Visual representation and cognition: a study using Science and Mathematics textbooks for Elementary Schools

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Abstract: To investigate the extent to which visual representations contribute to triggering cognitive processes, we have selected for this article visual representations from Science and Mathematics textbooks that compose the stratified sample of books reviewed in the 2011 Textbooks Guide of the Brazilian Program for Textbooks (*Programa Nacional do Livro Didático* – PNLD), for final grades of Elementary School in Science, Mathematics, History, Geography, Portuguese Language and Foreign Language in the developed research *corpus*. After the initial systematization, the different modalities of visual representation were classified and analyzed considering Peirce's semiotics theory. These discussions are relevant to the communication/education interface since they present the possibility that the involved school disciplines being considered as languages that, when incorporating signs other than verbal, imply new knowledge about such types of representations.

Keywords: communication; education; visual representation; cognition; textbook.

Resumo: Com o propósito de averiguar em que medida as representações visuais contribuem para desencadear processos cognitivos, selecionamos, para este artigo, as representações visuais de livros de Ciências e Matemática que compõem a amostra estratificada dos resenhados no *Guia de livros didáticos 2011*, do Programa Nacional do Livro Didático (PNDL), para as séries finais do Ensino Fundamental de Ciências, Matemática, História, Geografia, Língua Portuguesa e Língua Estrangeira no *corpus* de pesquisa desenvolvida. Após primeira sistematização, as diversas modalidades de representação visual foram classificadas e analisadas sob a perspectiva da semiótica peirceana. As reflexões são relevantes para a interface comunicação/educação, pois trazem à tona a possibilidade de que as disciplinas escolares envolvidas sejam vistas como linguagens que, ao incorporarem signos distintos do verbal, impliquem novos conhecimentos sobre tais modalidades de representações.

Palavras-chave: comunicação; educação; representação visual; cognição; livro didático

Received: 01/08/2018
Approved: 05/30/2018

1. INTRODUCTION

The omnipresence of the image at all levels of representation and the psyche of Western or Westernized man compels a more specialized view of this phenomenon, which is especially inscribed in the media image that determines

> the intentions of anonymous or hidden producers: in the pedagogical awakening of the child, in the typological (the appearance) choices of each person, even in public or private uses and customs, sometimes as 'information', sometimes veiling the ideology of a propaganda, and in others hiding behind seductive 'marketing'[1].

Images can be added to the factors that weave relationships in contemporary society, because they play, in an ironic game, with aspects of daily life that, either by letting themselves be seen or presented – visual representations, in general –, or by incorporating the imaginary of people to some extent[2]. Such relationships can also be perceived in the teaching environment and in several types of media, including textbooks.

In this article, we turn our attention to images – visual representations – found in four book collections, two of Science and two of Mathematics, which compose a stratified sample for the books reviewed in the *Guide to Textbooks 2011*, of the National Textbook Program (*Programa Nacional do Livro Didático* – PNDL)[3], of the final series of the Basic Education of Science, Mathematics, History, Geography, Portuguese Language and Foreign Language, constituting the *corpus* of the developed research. The analysis of these collections allowed the images to be classified in modalities: photography; map; graph; table; flowchart; infographic; portrait; work of art and media product. The first systematization of the visual representations is shown in Graphs 1 and 2.

In the two Science collections, designated as collection A and collection B, both with four volumes destined to 5th, 6th, 7th and 8th grades of Elementary Education, we found 1,304 and 976 pages in total, respectively. In collection A, we counted 2,067 visual representations and 2,199 in B, with 1.85 visual representations per page on average.

In the two Mathematics collections, designated as collection A and collection B, both with four volumes destined to 5th, 6th, 7th, and 8th grades of Elementary School, we found 1,236 and 1,488 pages in total, respectively. We counted 5,095 visual representations or images in collection A and 4,120 in B, with 3.4 visual representations per page on average.

Considering Pierce's semiotics[4], we deem that a school discipline, e.g., Mathematics, can be seen as language constituted by other types of representation that are not necessarily words, non-verbal signs such as formulas, graphs, tables, drawings etc. Speculative grammar provides definitions and classifications for the analysis of all types of languages. This branch of semiotics or logic, in addition to "providing us with rigorous definitions of a sign and how signs act, […] contains a vast inventory of sign types and sign mixtures, in the innumerable gradations between verbal and non-verbal until the limit of a quasi-sign"[5].

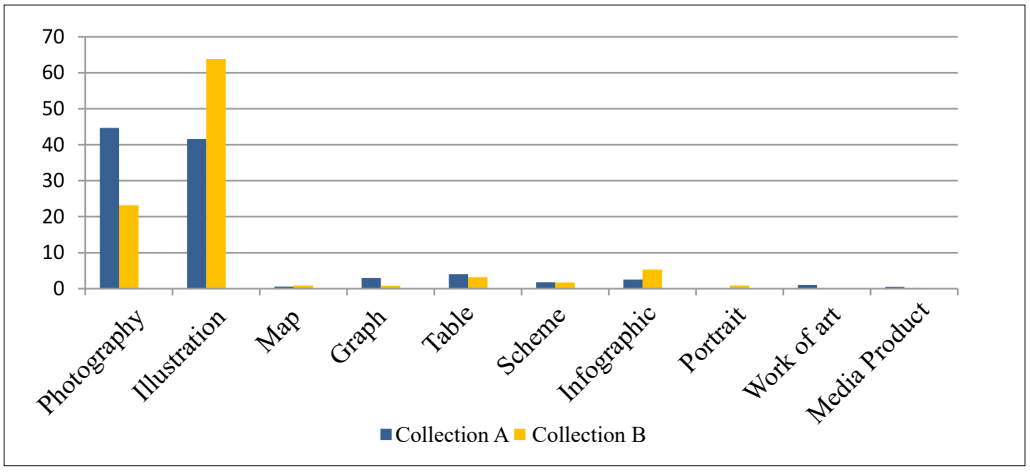
1. DURAND, Gilbert. **O imaginário**: ensaio acerca das ciências e da filosofia da imagem. Rio de Janeiro: Difel, 2004. p. 34.

2. MAFFESOLI, Michel. **No fundo das aparências.** Petrópolis: Vozes, 2005.

3. Among the 66 collections reviewed in the National Program of the Didactic Book (PNDL) 2011, 11 were of Science and 10 of Mathematics.

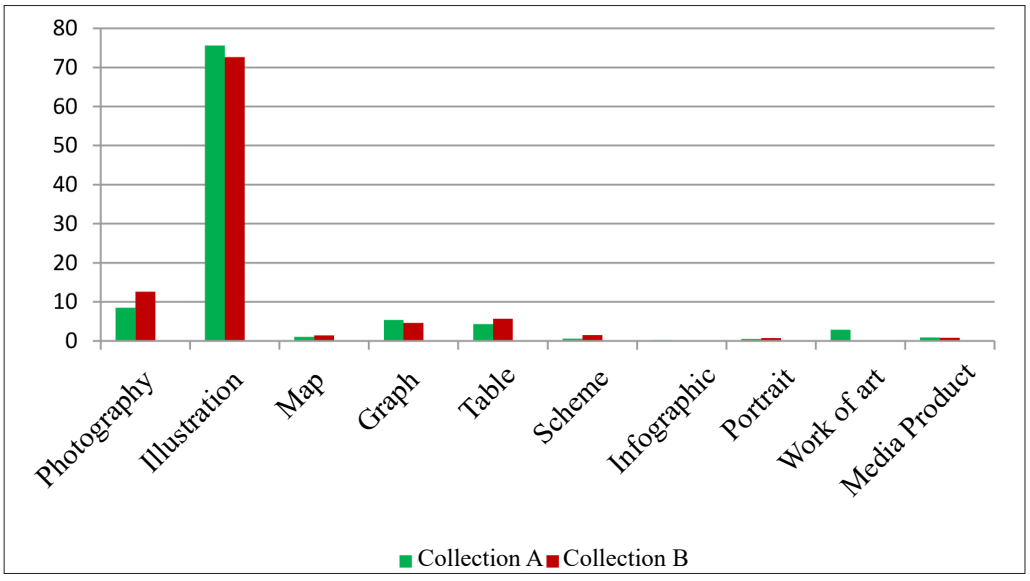
4. Part of the philosophical architecture elaborated by Charles Sanders Peirce (1839-1914), founder of semiotics and philosophical pragmatism who also developed studies in astronomy, geodesy, mathematics, philosophy and theory and history of science. Semiotics or logic is divided into three branches: speculative grammar, which deals with the study of proper signs and the classification of signs into icons, indexes and symbols, describing and analyzing them; critical logic, which deals with types of reasoning – abduction, deduction and induction; and speculative rhetoric, which studies the methods that should be used in the investigation, exposition, and application of truth.

5. SANTAELLA, Lucia. **Semiótica aplicada**. São Paulo: Pioneira Thomson Learning, 2002, p. XIV.



Source: Prepared by the authors.

Graph 1: Distribution of visual representations of Science books by type.



Source: Prepared by the authors.

Graph 2: Distribution of visual representations of Mathematics books by type.

Thus, seeking to evaluate the pertinence of these visual representations to cognition, this article presents a classification of them, all found in the selected books. Following, analyses are made using speculative grammar, from which "we can extract methodological strategies to read and analyze empirical processes of signs"[6].

CLASSIFICATION/COGNITION AND VISUAL REPRESENTATIONS

The visual representations presented – photographs, illustrations (drawings), graphs, tables and others – can be classified, based on Pierce's semiotics, considering their relationship with the object. In this instance, when

6. SANTAELLA, Lucia. **Semiótica aplicada**. São Paulo: Pioneira Thomson Learning, 2002, p. XIV.

the sign is synonymous with representation (considering that "to represent" is the same as "to be" or "to act as"), the sign can be classified as an icon, index or symbol. We shall begin with the icon and its subdivisions.

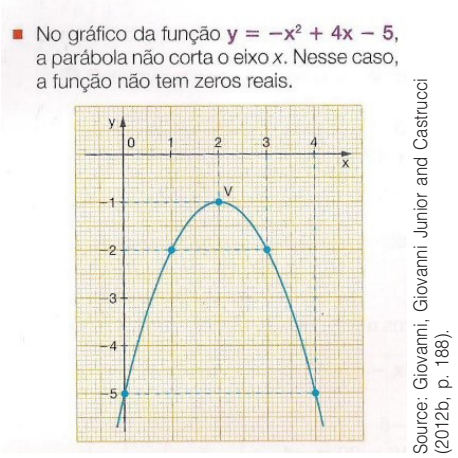
The iconic sign or hypoicon is constituted when the reader/interpreter's mind retrieves comparison relations between the sign and the "probable" object that is presented by the sign. This is a fragile representation since the mediation established in a comparison relation has the nature of a hypothesis, which can be contested. There are three types of hypoicon: 1) image, 2) diagram and 3) metaphor.

> Images participate in simple qualities [...]. Diagrams represent the relations, especially dyadic relations or relations considered as such – of the parts of a thing, using analogous relations in its own parts. [...] Metaphors represent the representative character of a sign, drawing a parallelism with something diverse[7].

Images offer qualities to the interpreter's look. Color, shape, texture and games built with these qualitative aspects lead one's mind to ramblings and associations that weave analogies. Images, at most, suggest their referent, i.e., what they refer to by similarity. On the other hand, the forms that relate to the object and reach it, in different nuances, are the figurative ones. Thus, in the specific case of these images, the iconic character is fragile, which leads the interpreter's mind to the identification or verification, an aspect that is also reinforced by the word.

For diagrams, the second type of hypoicon, the similarity with what is presented does not lead the interpretative process, but rather the relations "of the parts of a thing through analogous relations in their own parts"[8]. Graphs, maps and mathematical formulas are examples of diagrams.

In the formula $y = -x^2 + 4x - 5$ (Figure 1), the variable y is dependent, and the variable x is independent. The relations established between them are given by the rules set in the equation, which are identified on the basis of the same mental operations that we perform when we decode them, regardless of the field in which they are performed.



Source: Giovanni, Giovanni Junior and Castrucci (2012b, p. 188).

Figure 1: Equation and graph

7. PEIRCE, Charles Sanders. **Collected papers**. Cambridge: Harvard University Press, 1931. v. 2. p. 277.

8. PEIRCE, Charles Sanders. **Collected papers**. Cambridge, Mass: Harvard University Press, 1931. v. 2. p. 277.

But would not the equation be a sign of law since this relation can fit or apply to different contexts – or even be constructed based on conventions?

> Icons whose similarity is aided by conventional rules are particularly noteworthy. Thus, an algebraic equation is an icon made such by the rules of commutation, association and distribution of symbols. At first glance, it may seem like an arbitrary classification to call an algebraic expression an icon; and that it could be in the same way, or even for the same reason, considered as a conventional sign [...]. But it does not work like that, since an important property that is peculiar to the icon is that, through its direct observation, other truths relating to its object can be discovered in addition those which are sufficient for its determination[9].

In an equation, the appearance or qualitative aspects of the materiality of the visual representation do not guide the semiosis or action of the sign, but how the "x" and "y" objects enter its composition. Thus, such sign is inserted in the hypoicon modality called diagram. However, when the student uses an equation to construct a graph – another type of representation of the same relations – in other words, when the students follows rules and standards that compose the mathematical language, the very equation becomes symbolic. In this regard, we can reinforce the idea that a sign can become an icon, index and symbol – and, at different moments, one of these prevails.

Tables and graphs also prevail as diagrams. Figure 2, a rather rudimentary diagram, leads the interpreter's mind to retrieve information by crossing rows and columns.

This representation uses few words and allows the construction of different paths in the search for information, i.e., the interpreter's eyes do not draw the lines on which the writing rests, they create intersections. In addition to being unusual, the images in the table are unnecessary because they are redundant when considering the names of living beings placed in the column on the side. In this case, the use of images reinforces the idea that textbooks try to become similar to mass media, seeking to compete with audiovisual media.

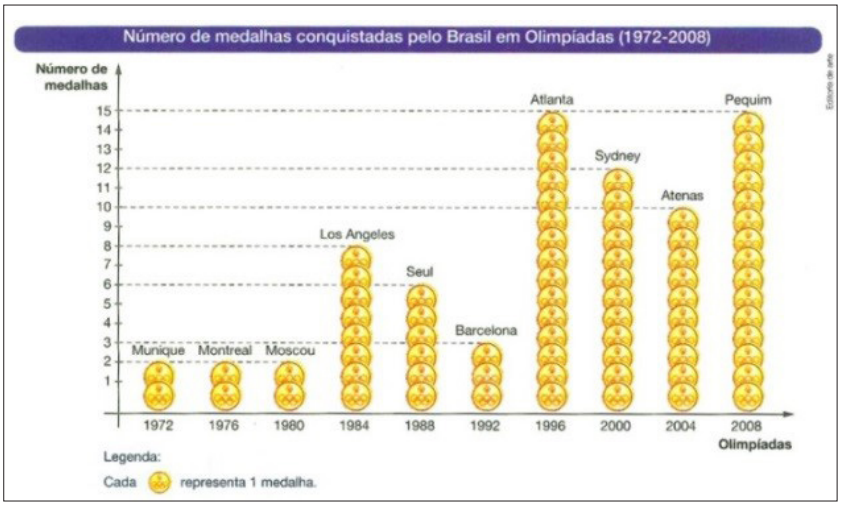
Figure 3 synthesizes data that, when properly organized in bars, show the details of a phenomenon. Information can be collected when the interpreter observes the title on the chart – which informs about the phenomenon –, as well as the two metrics involved, which are on the horizontal and vertical axes, the year in which the Olympics took place and the number of medals won, respectively. Possibly, the medals, which compose the bars, were used as a measurement unit to aid in concentrated attention and facilitate data comparison.

9. Ibidem, p. 279.

Ser vivo		Número de cromossomos nas células do corpo	Número de cromossomos nos gametas
Fabio Colombini	Mosca-das-frutas	8	4
Stockbyte/ Getty Images	Cebola	16	8
Fabio Colombini	Sapo-boi	22	11
Fabio Colombini	Rã-pimenta	26	13
Fabio Colombini	Jacaré	32	16
Corel Stock Photo	Gato	38	19
Photodisc/ Getty Images	Ervilha	14	7
Photodisc/ Getty Images	Trigo	42	21
DC Productions/ Photodisc/ Getty Images	Porco	40	20
Corel Stock Photo	Cavalo	64	32
Blickwinkel/Alamy/ Othermages	Macaco (rhesus)	42	21
Photodisc/ Getty Images	Milho	20	10
Photodisc/ Getty Images	Ser humano	46	23
Digital Vision/ Getty Images	Batata	48	24

Source: Trivellato et al. (2008c, p. 242).

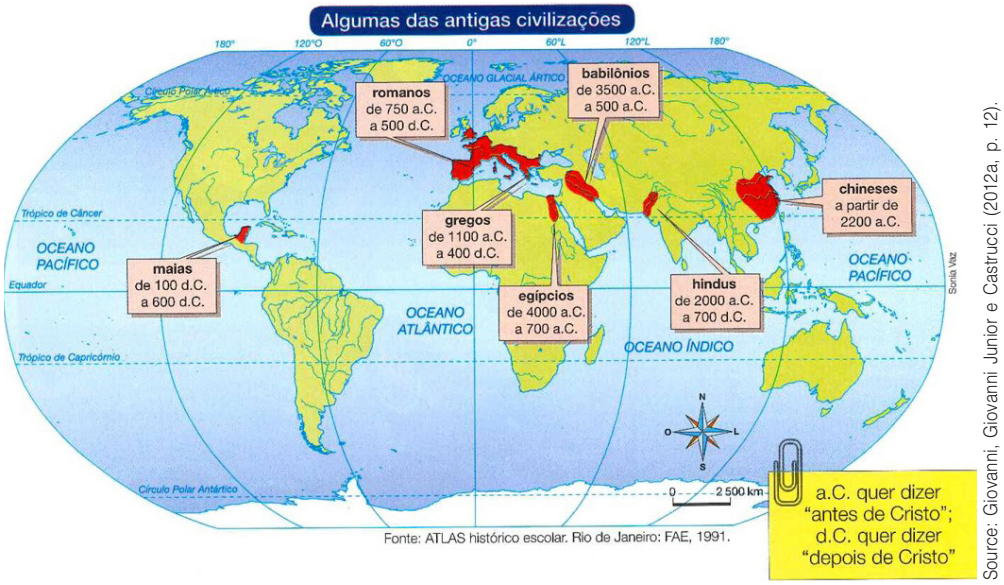
Figure 2: Table



Source: Giovanni, Giovanni Junior e Castrucci (2012b, p. 18).

Figure 3: Bars graphic

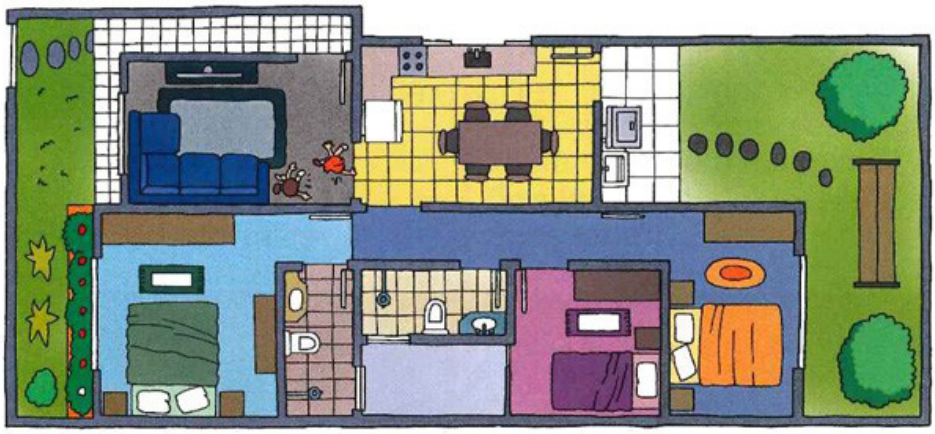
Maps are also prevalent diagrams. The same existing relations among all parts of what is represented must be present in a map, which is possible due to conventions of different shades: the ways to identify highways and constructions, as well as comparisons between sizes, distances, constructed areas, different objects and people. As a representation, a map is also in place of what was represented, but is not identical to it. In the analyzed textbooks, 0.75% of the visual representations were maps or used them to compose illustrations in the Science collections, and 1.2% in Mathematics. In the visual representation (Figure 4), the map composes an illustration that, by aggregating information not related to the map itself in the conventional sense, becomes something that could be considered an infographic, which we will be discussed in detail below.



Source: Giovanni, Giovanni Junior e Castrucci (2012a, p. 12).

Figure 4: Map composing an illustration

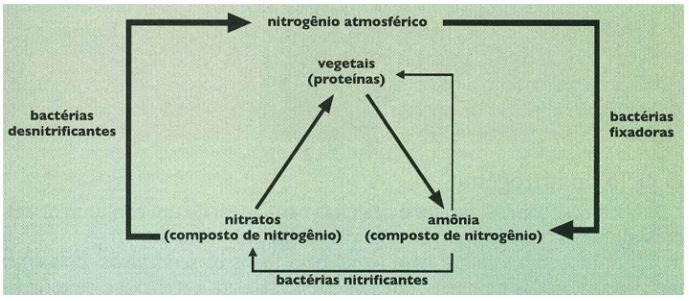
We can also call other types of diagrams "visual representation", such as architectural plans (Figure 5) – drawings that represent the particularities of a building projected on a horizontal surface –, schemes (Figure 6) and infographics (Figure 7).



Source: Giovanni, Giovanni Junior e Castrucci (2012a, p. 263).

Figure 5: Architectural plan

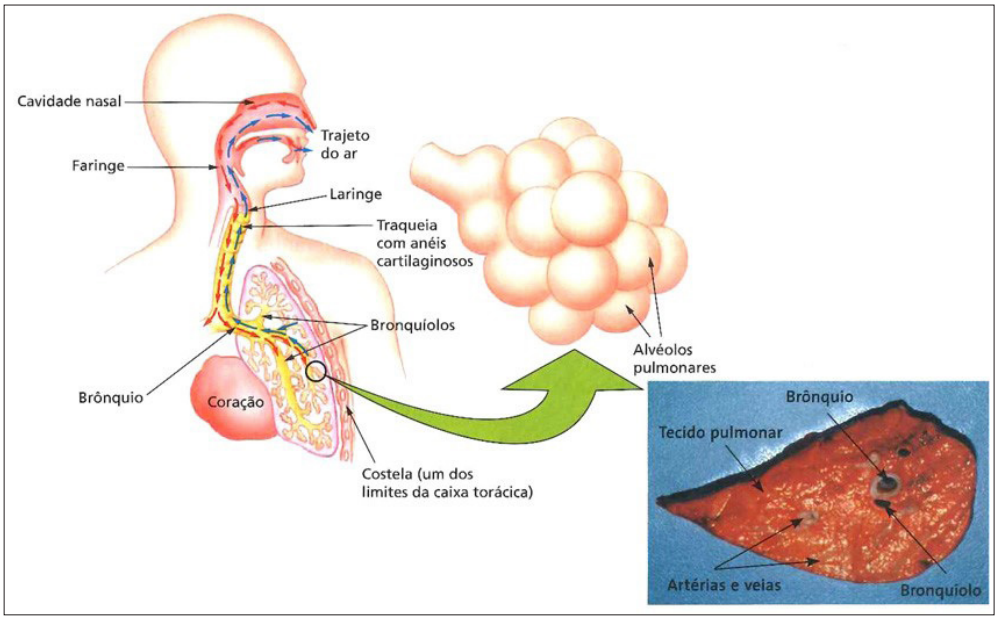
A scheme can also be considered as a diagram within Peirce's semiotics (Figure 6). Schemes privilege the course of a phenomenon, i.e., it shows the sequence of its stages or phases. The presented scheme shows the processing sequence of chemical substances by three types of bacteria.



Source: Trivellato et al. (2008a, p. 88).

Figura 6: Scheme

Infographics (Figure 7), which are commonly used by newspapers, are not a recent invention: the first can be found in Michelangelo and Leonardo da Vinci's studies of the human body. These illustrations are from one of the volumes of the Science collection (Figure 8).



Source: Santana (2012c, p. 135).

Figure 7: Infographics

Source: Trivellato et al. (2008b, p. 9).

Figure 8: Infographics

According[10] to Sancho, infographics can be traced to over fifteen thousand years ago, when cavemen recorded characters that correspond to a type of writing in cave paintings – in the current context, the development of computer science and graphic *software* gave new possibilities to the production of this form of representation. Infographics are a hybrid communication system, combining verbal and visual language by employing both words and phrases like images and other visual representations. Thanks to its power of synthesis, such system is widely used in business reports and catalogs, in science, advertising, product *design* and face-to-face and online education, as well as in information technology, in communication and entertainment companies, in instruction manuals, in scientific dissemination and journalism.

The visual representations that compose the infographics offer additional information and provide concentrated attention by spatially demarcating

10. VALERO SANCHO, José L. **La infografia**: técnicas, análisis y usos periodísticos. Barcelona: Belaterra, 2002.

important points, which leads the interpreter to make guesses, assumptions. Such representation model must be analogous to the spatial-analogical mental model needed for the understanding of the content, thus being capable of reconstructing a model. On the other hand, the use of verbal language initially demands the construction of a diagrammatic representation of the content and then the elaboration of a spatial-analog model.

Colle[11], Valero Sancho[12] and Ribas[13] elaborated several classifications for journalistic infographics. In this article, we that Peltzer's[14] especification is adequate, who presents three infographic classifications: of view, explanatory, or infographic report.

Each of these types is better explained below. Viewing infographics present explicit drawings, which show real elements placed in their place, with details and proportion, accompanied or not by captions and explanatory numbers. These can be subdivided in: a) plan, as the graphic representation in a surface, terrain, environment or any external place; b) cut, the inside view of a body; c) perspective, three-dimensional representation of objects; and d) panorama, which constructs the view of a horizon.

The second modality, explanatory infographics, as the very name indicates, explains facts, events, phenomena or processes. Its subdivisions are as follows: a) cause-effect, which explains the cause and effect of a fact, phenomenon, event or process; b) retrospective, which explains something that happened in the past, answering the questions "what?", "when?", "where?" and "why?"; c) anticipatory, which explains, through predictions and assumptions, something that may occur; d) step-by-step, which expresses the steps and sequences of a process; and e) flow, which describes the connections and steps of a process or series of procedures.

The third type, infographic report, is suitable to newspapers, mainly presenting the informative report of a fact, it can be subdivided into: a) realistic, in which people or things are represented from the perspective of the infograph maker, and b) simulated, in which the representations follows the creative process of the infographic maker, relying, however, on real data.

The viewing and explanatory infographics are the most common in the analyzed textbooks. Figure 4 presents an infographic that can be classified as of view and in cut mode. Considering the relevance of this type due to its capacity of diagrammatically showing the synthesis of an idea, concept or content, we can argue that its presence in the sample was not significant when compared to the number of photographs. In the Mathematics collections, the percentages were imperceptible (0.2% and 0.1%); in the Science collections these values reached 2.5% and 5.3%. The highest percentage was found in books on the human body, which traditionally present infographics for teaching.

After analyzing the found visual representations, we shall resume the subdivisions of the iconic sign. We mentioned two so far: image and diagram; now, on to the metaphor. If the image is characterized by similarity in appearance and the diagram by the similarity of relations, the metaphor uses the similarity of meanings.

11. COLLE, Raymond. Infografía: tipologias. **Revista Latina de Comunicación Social**, n. 58, 2004, La Laguna. Available from: <http://www.ull.es/publicaciones/latina/latina_art660.pdf>. Access on: Jun. 28, 2014.

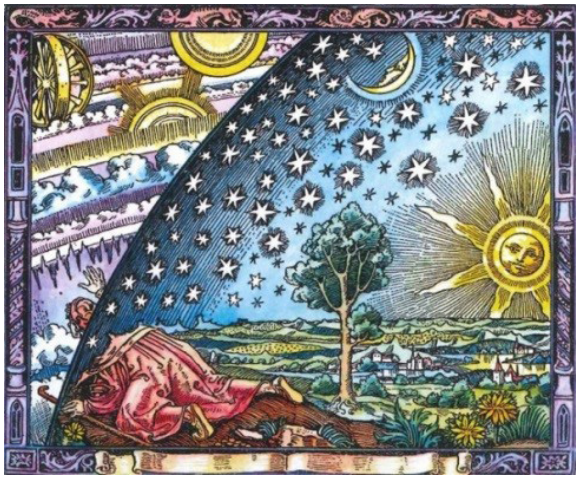
12. VALERO SANCHO, José L. **La infografia**: técnicas, análisis y usos periodísticos. Barcelona: Belaterra, 2002.

13. RIBAS, Beatriz. Infografia multimídia: um modelo narrativo para o webjornalismo. **Grupo JOL**, Salvador, 2004. Available from: <http://www.facom.ufba.br/jol/pdf/2004_ribas_infografia_multimidia.pdf>. Access on: Jul. 2, 2014.

14. PELTZER, Gonzalo. **Jornalismo iconográfico**. Lisboa: Planeta, 1991.

Metaphors construct new meanings by associating the representative character of the sign with that of a possible object. They enclose the meaning of two distinct things and transfer them, transforming literal (denotative) language into figurative (connotative) language. Thus, in "the dawn of my life", the meaning of dawn parallels with the meaning of life and vice versa, emphasizing a relationship of similarity between the two.

Metaphors are also found in images. Visual forms that correspond to the metaphor "are those that, even if reproducing the external appearance of things are only used as a form of representing something that is not visually accessible and that, as a rule, has an abstract and general character"[15]. In the Science collections we only found two visual metaphors (Figures 9 and 10); considering that both refer to interpretations related to the Earth from othercultures.



Source: Santana (2012b, p. 12).

Figure 9: Is the sky the limit?

Figure 9 represents a 16th-century engraving, which depicts the belief of ancient peoples in the relationship between the appearance of stars and rain; Figure 10 is a visual representation elaborated from the explanation that Hindus gave to the shape of the earth. The iconic nature of this type of visual representation instigates the interpreter's imagination and curiosity, prompting him/her to elaborate hypotheses – which leads us to infer that textbooks should intensify the use of visual metaphors.

Source: Santana (2012b, p. 12).

Figure 10: What sustains the tortoise?

15. SANTAELLA, Lucia; NÖTH, Winfried. **Imagem**: cognição, semiótica, mídia. São Paulo: Iluminuras, 2001. p. 59.

We shall now observe the performance of Peirce's index in cognition. Photography is the most genuine example of index among visual representations since its bond with what is real is very strong – after all, the presence of the referent (photographed object) in front of the camera cannot be denied. Photographs appear in large numbers in both collections. It is worth remembering that the percentage of photographs (with or without people) was 33.95% and 10.55% for the Science and Mathematics collections, respectively. The number of photographs in the books of the Science collections is significant. But to what extent do they aid cognition?

The index connects us to the real world and this link comes as a force that propels, directs and drives, "like a pointing finger [that] exerts on attention a real physiological force, like the power of a magnetizer, driving it to a particular object of senses"[16].

> The index refers to its object, not so much by virtue of a similarity or analogy with it, nor because it is associated with general characters that this object happens to have, but because it is in a dynamic connection (including spatial) with both the object individual and with the senses or memory of the person to whom it serves as a sign[17].

According to Drigo & Souza[18], in general, indexes are not similar to the objects to which they point or signal; they refer to individuals, units, singularities, unique collections of units or singular continuums. Finally, indices direct the attention to their objects with blind compulsion. There are no absolutely pure indices, in other words, there are no indices free of iconic remnants and no signs absolutely devoid of indicial qualities. Psychologically, the action of the index depends on association by contiguity, and not on association by similarity – as required by an icon –, or of an intellectual operation, which is indispensable for the symbol. The effects of the index lie in the seesaw of observation, of action-reaction.

For example, in mathematical language, capital letters that appear with the vertices of a geometric solid of the visual representation (Figure 11), the arrows that indicate the height of the solid represented by a line segment and the line segment that shows the length of the shadow.

Resuming the discussion on photographs, we can infer that, as indexes, they are present in textbooks to serve as witnesses and documents (Figure 12).

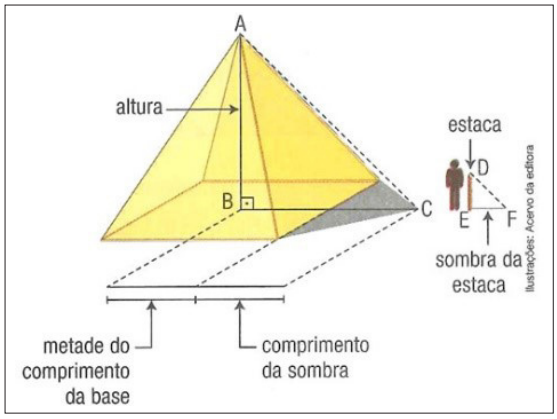
Photographs may cause specific effects, in relation to the content or concept being taught, such as redundancy, thus aiding in memorization. However, considering that photographs flood other types of media, e.g. the internet, other types of visual representation that are more suitable to cognition could occupy this vast space, as we have already discussed from Graphs 1 and 2.

The symbol, the third classification of sign in relation to the object, receives new clothing for not only words constitute the language of Science and Mathematics: there are symbols representing the chemical elements, mathematical operations, numbers.

16. PEIRCE, Charles Sanders. **Collected papers**. Cambridge: Harvard University Press, 1958. v. 8. p. 41.

17. Idem, 1931. v. 2. p. 305.

18. DRIGO, Maria Ogécia; SOUZA, Luciana C. P. **Aulas de semiótica peirceana**. São Paulo: Annablume, 2013.



Source: Souza e Pataro (2012b, p. 141).

Figure 11: Geometric solid

Source: Santana (2012c, p. 192).

Figure 12: The photograph as a record of the real

According to Drigo & Souza[19], the symbol designates a conventional sign or that depends on a habit that can be acquired or that is natural. It does not indicate something in particular, but a collection of things. Symbols can thus be a banner or insignia, a password, an emblem, a religious belief – because it serves as a password or emblem –, a ticket that authorizes someone to receive something, a theater ticket. In one of his exemples, Peirce uses the word "star". Such word is not conceivable in itself, since even when transposed to paper or pronounced, only one of its aspects can be considered. It is a specific word when it means "astronomical object with its own light", another when it means "celebrity" and another when it is used a "luck". "We can write the word 'star', but this does not make the one who wrote the word its creator, as well as when we erase the word, we are not destroying it. The word lives in the mind of those who use them"[20]. And it is by virtue of the "idea of the mind-that-uses-the-symbol"[21] that the symbol connects itself to the object; without it, such connection would be impossible.

The raison d'être of the symbol as a sign because of the interpretant, the third constituent element of the sign responsible for the meaning which onsets

19. DRIGO, Maria Ogécia; SOUZA, Luciana C. P. **Aulas de semiótica peirceana**. São Paulo: Annablume, 2013.

20. PEIRCE, Charles Sanders. **Collected papers**. Cambridge: Harvard University Press, 1931. v. 2. p. 301.

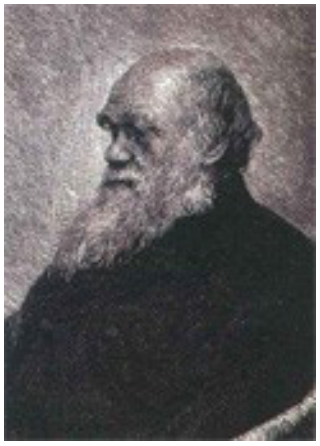
21. Ibidem, p. 299.

the semiosis. The character of the symbol is in the generality and its function is to grow in the interpretants or in the meanings which it will produce. Symbols function "not by virtue of a character that belongs to them as things, nor by virtue of a real connection with their objects, but simply by virtue of being represented as signs"[22]. The symbol is abstract, it has the character of law; thus requiring manifestations, updates that are called replicas. The mathematical sentence $y = -x^2 + 4x - 5$ (Figure 1) becomes a symbol when the interpreter executes the rules expressed by it.

However, still among visual representations, there are those that we classify as portraits, works of art and media products. We shall analyzed in general terms how these are used by the sample books.

PORTRAITS, WORKS OF ART AND MEDIA PRODUCTS

Portraits, works of art or photographs (Figure 13) present in the biographical notes of scientists and mathematicians make up 0.55% of the visual representations found in the sample collections.



Source: Trivellato et al. (2008c, p. 223).

Figure 13: Charles Darwin

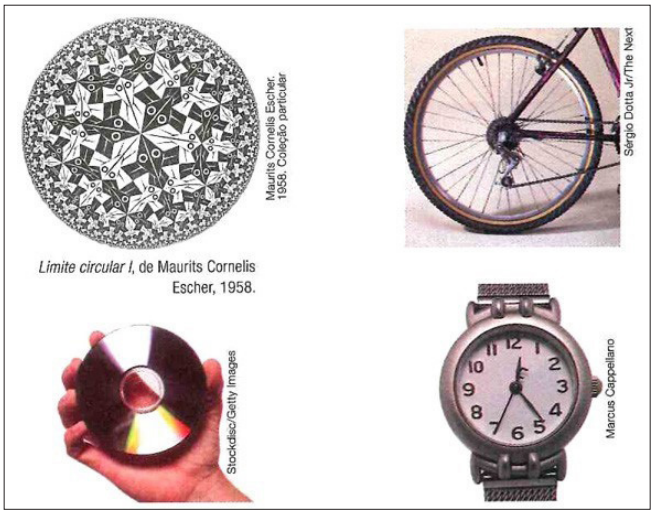
These types of information may establish a closer bond with the developed subject; however, this does not always occur. The same is true for works of art. In the case of Figure 14, which corresponds to 1% of the total visual representations in the sample books, there are no explanations on the aspects of artistic production or information regarding medical knowledge that could come with the interpretative process of the work, as well as the context in which it was made.

22. PEIRCE, Charles Sanders. **Collected papers.** Cambridge: Harvard University Press, 1958. v. 8. p. 119.

Fonte: Trivellato et al. (2008b, p. 8).

Figure 14: *The anatomy lesson of Dr. Nicolaes Tulp*, by Rembrandt (1632)

Furthermore, in Escher's work (Figure 15), using it to introduce some notions of non-Euclidean geometry to students would be much more appropriate. Works of art, in general, could be used to handle the approximations between science and art.



Source: Souza e Pataro (2012a, p. 286).

Figure 15: Circular shape and Escher's work

Regarding media products, the most found were posters and comics, but with 0.6% for the books in the sample. Using comics to emphasize some aspects of an idea or concept can be useful for cognition, given that it is always possible to highlight them with comedy (Figure 16).

On the other hand, posters can elicit reflections both in relation to the subject it addresses and the aspects involved in the creation process of this medium, which characterizes a small advance for media education. This theme should not become another school discipline, but follow the languages of the existing ones.

Through posters (Figure 17), a new modality of activity is announced, "reading images", which shows a certain interest in media languages.

Source: Santana (2012a, p. 83).

Figure 16: The caterpillar and the butterfly in comics

Source: Santana (2012a, p. 318).

Figure 17: Blue... of water

We can assume that this activity was elaborated so the student can learn, not only to observe, but to interpret images, whether scientific or not. For such, the following questions were elaborated:

> 1. What are the basic elements that this image presents? 2. Although the image only has two colors, do you think they are important? Why? What do the shapes and colors of the drawings tell us? 3. What idea does this image transmit to you? Justify your answer[23].

23. SANTANA, Olga A. **Ciências naturais**: 6°ano. São Paulo: Saraiva, 2012a. p. 318.

If the teacher has knowledge of visual language, students will be able to perceive or verify that colors and forms also have latent meanings. Words have always been prioritized over visual language in the teaching environment; thus, we cannot be certain that these questions can be effectively discussed.

In teaching, one must avoid that the interpretive processes head towards fantasies or that they are left to the field of taste, to subjective and self-reflexive evaluation of the sender or receiver, without being guided by knowledge on visual language[24].

> In many cases, students are bombarded with visual resources – movies, *slides*, audiovisual projections – but these are presentations that reinforce their passive experience of television consumers. Communication resources that are being produced and used for teaching purposes are presented with very poor criteria for the evaluation and understanding of the effects they produce[25].

Science and Mathematics textbooks can encapsulate the list of visual resources that are used in teaching without their possible effects being understood.

FINAL REMARKS

Tracing Peirce's view, whose conception of language supplants mere linguistics, we find that the languages of Science and Mathematics, as school subjects, are not only symbols or arbitrary signs, they are also icons and indexes: signs that establish both relations of similarity and connection with the object to which they refer to.

Mathematical language predominates as iconic due to requiring diagrams and equations, which are iconic signs. Science require the use of infographics, which we classified as diagrams. These iconic signs are prodigal because of their power of synthesis and of generating questions in the interpreter. Thus, infographics must be prioritized to the detriment of mere illustrations or registers in teaching, since they contribute in improving cognition by – visually – showing the relation between concepts and weaving paths for their understanding.

Thus, textbooks should care for their visual representations. To us, there are two measures to be taken: first, to avoid the excess of images, and second, to prioritize the ones most proficient to cognition, like diagrams and visual metaphors.

The importance of these reflections is in shedding light on considerations about the link between communication and education posed by language, which implies, more specifically, also to consider school subjects as languages other than verbal. From educators, the need to construct new looks for visual representations is required, which should include knowledge about the role of such signs in cognition, as well as the search for methodologies to visually interpret ideas, i.e., for the elaboration and analysis of diagrams, visual metaphors and equations.

24. DONDIS, Donis A. **Sintaxe da linguagem visual.** São Paulo: Martins Fontes, 2010. p. 17.

25. DONDIS, Donis A. **Sintaxe da linguagem visual**. São Paulo: Martins Fontes, 2010. p. 26.

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