Classification Systems of Visual Representations Included in Biology Textbooks

Kalliopi Papatheodosiou[1], Katerina Salta[2], Dionysios Koulougliotis[3]

Ionian University, Greece[1, 3]
National and Kapodistrian University of Athens, Greece[2]

Abstract

During the last 4 decades different classification systems have been developed in order to sort visual representations into categories and subsequently study their effectiveness in learning. In the international literature, various criteria are used in order to classify the visual representations. Some classifications are based on the function of the graphic, while others rely on the degree of abstractness. Additional classification criteria are the level of the representation, the semantic relationship with the corresponding text and the physical integration in the text. Although researchers often use the same classification criteria, they, however, tend to use different terms for similar thematic categories. This may lead to confusion that makes analysis of the visual representations more difficult. In the present study, systematic bibliographic research was carried out in order to collect and organize the different classifications employed in the analysis of visual representations included in biology textbooks. Subsequently, qualitative analysis of the content of the classification systems was conducted in order to identify common features as well as semantic differences and produce a novel more sophisticated classification framework for the study of the visual representations.

Keywords: *visual representations, biology textbooks, classification framework*

1. Introduction

Images have a central role in modern societies. Visual representations have an important contribution to communication in scientific communities and consequently in science education. [1] The increased use of visual representations in textbooks in recent years reflects their growing importance in educational contexts as they are a significant learning resource. [2]

Visual representations are an integral part of high school science textbooks and play an important role in understanding the concepts of Biology. [3] Their major contribution in learning and teaching is the construction of meaningful mental models or internal representations of biological concepts and phenomena. [4] A variety of visual representations that can be interpreted by students in different ways have been found in science textbooks. [5] Learners can better understand a biological concept when it is presented in multiple visual representations as each one of them focuses on different information and details. [6] Presenting a biological concept or phenomenon by using different types of visual representations contributes to understanding its various parameters and results in a more effective learning process. [5, 7, 8]

The visual representations that are present in biology textbooks can be sorted into categories according to various criteria resulting to different taxonomies. In many instances, researchers use the same classification criteria with different terms for similar thematic categories. [9] This leads to confusion that makes analysis of the visual representations more difficult. A synthesis of existing classifications, via careful comparison, could overcome this problem.

The present study aims to review the existing classifications of the visual representations used in biology textbooks in order to examine the possibility of integrating them.

2. Methodology

A systematic bibliographic research was carried out in order to collect and organize the classifications employed in the analysis of visual representations included in biology textbooks. Subsequently, a qualitative content analysis of the classification systems was conducted in order to identify common features as well as semantic differences and produce a novel more sophisticated classification framework for the study of visual representations.

3. Results

Researchers employ several terms when referring to visual representations. Some of the most commonly used terms are representations, inscriptions, visual displays, graphical displays, graphical

representations or simply images. [10] An attempt to produce an integrative organization of the numerous existing classification categories can be based on the use of specific classification criteria. The three criteria employed in the current study are function, form and level of representation

3.1 Function of visual representation

Many researchers classify visual representations according to the function they are intended to serve (Table 1). The taxonomy presented in Levin et al.[11] includes five categories of visual representations namely decorative, representational, organizational, interpretational and transformational.

The term "decorative" refers to graphics that do not meaningfully support the text and mostly serve the function of adding an affective component.

The "representational" function [11] characterizes graphics which are strongly related to the text they support, showing exactly what is referred in the text and thereby add an element of concreteness. In subsequent works [10, 12] the term "analytical" was employed to describe visual representations that either depicted an object or entity without elaboration as well as graphics with explicit labelling or other devices showing parts. It is thus deduced that the terms "representational" and "analytical" refer to similar function and may be treated as equivalent. In the later work of Wiley et al. [13], the "analytical" functional category was subdivided into two distinct functions which are referred as "depictive" and "deconstructive". The term "depictive" refers to graphics that only present an object without any other explanations or labels, while the term "deconstructive" refers to depictions that present the components of an object and their in-between relationships.

The "organizational" function [11] refers to graphics which organize the information and components they contain thereby providing cohesion. In later works [10, 12, 13], the term "classificational" was employed for visual representations that show the relationship between the exhibited objects or represent a taxonomy. It is thus deduced that the terms "organizational" and "classificational" refer to similar function and may be considered equivalent.

Table 1: Classifications based on the function of the visual representation

	Levin, Anglin, and Carney (1987)	Kress and Van Leeuwen (1996) Dimopoulos, Koulaidis, & Sklaveniti, (2003)	Wiley, Sarmento, Griffin, & Hinze (2017)
A	Decorative		
B.	Representational	Analytical	Depictive
C.			Deconstructive
D.	Organizational	Classificational	Classificational
E.	Interpretational	Narrative	Explanative
F.	Transformational	Metaphorical	Metaphorical

The "interpretational" function [11] refers to graphics that provide more information than the "organizational" and which are used for describing more difficult or unfamiliar concepts, objects or phenomena. In later works, the use of the terms "narrative" [10, 12] and "explanative" [13] refer to graphics that depict causal or logical sequences, or processes of change, with action often visualized by arrows in order to illustrate technical or natural processes. It is thus deduced that the terms "interpretational", "narrative" and "explanative" refer to similar function and may be treated as equivalent.

Finally, the "transformational" function [11] refers to graphics that attempt to recode into a form that it is easier to remember. In subsequent works [10, 12, 13], the term "metaphorical" was used to "connote or symbolise meanings and values over and above what they literally represent" [10]. It is thus concluded that the terms "transformational" and "metaphorical" refer to similar function and may be considered to be equivalent.

3.2 Form of visual representation (Degree of abstractness)

Another principal criterion employed for the classification of visual representations is the degree of abstractness (Table 2). This refers to the amount of information that can be summarized in an inscription and the degree of similarity to the object or the phenomenon it represents.

The first category consists of the least abstract visual representations that bear a strong resemblance with the original object or phenomenon. Several different terms have been employed for characterizing the visual representations holding this form and may be considered to be equivalent: iconic diagrams

[14], realistic (embodied by photographs and drawings) [12], Photographs/naturalistic drawings [3] and illustrations (embodied by photographs, technical images and drawings). [15]
The second category refers to visual representations holding a higher degree of abstractness. The different corresponding terms employed in the literature are schematic diagrams [14], conventional [12], maps and diagrams [3] and visual or verbal diagrams (embodied by several types of representations shown in Table 2) [15]. The conventional form includes a wide spectrum of representations which covers the ones that belong to the third category as well.
The third category refers to visual representations holding the highest degree of abstractness and show the numeric or quantitative relationship between represented variables. The different corresponding terms employed in the literature are graphs and charts [14], graphs, tables and equations [3] and quantitative representations [15].
Finally, a fourth category refers to visual representations that involve elements that mix the first category with at least one of either the second or the third category and they are known as hybrids [12].

Table 2: Classifications based on the form of the visual representation (degree of abstractness)

<table>
<tr><th>Hegarty, Carpenter, & Just (1991)</th><th>Dimopoulos, Koulaidis, & Sklaveniti (2003)</th><th>Pozzer & Roth (2003)</th><th colspan="2">Postigo & López-Manjón (2015)</th></tr>
<tr><td rowspan="3">Iconic diagrams</td><td rowspan="3">Realistic (Photographs, drawings)</td><td rowspan="2">Photographs</td><td rowspan="3">Illustrations</td><td>Photograph</td></tr>
<tr><td>Technical image</td></tr>
<tr><td>Naturalistic drawings</td><td>Drawing</td></tr>
<tr><td rowspan="3">Schematic diagrams</td><td rowspan="4">Conventional (Graphs, maps, flowcharts, molecular structures and diagrams)</td><td rowspan="3">Maps, Diagrams</td><td rowspan="2">Visual diagrams</td><td>Structure diagram</td></tr>
<tr><td>Process diagram</td></tr>
<tr><td rowspan="2">Verbal diagrams</td><td>Concept map</td></tr>
<tr><td rowspan="2">Graphs, Charts</td><td>Graphs, Tables</td><td>Table and layout</td></tr>
<tr><td>Equations</td><td rowspan="2">Quantitative representations</td><td></td></tr>
<tr><td></td><td>Hybrids</td><td></td><td></td><td></td></tr>
</table>

3.3 Level of the representation

Visual representations in biology textbooks may be classified according to the domain specific criterion related with the level of the representation. The macroscopic level refers to biological entities which are visible to the naked eye. Subsequently, the cellular or subcellular (microscopic) level refers to entities that are visible only under some type of microscope. The microscopic level is followed by the molecular (or submicroscopic) level of representation at which macromolecules such as DNA or proteins may be “visualized” via different analytical techniques (eg. electrophoresis, analytical centrifugation, X-ray crystallography). Finally, the symbolic level of representation refers to explanatory mechanisms of phenomena represented by symbols, formulas, chemical equations, metabolic pathways, numerical calculations, genotypes, inheritance patterns or phylogenetic trees. [7]

4. Conclusion

The analysis undertaken in the current work led to the identification of common as well as unique features among the existing classification systems available for the study of visual representations present in biology textbooks. It resulted to the proposal of more cohesive classification tools which are based in different classificational criteria related to distinct attributes of the visual representations.
Future work will involve the application of these classification tools for the detailed analysis of visual representations related with specific biological themes in biology textbooks used in different educational levels.

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