WAYS OF PORTRAYING SCIENCE IDEAS ON THE INTERNET AND THEIR INTERACTION WITH SCIENCE EDUCATION

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ABSTRACT
In this work, Internet serves as a field of research for the study of the various ways of visual representation on several scientific areas. The variety of sources on the Internet allows the detection of alternative ways of image construction, which aim at the organization of information and the creation of the corresponding mental representation in the recipient. The present symposium is dedicated to the exploration of the different ways science concepts are visually represented on several sites of the Internet. It is of great importance to study these depictions found on the Internet, because many of them are disseminated in school textbooks or other educational materials and are used by teachers in science classrooms. The symposium is focused on 4 different areas of science: a) the electromagnetic spectrum, which in its various forms of depiction condenses and organizes a plethora of information, constituting a conceptual map, b) the Brownian motion, which refers to the microcosmos, trying to portray its invisible entities, c) the friction effect, a daily life phenomenon depicting, in an abstract form, concepts of the macrocosmos, and d) the phenomenon of mitosis and meiosis, from the world of Biology, which in the detected applets simulates the development of the whole phenomenon.

KEYWORDS
Internet, science concepts, images, depiction

INTRODUCTION

During the past decade, the ways in which the Internet is introduced and implemented in education has become a pivotal point of educational research. It marks new forms of communication between school and the 'outside world'; it allows direct access to primary sources of knowledge production (Research centers, Laboratories, Universities); it facilitates the development of student skills in searching for the appropriate sites and in composing their schoolwork (Clinch and Richards, 2002; Linn, 2000). At the same time, many of those primary sources are compelled to develop skills of transforming scientific knowledge into various other forms of knowledge (school knowledge, popularized knowledge), so that they can communicate more effectively with the visitors to their network sites (high school students, undergraduate students, teachers or lay citizens).

In this work, Internet serves as a field of research for the study of the various ways of visual representation on several scientific areas. The variety of sources on the Internet allows the detection of alternative ways of image construction, which aim at the organization of information and the creation of the corresponding mental representation in the recipient (Lemke, 1998; Kress and van Leeuwen, 1996).

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The symposium is focused on 4 different areas of science: a) the electromagnetic spectrum, which in its various forms of depiction condenses and organizes a plethora of information, constituting a conceptual map, b) the Brownian motion, which refers to the microcosmos, trying to portray its invisible entities and its random movements, c) the phenomenon of friction, a daily life phenomenon depicting, in an abstract form, concepts of the macrocosmos, and d) the phenomenon of mitosis, from the world of Biology, which in the detected applets simulates the development of the whole phenomenon.

The images of the above examples referring to different aspects of science, often offer innovative and attractive visual solutions in presenting the relevant phenomena, thus providing a better understanding to students. But at the same time, in many of these images, misleading features have been detected, which may confuse students by creating alternative conceptions for the relevant scientific phenomena.

THE COMMUNICATION LANGUAGE OF SCIENCE AND THE WAY SCIENCE CONCEPTS ARE REPRESENTED VISUALLY

The study of the communication language of science is a prime requirement when investigating the way science concepts are visually represented on the Internet. The communication language of science is multimodal and because of that it appears to be quite complex. As Lemke (1998) commented, it is in the nature of science concepts that they are *semiotically multimodal*, since they developed historically with the use of several semiotic resource systems. Thus, they can be considered as semiotic *'hybrids'*, which simultaneously combine verbal, mathematical, visual-graphical and actional-operational components

Communication in science demands the interconnection and the co-deployment of several genres, like verbal and written text with mathematical expressions, graphs and diagrams, tables, maps, drawings, photographs and other specialized visual genres. It should be pointed out that no semiotic modalidy (e.g. text, picture, etc.) is equivalent to another. Instead, each one contributes in its own unique way to the comprehension of science concepts. Thus, it is useless to compare alternative modalities used to represent a science concept or to believe one modality can substitute another: a written text does not convey the same meaning with a picture nor does a graph create the same meaning with a mathematical equation. In science education we have to learn how to construct interrelations and interconnections among these semiotic systems (Lemke, 1998).

When a science concept is represented in a multimodal way utilizing every possible semiotic modality, its meaning for students is multiplied. This is done by the multiplication of its comprehensible possibilities, while, with the coordination of the alternative ways of the visual representation of its core subject matter, it allows the creation of the appropriate mental representations to the student.
The functional combination of verbal and written text, of graphs and diagrams, of mathematical equations and pictures can be realized in its most dynamic evolution and expression, in the simulations, the animations and the applets found in several websites on the Internet. The exploration of the relevant sites on the Internet reveals a new semiotic hybrid reality, which makes possible the formation of a visual-multi-semiotic 'text' for the presentation of science concepts, multiplying in that way our ability to grasp those concepts.

THE WAY INFORMATION IS ORGANIZED IN SCIENCE ILLUSTRATIONS

From time to time, many researchers have stressed the crucial role of images in science communication and education (Kress and Van Leeuwen, 1996). Today, the tools that new technologies offer, allow to a large number of the Internet users quick and easy access to a variety of images which convey scientific knowledge in a concise way. This ability makes it necessary for students and teachers to develop the appropriate skills of reading visual messages and understanding the codes used for the communication of scientific ideas (Pinto, 2002). Otherwise, a misuse of a science image in science classroom might create some problems. As Pinto and Ametller have pointed out: 'Misuse of the visual language can affect the communication of the concepts intended to be presented by the image. Thus, on one hand an image that has not been well designed may transmit wrong ideas and, on the other hand, a lack of knowledge of the visual language may hinter the interpretation of an image' (Pinto and Ametller, 2002).

Pictures contain information which helps in constructing the actual meaning. The information and the messages, which pictures carry, are not passively perceived by the recipients, but are translated, reconstructed and transformed (Colin et al., 2002). The illustration of a science text is a vital means of organizing and transmitting information.

The ways of representing the development of physical phenomena of microcosmos on the Internet, seems to be affected by the long-time struggle of two opposite traditions held in the history of science. As Gallison (1997) points out: 'The *'image tradition'* has had as its goals the representation of natural processes in all their fullness and complexity- the production of images of such clarity that a single picture can serve as evidence for a new entity or effect. These images… purport to preserve the form of things as they occur in the world'. On the other hand, the *'logic tradition'* has used electronic counters coupled to electronic logic circuits. These counting (rather than picturing) machines aggregate masses of data to make statistical arguments for the existence of a particle or effect… On the image side resides a deep-seated commitment to the production of the *'golden event'*: the single picture of such clarity and distinctiveness that it commands acceptance… In contrary, the logic tradition relied fundamentally on statistical demonstration' (Galison, 1997).

In the representations studied, we traced one more very powerful tradition in the history of science images. The *'model tradition'* expresses the scientists or educators' efforts to transform all kinds of 'data' (the actual pictures of a science event or the statistical handling of masses of data which counts the presence of a scientific event) into an abstracted symbolic 'model' which, according to the accepted scientific theory, helps the viewer to comprehend these 'data'. Thus, in the case of Brownian Motion, it was found that images of the 'model tradition' were coupled with abstracted diagrams of the 'logic tradition', while in the case of Cell Division, it was found that photographs of the 'image tradition' were coupled with abstracted models of the 'model tradition'.

INTERNET AS AN EDUCATIONAL TOOL

The Internet has provided an opportunity for all major research centers and their scientists, to address to the wider public and communicate the results of their work (Eveland and Dunwoody, 1998). Thus, the Internet constitutes an immense and universal field that *inter alia* portrays the efforts of the primary sources and those using them by transforming scientific knowledge into more popularized forms. In that sense, the relevant sites constitute a 'window' for the exhibition of science, as well as a 'window' into science. This compels the relevant researchers to seek ways of communication with their public or, in other words, develop educational initiatives.

Often, many of the proposed forms of organizing science knowledge on the Internet are incorporated in the official school education of various countries (school textbooks and other educational material) (Clinch and Richards, 2002, Davis and Linn, 2000). The Internet has the advantage of addressing a wide spectrum of citizens, who can thereby utilize it in many and various ways (Wiesenmayer and Koul, 1998). Thus, it can be used: a) for the life long education of citizens through organized programs that have been designed and produced by large research centers and educational organizations (Linn, 2000); b) for the provision of supportive educational material for teachers, and c) for information search and the composition of schoolwork by students. Simultaneously, it can be developed as a means of presenting schoolwork and of communicating school networks or as a means of publishing self-made, original educational material and thereby supporting the interaction between teachers all over the world.

Students' ability to trace the information among many, alternative and unexpected Internet resources meets with many difficulties for them (time consuming, difficulty in handling and assessing the plethora of information found etc.), but it also presents them with many advantages if appropriately guided. Some of these advantages are:

The revelation to students of several aspects of the studied subject matter beyond those presented by the curriculum: Thus, the area of study of science concepts is broadened and this facilitates the interconnection with several other science subjects, with technology and with everyday life. Sometimes, these interconnections are more interesting for students and may constitute the 'hook' to catch the prime core concepts. In that way schools reach out to society and contemporary areas of scientific research, thus preparing the future citizens. In the issues studied in the proceeding articles, their interconnection with technology becomes obvious, either in the way the presented information has been extracted (e.g. photos with high definition and elaboration and/or organism-coloring techniques in the mitosis phenomenon), or in the way the scientific information is used for the creation of technological products (e.g. microwaves in the electromagnetic spectrum).

Students' exposure to the alternative representations of the same science concept coming from different Internet resources: These representations depict the aesthetic and didactic perceptions of their designers. For example, in the case of mitosis the following kinds of representations have been traced:

Representations of the phenomenon with emphasis on depiction as 'faithful' to the 'reality' as possible: These are usually photos taken through a microscope. In this case, the researcher intends to expose the possible image-viewers to every detail of the specific phenomenon, as it is when photographed through the microscope or as it is when the researcher watches it through the microscope. Thus, he does not care about the 'noise' inherent in the photo, because he believes that it is part of the reality. Usually he/she is addressing specialized viewers, with a thorough knowledge of Biology.

Representations of the phenomenon with emphasis on depiction as 'faithful' to the 'reality' as possible, but also with the clear intention by the designer to guide the readers/viewers to the crucial points of the phenomenon easily: Thus, important parts of the phenomenon, necessary for its comprehension by the lay public, are highlighted through coloring substances which penetrate the relevant cells. Sometimes, this process is backed up by additional symbols (e.g. arrows). It is obvious that in this case the researcher acts like an educator, since he/she seems to be aware that he/she is addressing a public with no special knowledge of Biology.

Representations of the phenomenon with emphasis on its basic structure: In that case the relevant phenomenon is represented by an abstract diagram, in which all the unimportant details ('noise') have been wiped off. Thus, the designer intends to draw the attention of the image-viewers to the basic parts of the mitosis phenomenon presented in the abstracted diagram. He/she seems to have a clear didactic aim and because of that does not care about the realistic depiction of the phenomenon.

Representations of the phenomenon with emphasis on those aspects which can function like a piece of art: The mitosis phenomenon provides artists with an opportunity to make use of the phenomenon to create a work of art. The result which comes out is aesthetically interesting, but didactically limited.

For each one of the above kinds of representations there are many alternative suggestions on the Internet.

The realization of the multimodality of science concepts: In the plethora of science representations found on the Internet, the multimodality of the representations of science concepts can be traced and the necessity of their joint co-deployment for the comprehension of science concepts can be recognized. A typical example of that are the images of the electromagnetic spectrum. In each of these images coexist: a) the text, b) the numerical values, c) the abstract graphs, d) the small symbolic icons depicting technological applications, e) the symbols, etc.

Another clear example of the multimodal way science concepts are represented is the Brownian motion. In each of the images traced on the Internet, students can realize the different aspects of the phenomenon the researchers-designers chose to present. Thus, some of these images are focused on the mathematical nature of the phenomenon represented by the trajectories of the particles or by the abstract graphs of their velocities; some others are focused on the randomization of the phenomenon connecting it to some other scientific areas (stock markets etc.); and finally some of them are focused on the microscopic nature of the explanation of the phenomenon, choosing to depict the entities of the microcosmos which cause the whole phenomenon (Einstein's explanation). All of these representations depict unique and complementary ways the comprehension of the phenomenon in all its aspects.

THE CHARACTERISTICS OF THE FOUR INVESTIGATED SCIENCE AREAS

The present symposium has been designed in such a way as to investigate 4 characteristic cases of visualizing science concepts. In particular, the criteria for the selection of the 4 specific scientific areas are the following:

- The multimodal way of the visual representation of the relevant science concepts (mathematical equations, numerical values, abstract diagrams, graphs, pictures, animation, etc.).
- The represented issues (to cover several science areas, which diversify from microcosmos to macrocosmos).
- The didactic models used to depict the relevant phenomena (conceptual maps, flow diagrams, animations simulating the development of a physical phenomenon, etc.).
- Their relevance to secondary science education (all the investigated science concepts are part of the science curriculum in lower, as well as in higher Greek secondary education).

According to the above criteria, the following cases were explored:

The Electromagnetic spectrum (E/M spectrum)

The E/M spectrum is visually represented as a kind of conceptual map, which in minimum space concentrates a huge amount of knowledge, by using a large number of alternative ways of conveying this knowledge.

The electromagnetic spectrum is of special interest in science education, because students do not have direct experience of the subject, and thus cannot easily construct the relative knowledge. The various forms of depiction of the E/M spectrum condense and organize a plethora of information. For that reason, it is interesting to investigate the alternative ways of organizing information, in its many images of E/M spectrum found on the Internet. These usually represent the propositions of well-known research centers on the subject. Often, they are disseminated in school textbooks or other educational materials and are used by the teachers in the classrooms.

The relevant research in several sites of the World Wide Web, revealed the multimodal way of depicting the key concepts involved in an image of the E/M spectrum, the visual solutions suggested to depict those concepts, as well as the problems which sometimes emerge from these kinds of depictions.

The research findings are supported by a complementary research done in schools. In that part of the research, high school students' responses to an experimental treatment, are analyzed by means of a discourse analysis. The findings of the research support that this type of image, like the E/M spectrum image, demand students with high mental skills to 'read' them visually. This is because they are images with highly condensed subject knowledge. Therefore, it might be didactically fruitful to present different images to students with different mental skills; e.g. to students with high mental capabilities to present images with heavy conceptual 'load', while to students with lower mental capabilities to address images with lighter conceptual 'load'. In that case, the Internet can provide physics education with a great variety of images, with all kinds of conceptual 'loads'.

The phenomenon of friction

The phenomenon of friction was selected because it is a phenomenon of everyday life, while its mechanism is due to interactions of microcosmos. Moreover it is a phenomenon which is a basic part of the physics curriculum in secondary education (lower and higher). Because of that, we expected to find a great diversity of applets using a multimodal way of visually representing the phenomenon. Instead of that, the research in the World Wide Web traced only a few applets, with a minimum of innovation in the way the phenomenon of friction was depicted. So, in most of the relevant applets the same pictures of the phenomenon, already known for decades from physics textbooks, were found. Moreover, the phenomenon of friction, which is a phenomenon of everyday life, is usually represented without any reference to the natural surroundings, in which it occurs. That is why to many students the textbook pictures seem meaningless.

These representations, which are usually highly abstracted, seem to be an extension of the known physics textbook exercises. They provide some kind of interaction with their users, by allowing the change of certain parameters of the phenomenon. But we should point out the finding of two applets which try to simulate in a realistic way scenes of everyday life, where we can notice the effect of the phenomenon.

Generally speaking, the images of the phenomenon of friction found on the relevant applets, seem to be of limited value to physics education.

The Brownian motion

The Brownian motion is a distinctive phenomenon which, apart from all its other qualities, has a special historical value; its theoretical explanation is due to Einstein. It demands the effective combination of two different “worlds”; the world of microcosmos and the world of macrocosmos. These two worlds interact with each other, in such a way as to say that sometimes “what you see” is due to “what you can not see”.

The comprehension of the Brownian motion depends on two crucial points:

to explain the movements of a pollen grain, you have to refer to the particles (molecules) of the microcosmos which collide with this grain. This needs an innovative depiction of the coexistence of the two worlds;

to study the randomness of the grain’s movements, you have to use the mathematical language and so to be limited to the depiction of abstracted graphs.

Thus, the Brownian motion phenomenon could function as a challenge to the physicists to try to depict it in a smart way. This, consequently, will help students to create mental images, compatible with the scientific model. But this type of attempt often meet severe problems in trying to depict the entities of microcosmos, because of their quantum mechanical properties.

The relevant article studies and analyzes several representations of the Brownian motion phenomenon found in the very many sites on the Internet. Thus, it traces the visual solutions given by their designers-creators and points out the various problems created by some of its depictions.

The cell division

Cell division is a very important biological phenomenon. It is one of the most favored subjects the biologists prefer to represent. It often inspires other people, like artists to create artistic works. It is characterized by some distinctive features:

It refers to an intermediate level of space, which extends in-between microcosmos and macrocosmos;

Although it is not visible, students can experience it by the means of technology (directly through a microscope or indirectly through a microscope and a camera);

It demands the depiction of some kind of movement, since it describes the development of a phenomenon consisting of several distinctive phases;

It refers to a crucial phenomenon, which determines the whole phenomenon of life (the phenomenon of cell division).

All the above features offer excellent opportunities to the biologists who act as designers-creators to depict the relevant phenomenon innovatively. Maybe, that is the main reason for its very many different representations traced on the Internet.

The relevant article analyzes and comments on these depictions. It points out their strong as well as their weak points, in case we intent to use them in biology classrooms. Also, it carries out a complementary research to detect 9^{th} grade students' responses towards the various representations of the phenomenon.

COMMENTS

The visualization of science concepts is an essential part of science education, since it helps students to comprehend those concepts and create mental representations approaching to the corresponding science models. But, the visualization of science concepts is not always an easy task.

The papers presented in this symposium analyze thoroughly a variety of images from several science areas. They explore all their latent aspects and they underline their potential in the understanding of the pictured science concepts, especially when they are presented in a multimodal way. Thus, they offer a panorama of the efforts made by several scientists from all over the world to portray these science concepts. They also suggest ways of using them efficiently in science classrooms.

If what Roald Hoffman, the Nobel Laureate, said is true, *'Science is about knowing without seeing'*, this symposium attempts to trace the multiple ways of making the *'invisible'*, *'visible'*.

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