels of modality of scientific formulations.

Claims that appear to be certain and obvious within a scientific field belong to level 5. Claims that are presented as unquestionable however are accompanied by detailed explanations belong to level 4. The claims of the educational material used for natural sciences in the school usually belong to these two levels. Claims that belong to levels 3 and 2 include expressions of reservations, restrictions, and conditions which suggest that the meaning of the claim is not undisputed. Claims that belong to level 3 are especially hard to distinguish (e.g., citation of a bibliographic reference weakens the certainty of a claim since support external to the text is needed). At level 2, the expressions of modality are a lot more powerful, and formalities indicate the availability or lack of evidence which enhance truth. Finally, the formalities of level 1 are

openly and frankly speculative and incorporate assumptions concerning the lack of sufficient evidence with regard to the truth. As formalities included in the educational material move from levels 5 and 4 towards levels 3, 2, and 1, their modality is increased, and therefore, it is possible that the reflexivity of the student-reader is also increased in terms of power.

A final word of caution regarding the textual types and figures of speech which highlight the textuality of the educational material would be that these elements of speech are commonly used in two communication fields of scientific knowledge, namely, in peer-reviewed publications in scientific journals as well as popularized publications in the public domain.

In both fields, the choice of the emergence of textuality is supported by the need to make skeptic readers more reflective and thus convince them. In the case of scientific publications, relevant texts are produced very near to the front of the primary construction of natural-scientific knowledge and therefore need to appear as reflective as possible in relation to the accuracy of their claims so as to overcome the test of organized skepticism of peer readers according to Merton. On the other hand, texts in the public domain are addressed to nonspecialists who do not have any epistemic commitment to science but, at the same time, function in a climate of growing skepticism about the results of techno-science and are in need of being convinced, especially in modern conditions where, according to Giddens (2001), knowledge and social practices feed into each other in a dialectical way.

Synopsis

This chapter stems from the observation that the epistemological images of the school science and science in the public domain, or at least how they are reflected in the texts of each field, are considerably diversified. This differentiation constitutes a fundamental barrier for the adoption of approaches aiming to teach natural sciences for citizenship. An important part of this image of school science is shaped by the rhetorical means used in school textbooks. The common denominator of these means is the concealment of textbook textuality and the associated absolutization of scientific knowledge for the sake of metaphysical realism.

In order to rebut this image of science, it is proposed to include unconventional textual types and figures of speech in school science textbooks which reveal their textuality, and therefore, the constructed and negotiable nature of science will be revealed, as it is presented in the public domain. The inclusion of such textual elements could potentially enhance the reflexivity of the student-reader and therefore help him/her to adopt a more realistic view of the conditions of formation and change of scientific knowledge.

In an era where the presence of techno-science is increasingly in the spotlight of the public life, only reflectivity and the healthy skepticism it creates can help students dealing with both a blind allegiance to an occult science (scientism) as well as the antiscientific, pseudoscientific, and anti-rational trends of postmodernity.

Postscriptum

If by now the reader of this chapter has not seen the glaring contradiction between our proposal with regard to the need of using textual types and figures of speech that enhance reflexivity and how this proposal is expressed (complete lack of such evidence in this chapter), then this means that resorting to the usual conventions of scientific writing has achieved its aim to hide the textuality of this chapter, namely, that it is merely a contrived position of the authors. "Exactly what had to be proven was proven."[7]

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[7]This postscriptum is the only reflective type reference in a text that otherwise takes position in favor of integrating reflectivity as a process in the educational material.

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