Toward a Pedagogy of Photographs in High School Biology Textbooks

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Abstract
Photographs are a major aspect of high school science textbooks, which dominate classroom approaches to teaching and learning. It is surprising then that the function of photographs and their relation to captions and texts have not been the topic of analysis. The purpose of this study was to construct a pedagogy of photographs in high school science. Our motivating research question was, “What can students learn from textbooks when they study photographs?” To answer this and several subordinate questions, we selected and analyzed four Brazilian biology textbooks. We focus on the use of photographs and the relation between them, various types of texts, and the subject matter presented. Our analysis reveals that the structural elements of text, caption, and photographs and the relations between them differ across the textbooks and at times even within the same book. This, of course, will influence readers’ interpretations of the photographs and changing their role in the text. The results of our study have implications for textbooks authors and textbook readers, including teachers and students. We suggest that future studies may focus on students’ and teachers’ interpretation of photographs in real time.
Photographs constitute a major aspect of high school science texts; a recent study showed that there are about 17 photographs on every 20 pages of high school biology textbooks (Roth, Bowen, & McGinn, 1999). It is surprising then that a photograph (like a word) on its own does not mean anything (Wittgenstein, 1994/58); it is only through recurrent use in similar situations that the relation of a word to other words, a photograph to other photographs and words are established. For example, one might ask, “What is the content of the photograph in Figure 1?”, which was taken from a Brazilian high school biology textbook. “What is its meaning?” There are some cows in the foreground, two trees and a fence further back. Then there is a field or meadow before an assembly of trees, which may be seen as a “forest.” So what does it mean? To find an answer, we have to seek recourse to the text from which we culled it the photograph. The caption to the photograph talks about there being distinct biomes (“The dividing line is a band with major vegetation that defines an ecotone”).¹ Knowing this, we can now return to the photograph and attempt to discover distinctness that would delimit the different biomes that we are to find. Further reading of the caption then tells us something about changes to greater density. The caption also talks about forest and savanna, the later being a kind of field.

Once we find these descriptions, our gaze separates forest and field, disregards the trees in the foreground, and isolates changes in density. What the text has done, therefore, is not just described what there is in the image—if it was only a description of something self-evident, it would not have been necessary. Rather, the text taught us what to look for and how to parse a rather dense visual field. The text contributes to teaching us how to detect biomes, ecotones, and how to distinguish them—though this particular photograph

¹ All texts have been translated from Portuguese to English by the authors. An ecotone is defined as an ecological community of mixed vegetation created by the overlap of adjoining communities (Kieft, White, Loftin, Aguilar, Craig, & Skaar, 1998); it is usually a belt rather than an abrupt line. For example, the floodplains of the Amazon River are sometimes interpreted as ecotones between upland and rivers, and sometimes they are viewed as specific ecosystems. But there is still a lot of controversy over the ecotone concept, in part because boundaries cannot be easily delineated (Fraser & Williams, 1998).
makes the concept of ecotone appears in a simplistic way as a clearly identifiable boundary. At the same time, the text in itself lacked something that the image provides. Here, the figure authenticates what the text is about, the existence of biomes and ecotones, and the borders that exist between biomes. In sum, the texts that are copresent with the photograph provide the pedagogy for reading the photographic image, allowing a small rather than a potentially infinite number of interpretations to be viable.

“What can students learn from textbooks when they in fact begin to study photographs?” The question is salient particularly in the context present photograph because of the difficulties of making distinctions between forest and savanna experienced even by scientists (Latour, 1999). Thus, Latour documents in great detail an expedition in which Brazilian and French scientists attempted to decide whether the forest was taking over the savanna or whether the savanna was taking over the forest. A major problem to be resolved by the scientists he studied was just where to locate the boundary between forest and savanna; another sociological study of ecologists also showed the tremendous
collaborative work that went into deciding what constitutes the boundary between forest and brush. Law and Lynch (1990) documented similar difficulties experienced by amateur birdwatchers as they attempted to identify birds even though they had the photographs of their bird field guide directly in front of them. In practice, therefore, making a distinction between forest and savanna appears much more difficult than the high school textbook leads us to believe. As science educators, we therefore question, what can and do photographs achieve when they are used in high school textbooks? What purpose do photographs serve if they cannot guarantee that students identify their equivalent in the natural world—after all, are science students not supposed to understand and be able to explain the world around them?

High school science is dominated by textbooks-oriented approaches to teaching and learning. However, little research has been done in science education research regarding the quality of curriculum materials, particularly textbooks. Therefore, “[f]ar more research should be done to provide consumers (e.g., science teachers and principals) with better information about curriculum materials” (Good, 1993, p. 619). The purpose of this study is to analyze the use of photographs in high school biology textbooks, the pedagogy of these photographs and the relation between them and the subject matter presented in the text. This study was motivated by our goal to understand the role and function of photographs in biology textbooks, that is, to arrive at a pedagogy of photographs in high school science. The textbooks chosen as data sources are widely used in Brazil.

Background

An increasing number of studies document the important role of representation practices in science (e.g., Knorr-Cetina & Amann, 1990; Latour, 1999; Lynch & Woolgar, 1990). In sociological studies of science, the notion of “inscription” is used instead of representation for all socially shared representations other than text independent of their medium (Latour 1987). Inscriptions that stand for natural
phenomena usually appear first in scientific laboratories and field research sites, and—after having been cleaned, superposed, transformed—are later used in scientific publications. The more information an inscription summarizes, the more it becomes complex, resistant to deconstruction, and powerful. However, the amount of information that can be summarized in an inscription also determines its abstractness. That is, the more information is collated together into one and the same inscription, to more contextual detail is being dropped (Latour, 1987). Thus, a photograph of a rose represents one particular rose, whereas a drawing of a rose may stand for roses more generally (Figure 2). This claim is supported by research that showed that it was easier to classify birds using a field guide with drawings, which represent birds more generally, than using a field guide with photographs, which display birds more specifically and with considerable background detail (Law & Lynch, 1990).

Figure 2. Representations lie along a continuum depending on the amount of contextual detail that they carry in the background of the central object proper.

The elimination of gratuitous detail is part of the move from the particularity of one observation to the generality of a scientific claim (Myers, 1990). Therefore, photographs are placed at one end of this set of categories, presenting the background as a space continuous with our own lived experience, and, then, full of gratuitous detail. All this detail may not carry relevant information; however, it does have a function, making the photograph seem to be an extension of nature into the pages of the book, even though the effect of realism does not depend on the complete reproduction of the world. The
photographs obtain their powerful role as representations of the real world through the reader’s work of interpretation, the viewer’s perception of the narrative and perceptual order of the document (Bjelic, 1992; Morrison, 1989).

Whereas in professional science there is a preference for inscriptions to the right side of Figure 2, high school science textbooks predominantly use photographs and naturalistic drawings (Roth et al., 1999). This is perhaps correlated with the fact that photographic and pictorial inscriptions are more likely to have an impact on individuals outside of science than graphs or equations that are often incomprehensible to students and other lay people (Myers, 1990). In the educational literature, there exist a number of reports that focus on student’s use of representations together with textual information. However, despite the large range of possible instructional functions of inscriptions, research provides little evidence that inscriptions live up to their potential in print (e.g., Schnottz, Picard, & Hron, 1993) and computer media (Lowe, 1999).

Despite the centrality of representation practices in science and despite the many open questions as to the role of inscriptions in instruction, relatively little work has been done in science education from either sociological or psychological perspectives. Consequently, a deep understanding and sound theory of cognition typically do not inform the use of inscriptions. Traditionally, textbooks have been important resources in students’ learning because most science classes are oriented toward these resources. However, teachers and students appear to focus almost exclusively on text, leaving aside inscriptions that could assist them in learning and understanding. How inscriptions are deployed in textbooks plays an important role in the living experience of students and in their associated appropriation of practices in the course of schooling. We therefore need a better understanding how various inscriptions interact with text.

Most students are familiar with photographs in general; however, appropriate instructions for how to read and analyze photographs are currently not provided to them. Outside science education, a small number of studies considered the role of photographs
in communication (Bastide, 1990; Livingston, 1995). Such studies show that photographs come with apparent self-evidence. Because of the similitude with the objects represented, photographs are taken as prima-facie evidence, that is, as guarantor of truthful representation (Myers, 1990). Because photographs are automatically produced, eidetic images of the object portrayed, their constructed nature normally disappears. To understand the effect of photographs in learning, we must consider not only the way they are produced, but also the way they are received by the reader.

Study Design

For this interpretive study of photographs, we took as starting point several existing studies concerned with the practices of reading and interpreting scientific representation in general (Bastide, 1990; Lemke, 1998) and photographs and naturalistic drawings in particular (Myers, 1990; Law & Lynch, 1990). We were particularly interested in the semiotic (meaning-making) resources that high school biology textbooks make available for reading and interpreting photographs, and therefore, in the pedagogy that is associated with photographs in introductory scientific texts.

Selecting the Domain

To study the function and use of photographs in science textbooks, we selected the four Brazilian high school biology textbooks most frequently adopted textbooks in and around Santa Maria (Brazil), the city where the principal author attended university and received her science teacher training. These textbooks present the entire high school program in biology in one and the same volume, that is, the content that would be taught in different grade levels. We initially surveyed the inscriptions in all chapters of the four books but, to make comparisons with an existing North American study (Roth et al., 1999), conducted detailed analyses of those chapters in four Brazilian high school biology textbooks concerned with ecology.
Analytic Frame

In this study, we conducted two types of analyses. First, a coarse-grained analysis was pertaining to types and frequencies of representations in Brazilian high school biology textbooks to test whether the distribution reported by a study of North American textbooks would be replicable in another culture. Second, a fine-grained approach was developed to analyze the semiotic resources provided by textbooks for reading and interpreting photographs.

We began our study with the category scheme of inscriptions published by the authors of the study to which we compare our own results. These included equations (mathematical and chemical), Cartesian graphs; histogram (bar chart); table (statistics, numerical data, or classification); map; drawing of system (causal model); diagram; (naturalistic) drawing; and photographs (micrographs). We counted inscriptions by “panels” or “plates”; panels or plates are expressed by the use of separate coordinate axes or different letters that distinguish the different parts of a single figure. If there were multiple types of inscriptions within the same plate, we counted the instance as belonging to the dominant category. Thus, we counted an inscription containing a world map, colored to identify different biomes, and including small photographs of each biome as “one” map. To align our classifications, we collaboratively classified inscriptions (seeking out those that were difficult and might lead to disagreement) until we agreed on every instance.

For the detailed analyses of photographs, we randomly opened different textbooks, selecting photographs for a preliminary analysis, only including subsequent samples if they somehow appeared different from all previous ones. We photocopied four photographs (including caption) and the paragraphs from the main text that contained (a) a reference to the photograph or (b) dealt with the same concept that the photograph was said to be an example of. We began by independently studying these examples to (a)
develop an analytic frame that we could subsequently use and (b) articulate sample analyses. In this initial approach, we were guided by the principles of analysis grounded in a semiotic of scientific texts (Bastide, 1990; Lemke, 1998). We subsequently met to discuss our individual analyses to evolve a frame that would work for our team. We also discussed all preliminary analyses to find themes that we agreed upon and that could be replicated with other photographs. For inclusion in this article, we ultimately selected photographs that would paradigmatically display the principles of the pedagogy of photographs that we derived through our analytic work.

Throughout our analyses, we strove to ascertain a high quality of our analyses following the precepts of Fourth Generation Evaluation (Guba & Lincoln, 1989). We monitored and recorded our emerging understanding, allowing us to enact prolonged engagement, sufficient observation, revision of hypotheses through the analysis of negative cases, and progressive subjectivity and to construct an audit trail. For example, we initially identified five different categories of photographs. These included photographs (a) without caption; (b) with captions that name what can be seen; (c) with captions that name and classify what is represented; (d) with captions that summarize the content of the main text; and (e) captions that present new information. Toward the end of our in-depth analyses, we abandoned the fourth category after discussing the following assertion made by the first author:

We have talked about five different categories of photographs in the proposal, but I really think we have only four, because “summary category” is not really exactly a summary, and I just could find three examples of this category, which is actually “forcing” it a little bit.

We revisited the three cases and decided to include these photographs in the fifth category, complementary function, as we believed they are more appropriately classified as a complement to the main text.
Abundance of Inscriptions and Dominance of Photographs

The quantitative data obtained in our analysis shows that the Brazilian textbooks contain even more inscriptions than the North American high school biology textbooks analyzed previously (Roth et al., 1999). The total number of inscriptions in the Brazilian textbooks was found to be 1.9 inscriptions per page versus 1.4 inscriptions per page reported for the North American textbooks (Figure 3). Photographs represent the most frequent inscriptions in these books: there are about 0.55 photographs per page in Brazilian textbooks compared to 0.79 in North American textbooks. These results show that photographs take an important place in Brazilian textbooks, though with smaller frequency than in the North American study. In comparison, the second most frequent category in the analyzed textbooks was about 0.27 per page, about one half the frequency.
of photographs (Figure 3). Comparing the sums of naturalistic drawings in the four Brazilian textbooks and in the six North American textbooks analyzed, the first present 0.21 naturalistic drawings per page, and the last one, 0.18. Taken together, photographs and naturalistic drawings present 0.75 inscriptions per page of the Brazilian textbooks compared to 0.96 inscriptions per page in the North American textbooks.

These results show that high school biology textbooks, as science more generally, heavily draw on inscriptions; in contrast to professional science, though, high school textbooks have a high frequency of photographs and naturalistic drawings. Despite this prevalence, we are not aware of any study that has shown what the semiotic resources of these images and their associated texts are and particularly what the pedagogical functions and the opportunities and constraints for sense making that they present to the novitiate reader. In the ecology-related chapters of the four textbooks, there were $N = 124$ classified as photographs. In the subsequent sections, we present our results that pertain to a semiotic analysis of these photographs.

Photographs and Texts: Principles of Analysis

We began this article by making the point that a photograph in and of itself means little; it is full of “gratuitous” detail that allows many different ways of looking at and interpreting it. This photographic detail provides a space that is continuous with our own lived world, allowing readers to establish a link with the everyday world that surrounds them. At the same time, the photograph provides few cultural codes (e.g., a line, letter, or recognizable shapes) that could delimit its sense and meaning as intended by the author. To control the range of possible meanings that a photograph can give rise to, authors use captions and embed this photograph/caption combination in still further text (main text) that together constrain the meaning a reader can make. In this section, we propose some principles for the analysis of photographs in school science textbooks.
From a semiotic perspective, the photograph and its caption are two different sign assemblages or two different texts, where text refers more broadly to any entity that can be interpreted (Eco, 1984). However, caption and photograph are not independent. As captions always appear just below or next to a photograph, the two different and arbitrary sign forms are directly associated with one another. They are said to be about the same thing. Take the photographs and captions in Figure 4 that appear in the context of a textbook treatment of “camouflage.” In the last sentence, the caption suggests, “This is a good example of camouflage.”

The caption articulates “winter” and “white plumage,” which calls attention to the color of the plumage during a particular season, winter, which, if students are familiar with snow, is easily identified with the left-most image in the figure. (Most of our Brazilian students have never seen snow and know it only through the media but not through their lived experience.) Simply by the fact of being articulated, even if it was not named, the white color of the plumage in winter is likely to become salient. Even more so, the presence of three images inherently calls for a comparison of seasons and plumage across all photographs, and thereby makes salient the changes across the three images. That is, the text elaborates and therefore teaches how to read each image and the sequence of images (to understand change). The presence of three images calls for comparisons to identify variant and invariant perceptual properties of what the caption marks as being the same animal.

However, the photographs also (and reflexively) elaborate the caption text in the sense that they provide evidence for particular statements. The photographs validate what the text states, the whiteness of plumage and the changes the plumage undergoes; the text elaborates how to read the photographs, contributing to its meaning. Here, we have two

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2 Over the past 30 years, the notion of “text” as a more generalized term to refer to anything that can be interpreted has evolved in various social sciences and humanities such as anthropology (Geertz, 1973), where culture is treated as text or in philosophy (Ricoeur, 1991), where action is elevated to the level of text.
forms of texts, one verbal one visual, each elaborating the other in their relation to the thing that they are about (e.g., Ricoeur, 1991), that is, the idea of camouflage. This “idea” is the real referent of the word and what is to be seen as difference in the collection of photographs. As arbitrary signs, both stand in an open and yet-to-be-elaborated relation to their content, the entity that they are about. The “this,” in “this is a good example of camouflage” can be read as an indexical reference to the content of the previous sentence(s), which describes how to read the photographs, and to the content of the series of photographs, which legitimate the text.

It may be useful here to draw on the notion of intertexts, which are all the other texts that readers use to make sense of and that therefore serve as a background against which he or she reads the primary text (Lemke, 1990). Without the intertexts, one would not be able to make sense, for “everything makes sense only against the background of other things like it” (p. 204). In the present situation, the caption and the photograph are about the same thing (co-thematic) and pertaining to the same activity structure (co-actional) but are of different genre (non-co-generic) texts. Texts and photographs are semiotic resources that are co-deployed and, becoming intertexts for one another, elaborate each other.

For the analysis of textbooks, we developed a scheme that articulates various semiotic resources and the nature of their relations (Figure 5). We view all relations between the different parts of a book (main text, figure, caption, and [sidebar] text box) as involving double movements, each pair of entities mutually constituting one another and the
relation. Thus, the title prepares the reader for what is coming, and thereby organizes his or her reading. At the same time, a title is not chosen arbitrarily, but has been motivated by the content of the main text. The main text makes certain claims or seeks to explicate a concept, which therefore motivates the use of a particular figure. The figure in turn validates the claims made in the main text. Finally, the caption describes and teaches how to read the figure (here photograph[s]) and the figure authenticates the caption text.

![Diagram of the relationship between title, main text, figure, and caption](image)

**Figure 5.** The framework that we developed for the analysis of inscriptions that accompany scientific texts in general and for photographs in particular.

In this article, we are centrally concerned with the relationship between photograph (figure) and caption, and their integration with the main text. This integration is achieved not only through the co-thematic nature of figure and caption but also through an index by means of which readers are referred from a particular place in the main text to figure and caption, which constitute a different genre. The caption is an essential part of the inscription that tells the reader what look for in the photograph and therefore how to read
and understand it. The photographs are associated with a text that explains the phenomenon. Thus, photograph and text together form the written correlate of a demonstration (Morrison, 1989); they constitute a particular form of pedagogy, though our informally acquired information in another study shows that most students disattend to anything other than the main text. If this is the case, then important concepts and information should be placed in the main text, with the appropriate reference to the inscription that would help the reader to make sense of the phenomenon under scrutiny.

Photographs in Brazilian High School Biology Textbooks

In our analysis of the pedagogical role of photographs in high school biology textbooks, two themes emerged: there are different functions that a photograph/caption has with respect to the main text and there are different ways in which the photographs and the texts are structured, with implications for the interpretation of these inscriptions in the textbook. In the following sections, we describe and provide evidence for these two themes.

Functions of Photographs

In the ecology sections of the four Brazilian biology textbooks, all 124 photographs could be classified as full-filling one of four functions (roles), which arise from the relation of photograph/caption to the main text. However, we also include in this classification those photographs that accompanied other inscriptions, as for example, maps. Series of or pairs of photographs were considered one single inscription in this classification. Therefore, the total of inscriptions classified in the four categories are N=148.

The categories we identified are: decorative \((n = 8 \text{ [5.4%]})\), illustrative \((n = 52 \text{ [35.1%]})\), explanatory \((n = 42 \text{ [28.4%]})\), and complementary function \((n = 46 \text{ [31.1%]})\). These functions—and therefore our categorization—largely arise from the interpretation
of caption, the text co-deployed and directly associated with each photograph. These functions also roughly define a hierarchy of increasing informational value (explaining a concept does more than simply illustrating a concept) and those with higher information value usually also do what the photographs of lesser informational value do. We exemplify and discuss each of these roles.

Decorative Function

A small number of photographs were classified as decorative. These photographs were not referred to in the main text, did not include a caption, and usually appeared at the beginning of a unit, chapter, or section of text. Figure 6, for instance, appeared on the opening page of a section on “energy and matter in the biosphere.” This photograph does not include a caption; there is no reference from the opening of the main text to the photograph. How the photograph functions in relation to other texts deployed (its intertextuality) requires analysis and does not “jump out” at the non-initiate. At the outset, it is a colorful plate from which relevant figure and ground have to be separated. Prior exposure to cultural categories allows readers of a certain age—a one- or two-year old may not perceptually differentiate what an adult sees as leaf or caterpillar—to identify a caterpillar on a leaf. That is, in the absence of a text inscribed in the book with reference to the photograph, the reader has to bring existing understanding as the intertext in reference to which the photograph becomes salient figure. What is the role of this
photograph at this place in the book? What can a student learn by looking at or analyzing (studying) the photograph? A photograph can be viewed in many different ways. To understand what this photograph is intended to show in this place, a reader may search for clues in nearby texts, such as the title of the unit. Assuming that the text is not only codeployed but also cothematic with the photograph, a reader seeks to relate individual words “energy,” “matter,” or “biosphere” to the photograph. A somewhat initiated reader may see the caterpillar nibbling away on or “eating” the leaf; but we insist that “nibbling” as a process is not available to readers, it has to be inferred based on extra-textual experience. However, not until a reader knows the relationship between “eating” and “energy” household of animals can s/he establish a connection with (one part of) the unit title. At the same time, the leaf has to be understood as matter rather than as an organism, and both the caterpillar and the leaf have to be seen as aspects of “biosphere” before the relation of this photograph to the unit title can be established. Students, however, are not likely to bring this understanding necessary for establishing these relationships between unit title and photograph. In fact, the purpose of the unit is to develop the understanding necessary to deconstruct the relationship between photograph and title.

This initial analysis shows how, for the initiate reader, unit title and photograph can be seen in a mutually constitutive relation expressed in Figure 5. The word “energy” makes a reading of “caterpillar eating leaf” a reasonable reading of the photograph, which, in turn, establishes a concrete instance of the relationship between biosphere and “matter and energy,” concepts usually introduced in the physical sciences. However, because students do not bring the interpretive resources required for the type of analysis provided and because of the lack of a text that could guide students in their analysis of the image, we categorized such photographs as decorative. They introduce color, may provide for certain aesthetics, but lack informational function for the individual who does not already know what the subsequent text is intended to teach.
Illustrative Function

Photographs included in this category include a caption that names or describes what the reader is to see in the photograph but the caption does not provide additional information to the main text. Such photograph-caption ensembles constitute a visual resource for the reader in the sense that a concrete specimen of a class or concept is depicted (e.g., Figure 7).

Fig. 4.3 Photograph of plants of aguapé in blossom.

Figure 7. An example of an illustrative photograph.

This photograph gives the reader a visual representation of the species mentioned in the main text (aguapé), but this is not an essential piece of information for the reader relative to the subject matter treated in the text. In the present case, the subject matter is the introduction of certain species in biomes, exemplified by the introduction of aguapé in hot regions. “Aguapé” and “hot regions” are special instances of the more general concepts of plant and biome.

The photograph illustrates the particular plant but does not show “introduction” that causes changes in the ecosystem. To show the effect of “introduction” of a plant, a minimum of multiple photographs are required that show some difference that can be noted as a difference before it, according to Bateson (1972), can function as “information.” That is, if there is not a difference that makes a difference, we cannot speak of information at all. Therefore, the very concept taught in the text is absent from the photograph: it does not exist as information in the image. The visual information possibly provided does not alter the understanding of the subject matter, that is, the photograph does not show the phenomenon treated in the text, but provides a visual
illustration of a plant that was only referred to in the text as an example of a species which introduction caused changes in the ecosystem. The reader still is able to understand the concept of ecological disequilibrium treated in the text without the information provided by this photograph and the caption.

There were several cases ($n = 29$) of illustrative photographs that were not associated with a (part of a) caption. Such photographs, a special case of photographs without caption, appeared together with “maps,” the dominant aspect of the inscription (Figure 8). Here, several photographs were co-deployed with the map but were not described or explained in the caption. One might therefore think that the photographs are decorative, especially because the caption of the inscription is related with the map. However, there is an important link between photographs and map: the color scheme of the legend relates photographs, presenting single (paradigmatic) instances of different landscapes, and regions. If map and photographs are interpreted as being co thematic, by virtue of appearing in the same plate, the different genres can be read as linked via the concept of biomes: “distribution of different biomes” and concrete instances of individual biomes. In this situation, there is one photograph for each biome but, in the presence of six images, a contrast is provided between what may be prototypical examples for each biome. The presence of only one example does not allow students to learn what characterizes each biome or more poignantly, how to distinguish one biome from another in more problematic cases near the border of the category. (See Lakoff [1987] on examples of a category that are nearer the center, and therefore more prototypical for a category versus those that are nearer the peripheries of two categories, and therefore more problematic in their assignment to one or the other.) But the presence of six prototypes, given learners attend to appropriate aspects of the landscapes depicted, may allow the recognition of some global distinctions between these biomes. Nevertheless, some of the very features that distinguish these biomes, the amount of water available, temperature, and other
physical and biological information, is not accessible by students through the analysis of the photographs.

**Explanatory Function**

This category includes photographs with captions that provide an explanation of or a classification of what is represented in the photographs. The captions do not only name the object or phenomenon in the photograph, but also add information about this object or phenomenon. Take the example of Figure 9. In the first part of the caption we can read “Aspect of a forest.” With this information, readers are guided in what to look for in the photograph, a forest. That is, what we see are not just a group of trees along a river but part of a larger whole. This information provided by the caption is important in helping the reader to make sense of what can be seen in the photograph, however, this
Figure 9. Example of an explanatory photograph. The words “climax community” provide a frame that allows the reader to establish a connection between the figure and the main text.

information is not enough to guide the reader to establish relations between the photograph and the subject matter treated in the main text.

The index presented in the main text and replicated in the caption allows the reader to connect figure and text. However the reader is not able without further information to appropriately relate the “forest” in the photograph with the concept of “ecological successions” that is the corresponding topic of the main text. Thus, if this were the only information provided in the caption, the photograph would function as an illustration of a forest, because somewhere in the main text the forest was mentioned. It is the second part of the caption that provides the information necessary to interpret the forest in the photograph as “something else,” which allows the reader to explicitly relate the figure and the text. These two words, “climax community,” represent an entire different perspective in the way in which the reader contextualizes the photograph and relates it to the main text.

The photograph not only represents a forest, but also is marked as an example of a climax community. Textual marks are not neutral but invite making salient some things to the exclusion of all the others that could be made salient (Derrida, 2001). That is, marked terms encourage readers to associate the characteristics of a climax community described in the main text with what they see in the photograph. In this sense, this caption
not only classifies the forest as a climax community, but also provides an explanation about how to interpret and relate the photograph with the main text.

At the same time, because this is a single photograph, the concept of succession is not available to readers, which would require several photographs showing the same physical location but with varying cover corresponding to varying stages in the ecological succession of the area. Similarly, the single photograph does not allow the initiate reader to learn how to distinguish climax forest from non-climax forest, or between the climax forest for different forms successions such as those that end in maple-beech forest (Northeastern US, Eastern Canada) or those that end in coniferous forests (Canadian shield, Newfoundland). Both types of forest are examples of climax forest but are very different in the way that they appear to the eye.

Complementary Function

Photographs in this category are associated with captions that add new information about the subject matter treated in the main text. This information is not only new, but it is also an important information, never mentioned before in the main text, and that helps readers to further understand the biological concept that is being taught. Figure 10, for example, presents two fishes against a black background. The title of the section of the text where this figure is inserted in is “Influence of light in the marine ambient,” and in the main text we can read about the distribution of species in the ocean according to the presence or absence of light. In the last paragraph the text presents some characteristics of fishes and other animals that live in the abyssal zone. Then the text refers the reader to the figure.

The text begins by providing a name and articulating it as an example of an “abyssal fish.” Inherently, the statement “linofrino, an example of an abyssal fish” requires the cultural competence of associating the name with the image, even though there is no specific index linking the name with the fish—parents reading to their preschool children might place their finger on the image and say, “linofrino.” The remainder of the caption
provides propositions with content not made available in the main text, and therefore constitutes new and relevant content. We therefore classify this photograph-caption ensemble as complementary.

The caption in this case provides information about what can be seen in the photograph, that is, characteristics of the abyssal fishes represented. The caption also adds new information, not directly related to the two fishes, but, rather, associated with the concept of abyssal fish treated in the text. Therefore, this plate constitutes a “complement” to the main text. The complementary photograph/caption thus presupposes continuity in the reading process, as readers iterate their reading between main text and plate. They are able to make sense of the concept presented only through the reading of all the information contained in these three elements. If the information in the caption is new and important, we therefore have to ask why this information is in the caption instead of in the main text—unless photographs/caption are regarded by students and teachers integral parts of the “material to be studied.”

Structures of Co-Deploying Photographs and Texts

Our analysis reveals considerable variation between and within textbooks in how the co-deployment of photographs and texts is structured. The structural elements and the relation between them are diverse among the selected textbooks and even within the same book. The variations include, for example, where the reference to a photograph occurs in
the main text, the distribution and arrangement of photographs on the page, and the co-deployment of multiple photographs for teaching a particular concept. These structural elements, undoubtedly, provide different resources for integrating co-deployed and co-thematic but non-co-generic text.

**Indexical Reference**

Photographs represent a different genre than text. They are two-dimensional arrangements of colored or areas, which, because of our prior experience in a three-dimensional world, can be decoded to provide additional information about depth. Color, areas covering other areas, relative size of known objects and so forth provide resources for reading that are deployed as the eyes scan the image according to the reader’s preference. Verbal texts, on the other hand, are linear, conventionally (in Euro-centric cultures) requiring the eye to move from left to right and jumping, at the end of a line, downward to the left of the subsequent line. Because of the different requirements for reading verbal text and images, the latter cannot be placed at the point in the text that is directly pertinent (co-thematic).³ The link between the text (word, sentence, or paragraph) and the photograph that appears somewhere else on the same or different page is established via an indexical reference usually as a string of letters and numbers in the form “Figure 1.2,” “Fig. 2,” or “see Fig. 3.4.” A copy of this index is also found in the caption of the figure that the index is designed to direct the reader. Here, the indexical function is achieved by duplicating a string in the main text and in caption. Whenever the string appears in the main text, the reader is referred to the photograph/caption that features the same (co-generic) string. That is, the relationship and “placement” of a photograph with respect to the dominant text is achieved by means of a string that appears twice but in different locations on the page or in the book. The role of the string

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³ Multimedia such as web pages allow different ways of accessing images, for example, by making available a “button” linked to an image so that the reader can, if desired, make the image appear in a new window, which itself may be moved around the monitor.
is salient when we consider that a similar relationship does not suggest how to link
caption and photograph. Here physical proximity is used to suggest that the text directly
bears on something in the image. How this bearing might be achieved still remains
undetermined at this point. (We discuss the nature of this relationship and how the reader
enacts it in the next section.)

Two textbooks consistently used the same way of referencing photographs/captions
either placing the indexical reference at the end of a paragraph in which the co-thematic
concept appeared (Amabis, 1997) or not using an indexical reference at all (Soares,
1999). The two other books each employed three different ways in placing the indexical
reference in the main text. Thus, the indexical reference was placed either at the end of
the paragraph or directly with the co-thematic word or sentence or was absent altogether.

When the indexical reference is placed immediately after the word or after/within the
sentence that is co-thematic with the photograph/caption, a direct link is established
between what are on the surface different (because non-co-generic) representations. On
the other hand, if the indexical reference is placed at the end of a paragraph where there
are potentially multiple concepts presented, the link is no longer direct. One may consider
the index “misplaced,” because the photograph/caption is not evoked simultaneously with
the verbal texts. There is the potential that misplaced indexical reference in books
interferes with sense-making processes in ways similar to misplaced gestural indexical
reference that make it difficult to learn from lectures (Roth & Bowen, 1999). Finally,
when there is no indexical reference at all, it is totally up to the reader to see whether
there is any relation at all between a photograph/caption on the main text on the same
particular page.

Figure 11 exemplifies a “misplaced” indexical reference. In this situation, because the
index is placed in the end of the paragraph, the reader may associate the photograph more
spontaneously with the last phrase or statement—particularly in those textbooks where
the indexical referencing changes. The photographs represent (1) a burned area and (2) an
a. Factors of Ecological Disequilibrium
Changes in the structure of ecosystems
Deforestation

One of the most important ecological problems today is the destruction of forests, as these occur with the Atlantic Forest in Brazil. Today less than 10% of this forest type remains compared to the period of colonization. Each year, the world loses forest areas; forests are cut or burned, leading to serious soil damage and causing atmospheric pollution. Furthermore, many species become extinct, thereby decreasing “global biodiversity,” as scientists call the large variety of living forms produced by biological evolution. (Fig 4.1)

Figure 4.1 Deforestation is a common way of damaging terrestrial ecosystems. (A) Photograph of burned area in the Amazonian Forest, used to create pasture areas for livestock farming. The fire kills the microorganisms that fertilize the soil, and the rains wash the nutrients away since the vegetal coverage was destroyed. (B) Photograph of regions of soil erosion provoked by the elimination of the forests.

Figure 11. Example of an inscription with a ‘misplaced’ indexical reference. a. Main text. b. Photograph and caption referred to at the end of the corresponding paragraph in the main text.

area of erosion of the soil. Although the main text mentions burning and cutting the trees as ways of causing deforestation, the index to the photograph is physically far away from the specific phrase where deforestation is mentioned.

To associate the photographs with the main text, the reader needs to go back to the middle of the paragraph and find the specific phrase that refers to deforestation. Then, the reader must go back and forth in his or her attempt to read the text. This reading requires the reader to work from the text and the photographs, at the same time “reading” and “seeing” to make sense of the biological concept presented.

Figure 12 presents an example of an inscription with no index in the main text. This inscription presents two photographs: the photograph in the left shows a river with abundant vegetation in both its banks, and the photograph in the right shows a desert. The caption reads, “The amount of water and the richness of life are interdependent.” Because the main text does not contain an indexical reference, we can only try to establish a
relation between text and photographs, the relationship of the photograph to the main text can only subsequent to reading the entire main text section and the photograph/captions.

When the photographs appear alongside one another, the composition highlights the importance of water for the existence of life. Thus, through a comparison of both photographs, the reader is supposed to associate life and water in the way intimated by the caption. However, this is just one way to interpret this inscription, and many other interpretations can also emerge since there are no explicit directions or enough information in the main text or caption to help the reader to make sense of this.

The situation becomes even more difficult when the photograph is physically placed far away (several pages) from the corresponding text (e.g., Soares, p. 311). In this situation, the reader will find him- or herself completely “lost in the book,” since s/he will not find any direct association between the text and the figure, because of the absence of the index. Furthermore, the reader will have difficulty to manage the book pages to associate the figure with the text, because of the disposition of the inscription many pages after the one in which the text was placed. At this point, the figures even
though associated with captions, may serve decorative rather than higher functions in the text.

**Single and Multiple Photographs**

The arrangement of the visual document within the text mediates our ability to see the phenomenon represented in the photograph, that is, part of our interpretation of the photograph depends on the way in which the figure is organized, and how the photograph relates to other photographs. One way in which a photograph can be related to others is as part of a pair or a series. Photographs arranged in series allow the reader to progressive focusing his or her attention on the concept examined by the text. Consider for instance Figure 13. At a first glance, the reader may see these two photographs as presenting the same butterfly, due to the enormous similarity between the species represented in both photographs. However, the caption cautions us that the photograph at right presents one species of butterfly, and that, actually, the butterfly in the photograph at left only seems to be the same species as the earliest, what constitutes the phenomenon called mimicry.

The authentication of the phenomenon of mimicry is presented in the main text is possible due to the arrangement of the photographs in a pair, which allows the significant differences become evident trough the process of comparison. Nevertheless, a
comparison between the two photographs is not enough to give the images meaning. The caption is also necessary to guide the reader to look for the differences—instead of the similarities that are more evident in this case—between the two photographs, to recognize the phenomenon of mimicry. Similarly, in a series of photographs, as for example in Figure 4 (p. 14), the process of authentication of the phenomenon presented in the text depends on the reader’s perception of the differences between the photographs. In making the photographs part of a series, the uncertainty about the meaning is reduced, and the reader, then, is able to eliminate everything that does not change, in a process that progressively highlights what there is to look at and make sense of in this figure.

Another way in which a photograph can be related to others is when it presents the same object as another photograph, but in a different way, which allows both photographs to become complementary to each other (Figure 14). The first photograph shows the plant in a broader view, while the second photograph focuses on a specific part of the same plant. Together, the two photographs allow the reader to identify the plant in the way in which it could appear in nature, and, at the same time, pay attention to the specific detail relevant to the concept presented by the main text. Both photographs, therefore, function as complementary to one another, the second photograph becoming

Figure 14. Example of multiple photographs, one being constituted by the text as presenting the detail of the other.
“part” of the first one, as a detail in higher magnitude, that provides the reader a better visualization of the phenomenon treated in the main text. Multiple photographs, therefore, allow the reader to make external comparisons and therefore visualize the phenomenon presented by the main text. A single photograph, however, can only provide internal comparisons, leading the reader to find the relevant details in the photograph on his or her own. Thus, in the process of interpretation of single photographs, the directions in the caption and other indications, as for example, letters or arrows added over the photograph itself, are important resources that guide the reader’s attention to the “right” detail.

For example, Figure 15 fails to demonstrate the object that it should represent according to the caption. The caption reads “Epiphyte plant,” but there are many different plants without distinction that allows him or her to identify the epiphyte plant. Even though there is a tree placed in the center of the photograph, which may draw the reader’s attention, it is not possible to identify the epiphyte plant, unless the reader already knows what to look for. That is, the reader has to know what an epiphyte plant looks like in order to find it in this photograph. The difficulty, in this case, is related to the “framing” (Bastide, 1990) of photographs, that is, the process by which the reader narrows the
perceptual field to eliminate as many irrelevant elements as possible from the background while trying to show the object as a whole.

The aim in framing photographs therefore has to be making sure that it contains the least information possible, for fear of confusing the meaning. The details in the background seem to carry no relevant information at all, despite their function of making the photograph more “natural,” because it can be perceived as a depiction of a particular piece of nature. However, the effect of realism does not depend on the complete reproduction of the world, but on the viewer’s perception of the narrative and perceptual order (Myers, 1990). Therefore, it could be more appropriate, at least in certain situations, to present an object against a neutral background, even if it compromises the ‘reality’ of the photograph as a depiction of the real world. Compare Figure 15 to Figure 16, which also represents an epiphyte plant. The relevant element in this photograph—the epiphyte plant—is clearly distinct from the background, even though the photograph still presents other plants. The epiphyte plant is not only in the center of the photograph but also the only object that the reader can clearly distinguish. The figure was framed to show just this particular plant, and all other objects are out of focus, becoming part of the irrelevant details in the background.
Sometimes a completely black background is a better alternative for highlighting the phenomenon or object in the photograph (Figure 17). The reader is immediately directed to whatever is shown against the black background that is easily identifiable as irrelevant. Thus, the arrangement of the photographs in the books, as well as the intrinsic characteristics of the photographs themselves, have an impact on the process of interpretation of the figures, and consequently, in reader’s ability to relate the photograph with caption and main text.

Discussion

We live in a visual culture and visual representations pervade our lives. This is especially true in the sciences that historically are associated with the emergence of representational practices. In this article, we show that photographs are the most frequent inscriptions in textbooks and can play different and important roles in the texts and that the photographic images and captions are often inappropriately referenced from the main text. That is, the photographs and captions almost function in a stand-alone mode.

We began this study of photographs because our informal survey of students at all levels of education showed that they hardly ever attend to the photographs despite their abundance in the textbooks. This tendency, of course, has to be seen in the context of
school science and university lessons that primarily focus on language (and mathematical formulae) as a carrier of scientific knowledge. We hypothesize that the true potential of photographs as pedagogical resources has not yet been achieved. To better understand current and potential future use of photographs in science lesson, we presented a framework for analyzing photograph and provide an initial analysis of photographs in four major Brazilian biology textbooks.

Our analysis of the photographs reveals that the structural elements and the relations between them are diverse among the books and even within the same book. Although the main function of the caption is to help understand and interpret the photograph, the “information” in the caption can vary, alternating the relations between the whole inscription and the other structural elements of the text. This alteration also changes the role of the inscription in the text. We identified four functions of photographs, decorative, illustrative, explanatory, and complementary.

These differences in the information provided by the caption not just influence the reader’s interpretation of the photograph, but also change the role of the inscriptions in the text. For example, we can infer from a photograph without any caption that, because there is no direct association to the text, its role is a “decorative” one, and so the book is more “beautiful,” “colored,” and “full-illustrated.” A caption that just identifies what is represented by the photograph gives us a clear idea that this photograph is playing an illustrative role. In these cases it is not even necessary to have the picture; it is a supplement to the text, adding details or specificity, or illustration of it. But as Derrida (e.g., 1981) points out a supplement is part of and not part of the text at the same time: it seems to be adding something to what is complete in itself, and the addition is thus implicitly a correction, sometimes to the point of a recantation.

The index in the main text also varies in the four textbooks and even in the same book. Two of the four textbooks analyzed present patterns related to the index; one of them always presents the index in the end of the paragraph, and the other one does not
have an index at all. The other two books present three different ways to place the index in the main text: in the end of the paragraph; in the middle of the text, just after the phrase or the specific word related to the inscription, or with no index at all. The way in which the index was written also varies in these two textbooks, that is, “(Figure 1)”, “(see figure 1)”, “... as we can see in Figure 1,” etc. As our analysis shows, these differences in the index can change or reinforce the role of the inscriptions in the text, and the relations that can be established between the photographs and the other structural elements of the text.

We conclude that textbook authors use many strategies for relating photographs to titles, main text, index, and captions. The use of individual photographs to illustrate a concept appears to be limited because variation between exemplars is not expressed but necessary to understand just what a photograph depicts. (For example, Law and Lynch [1990] show that novice birdwatchers have difficulties matching a bird to one of the photographs in their bird guide.) Some of these ways appear to interfere with sense making, whereas others potentially offer support in the construction of meaning. Evidently, misplaced indices, that is, indices that “point the reader in the wrong direction,” disrupt the making of sense.

Our analyses of the way in which these photographs are used in the textbooks have some implications for (1) textbook authors and (2) textbook readers, including teachers and students. Our work implies that textbook authors and publishers attend to the appropriate integration of the different representational means so that they in fact assist students in making sense. Further, the use of single photographs often does not allow a reader to disclose what really matters—(time) series of or contrasting photographs, on the other hand make salient variation that are more likely to lead readers to identify the crucial and learning-enhancing aspects. Pertaining to readers, anecdotal information shows that students and teachers often do not attend to the photographs and their captions while perusing textbooks. If, however, there is information to be obtained from the dialectically related caption and photograph, students miss out on an important resource
for understanding the topic that they study. Teachers and students need to pay more attention to the possibilities of photographs to enhance understanding of textual information. Perhaps the photographs could become themselves objects of discussions, which would allow students and the teacher to develop insights about how and what others see when they look at a photograph, and how they interpret it in the context of various other textual sources provided on the page. We suggest that future studies may focus on students’ and teachers’ interpretation of photographs (cum caption and main text) in real time.

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