The role of visualization of biological knowledge in the formation of sets of educational skills

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Abstract

Visual learning aids play a major role in students' learning processes because they directly affect the correct perception of the studied concepts. This is especially true in Biology where the visual presentation of various biological objects, processes and events is crucial to their understanding. In general, images (including biology-related ones) serve as information carriers, while simultaneously also helping to organize the student's specific activities in the context of various forms of learning.

This article describes a structuro-functional analysis of visual learning aids in Biology and will propose a pedagogical way to design them based on: the structure of certain groups of educational skills - levels of visualization and their types of properties with respect to the visual aids.

In summary, we will try to give an answer to the following questions:

1. How can we form different sets of skills through the usage of visual aids?

2. How should their pedagogical design be organized?

Key words: visual learning aids, sets of skills structure, levels of visualization, types of properties, pedagogical design

Introduction

Much science education research has concentrated on the analysis and interpretation of verbal text – whether written or oral (e.g. the recent growth in studies on argumentation). Yet recent work has emphasised the extent to which visual images are central to much of academic science and science education (Gilbert 2007; Roth et al. 2007). At the same time, the process of reform in science education in many countries (including ours – Bulgaria and the UK) requires
new approaches that make appropriate use of new technological possibilities including improvements to the teaching aids that are used.

The functional realization of the education process is greatly influenced by the quality of the specific teaching aids and their ability to govern students’ activities and to influence and improve their autodidactic skills. An example of these teaching aids is the educational methodology complex, whose structure includes two interconnected parts:

a) Normative – these are the National Educational Requirements (standards) concerning the content of education subjects and programmes;

b) Content and its delivery carriers (including technological ones) – textbooks, notebooks, supplementary information, electronic learning aids and other multimedia products, methodology-related teaching aids, didactic products. This product, generally speaking, is responsible for:

– the content model;

– **the visualization model of the selected information with regards to the various products and the ways to apply the visualized information in order to achieve certain goals**;

– a model of the different processes in education based on different tasks categorized by type and size depending on the content of the different products and their intended functions;

– a model concerning feedback, regulation and self-regulation;

– a model of extracurricular cognitive and practical activities of students in the framework of the general methodology complex.

As far as structure and technology are concerned, the educational methodology complex must ensure the formation of cognitive, affective and practical skills of the student through the content of the specific school subjects. It must offer concepts corresponding to the following key questions: ‘What?’, ‘For what?’, ‘Through what?’ and ‘How?’. We will pay special attention to one of these questions, namely ‘Through what?’, which can act, in the context of visual aids, as a medium aimed at developing certain educational skills. If we want to make a proper structuro-functional analysis, we must examine the position of visual aids in the general structure of a textbook.

**Position of visual aids in the general structure of textbooks**

A structural component is “a necessary element of modern textbooks with a well defined form, which places an active, functional load using its unique characteristics, and which is interconnected with other elements in the textbook” (Zuev 1973:97). A specific example of this definition can be illustrated using the following diagram:
Visual aids function in the cognitive processes

Scientific knowledge is an unusual psycho-didactic construct, whose verbal and visual presentation requires the application of specific criteria. Part of the information in textbooks is encoded in images with various functions, which have a very specific place and cognitive values corresponding to the particular features of the higher psychological functions of specific age groups.

In accordance with the general textbook theory, images are an integral part of the structure of any textbook. Depending on their specific incarnation, visual aids can be categorized as photos, drawings, diagrams and maps. All of these variations of visual information representation are considered illustrations and are defined as "color or black-and-white images interconnected with other structural components with unique properties, working towards applying the pedagogical principles embedded in the textbook" (Zuev 1973:112). Depending on their intended functions, illustrations are grouped in three major categories:
Diagram 2: Illustration types

The formation of these three groups is necessitated by the age specifics of students, the particular subjects and the intended functions of the images. The so-called fundamental illustrations are tasked with presenting most of the content of a particular subject, replacing the main text and turning into the main information source for students. Keeping in mind the information available for this type of images regarding their cognitive role in the education process, the problem of developing a system of criteria which would help us evaluate them on an equal level becomes even more pressing.

"Equivalent" illustrations carry the same content as the main text in textbooks. Their main forms are thematic images, photos, diagrams, maps, photo charts and scientific drawings.

The name of "supplemental" illustrations is based on their main function which is to complete and expand the existing information in textbooks. It is a fact that every textbook almost always features all three types of images which complement each other and work together in the complexity of their functional loads.

The aforementioned explains the necessity of producing a criteria system, acting as filter and a guide for the proper visualization of academic knowledge in a particular educational environment. The lack of unified criteria for the analysis of visual teaching aids also has an objective reason. Mostly this has to do with a specific peculiarity of human perception, one of the higher psychological functions - human subjectivity. The perception of a particular object which affects our senses leads to the formation of specific mental images. Some authors define these mental images as "creations of a person's internal world." The subjectivity of the image is created by the internal convictions, needs and motivations of the personality. This combination creates unique mental images and their complementary emotions. We should also consider the complications caused by the different age groups since they cause a large variation in the created mental images. An example of this can be found in Antoine de Saint-Exupéry's brilliant work “Le Petit Prince” (Part 1:11).

Everything mentioned so far is also true in the field of education in Biology. In an environment in which the teacher has specific normative criteria for the quality of the visual aids with respect to the biological knowledge and sets of skills being formed, we propose an idea for the design of visual biological information based on certain rules. During the development of our idea, we used as a theoretical basis elements of applied logic and general skill structure. A starting point in the development were the following questions:

- Which are the basic elements of biological knowledge in textbooks?
- What is the structure of the basic skill sets which will be formed during the education process?
- How should the visual aids look like in order to help form a specific biological knowledge?

As far as the first question is concerned, the smallest structuro-functional unit of knowledge is the concept as a mental model. By definition, it is a form of thinking which represents
common essential features of a class of objects from objective reality (Bankov 1975:50; Deikov 1999:42). Every concept has two structural parts: volume and content. Volume includes all objects of a given class represented by the concept. Content includes a system of common essential features, which serve as a basis for the categorization of the objects represented by the given concept. Biological objects possess an extremely large variety of features which are described through text and/or visual aids in Biology textbooks. In the education process, however, they have a different function which allows us to group them in four major groups:

Table 1

<table>
<thead>
<tr>
<th>Types of features</th>
<th>Characteristic</th>
<th>Function in the education process</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Common essential features</td>
<td>They are common in all objects included in a given definition.</td>
<td>They give the answer to the question “What is this?” and they help us differentiate objects</td>
<td>The class of insects has the following common features:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>included in a given definition from all other ones. They help us define commonalities.</td>
<td><em>A body divided into three parts – head, thorax and abdomen with 3 pairs of legs coming out of the thorax</em></td>
</tr>
<tr>
<td>2. Special features</td>
<td>They are characteristic of a specific subset of objects in a given concept/definition.</td>
<td>They allow us to identify objects from a specific subset and based on these features, we can define commonalities.</td>
<td>The class of insects includes objects which can be grouped in several subclasses like <em>insects of the order Diptera</em>. Their special feature is a pair of wings on the mesothorax and a pair of halters, derived from the hind wings on the metathorax.</td>
</tr>
<tr>
<td>3. Common non-essential features</td>
<td>They are different for objects from different concepts.</td>
<td>We use them to identify similarities and differences between objects belonging to different</td>
<td>Such features are the place of habitat, shape, type of food and other such</td>
</tr>
</tbody>
</table>


We cannot define commonalities using non-essential features.

4. Individual features

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Features characteristic of objects from different concepts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual features</td>
<td>They are characteristic of a single biological object (representative).</td>
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<tr>
<td></td>
<td>They help us define the individual features of a particular subject.</td>
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<td></td>
<td>Features like size, colour, specific adaptations of a particular subject, etc.</td>
</tr>
</tbody>
</table>

Of particular importance in the Biology education process are the first two types of features, which are linked to the formation of key skills and which also should be visualized in a very specific way. Depending on the specific function of the different features, which are to be visualized, and the particular structure of a given skill, we propose the following model for the pedagogical design of visual teaching aids, subject to the relationships between:

![Skill structure](image1)

![Level of visualization](image2)

![Types of features with respect to the visual aids](image3)

The main idea, which we will illustrate using a table, is that visual aids have the ability to help form certain cognitive skills and the knowledge carried with them. Keeping this idea in mind, we offer another option for the pedagogical design of biological educational information, which will aid the completion of the subject's educational goals.
<table>
<thead>
<tr>
<th>Kind of skills</th>
<th>Levels of visualization</th>
<th>Kinds of features in the visualization</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>1. Biology object</td>
<td>• common essential features;</td>
<td>![Image 1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• significant features;</td>
<td>![Image 2]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• common <em>non</em> essential features;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• individual features</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Biology concept</td>
<td>• common essential features;</td>
<td>![Image 3]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• significant features;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• common <em>non</em> essential features;</td>
<td></td>
</tr>
<tr>
<td><strong>Definition</strong></td>
<td>1. Biology concept</td>
<td>• common essential features;</td>
<td>![Image 4]</td>
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</table>
3. Conclusion

If we had to comment on future trends and possibilities regarding the aforementioned problem, we would say that they are without a doubt linked to an increase in the professional qualifications of biology teachers, which would provide them with another point of view regarding the place and role of visual aids in the relationship between a goal-an instrument-a result. Based on his/hers professional skills, the Biology teacher can create science-based visualization models for the given educational information. He/she will also be able to make an informed decision regarding textbooks and teaching supplements based on the visual aids included in them. In summary, the increase in the quality of educational tools (including visual teaching aids) is a result of the improved quality of preparation of future teachers.
REFERENCES


