Bridging art and science in science education

Estableciendo puentes entre el arte y la ciencia en la educación en ciencias

António F. Cachapuz, Paula C. Ferreira

Centro de Investigação Didáctica e Tecnologia na Formação de Formadores,
University of Aveiro, Portugal, cachapuz@ua.pt, paula.mail@mail.pt

Abstract

Art and Science mirror the creative potential of Man as the maker of symbols, be it a masterpiece by Leonardo or a Newtonian formula. The argument suggests the need for an interdisciplinary view of knowledge in order to build bridges between areas of knowledge that Positivism separated. Edgar Morin's theory of complexity is a possible epistemic accommodation of such a view that goes beyond the frontiers of Epistemology and is of interest to Education in general and Science Education in particular. On the basis of these epistemic arguments and the science-based aesthetic of George Seurat, here follows the conception, development and assessment of a recent Science Education work exploring an Art/Science dialogue successfully accomplished by a teacher with her young pupils.

Key words: *science, art, science education, interdisciplinarity*

Resumen

Arte y ciencia espejan el potencial creador del hombre como un hacedor de símbolos, sea una obra-maestra de Leonardo o una fórmula de Newton. El argumento sugiere la necesidad de una visión interdisciplinaria del conocimiento que ayude a establecer puentes entre áreas del conocimiento alejadas por el positivismo. La teoría de la complejidad de Edgar Morin se presenta como un posible marco epistémico de una tal visión que transpone las fronteras de la epistemología e interesa a la educación en general y a la educación en ciencias de una forma particular. Basado en estos presupuestos epistémicos y en la estética de base científica de George Seurat, se presenta la concepción, desarrollo y evaluación de un reciente trabajo en el ámbito de la educación en ciencia, explorando el diálogo arte/ciencia y conducido con éxito por una profesora con su joven alumnado.

Palabras clave*: ciencia, arte, educación en ciencia, interdisciplinariedad.*

INTRODUCTION

The aim of this study is to assist and promote a different perspective on the nature of relations between Art and Science (epistemic dimension) and of how this new perspective may be explored within the framework of Science Education (educational dimension). Despite being traditionally regarded as irreconcilable cultures (the Positivist view), Art and Science both represent Man's struggle to find meaning in life and both help correct the limitations of common sense. For that very reason the study of the interface between them becomes relevant. Morin (1996) draws our attention to the need of a new strategic relationship with knowledge that replaces the traditional view as something stable and safe with something that features uncertainty and complexity: "Le príncipe de simplicité impose de disjoindre et de reduire. Le principe de complexité enjoint de relier, tout en distinguant". Roth (1993) reflecting on the limitations of the Newtonian determinism and the implications of the works of Heisenberg and Prigogine says that "we should accept both uncertainty and indeterminacy as part of our ability to know". And the same author adds the need of bearing in mind the interconnection between knowledge and values suggesting that "science educators with constructivist commitments should emphasize collaborative, hermeneutic, and dialectic approaches to the construction of knowledge". The utopia of Positivism is thus questioned, given the epistemological difficulties arising from the strictness and segmented nature encompassed by that view. For Science it is no longer a question of seeking "the" truth but instead more truth (new truths) and coming to terms with "disorder", uncertainty and indeterminacy. And in recognising a new dynamism of its development processes Science itself became more tolerant. So the opposition between the world of rationalism and the world of emotion and beauty became more difficult, according to notable philosophers (Bachelard, 1943, "the world is beautiful before being true"), mathematicians (Poincaré, 1920, "civilizations have no value other than their Art and Science"), chemists (Hoffmann, 1986): "establishing perfectly defined parameters for interpreting the universe is easier than attempting to question death or the invention of love") and painters like Kandinsky and Seurat (see below).

Historians like Martin Kemp (1990; 2000) suggest various ways of structuring the dialogue between Art and Science: Analytical Description, Abstraction and the Processual way. Thus in Analytical Description belong the works of Leonardo de Vinci (15th century) and Andreas Vesalius (16th century), veritable fathers of modern anatomy, with regard to representations in which the aspects of visual appearance are accommodated as based on intuitive or intellectualized interpretation of the nature (what is observed and how is observed). Abstraction explores sensory parameters of our daily experience with the help of technological equipment that takes on new realities and perspectives which are otherwise inaccessible, revolutionizing the scales of perception, such as electronic graphism, digital collages or holography, on objects of Chemistry, Mathematics or Biology (e.g. Muller et al., 1988 or the "Art & Science Collaborations. Inc" site, since 1988). Finally, in the case of the Processual way, the dialogue concerns the very processes of the research activity pertaining to Art and to Science, particularly the mobilization of analogous cognitive mechanisms. The latter is pertinent to this study since it enshrines the science-based aesthetic of Pointillism created by George Seurat (a French painter of the 19th century and a pioneer of the art movement known as post-Impressionism). What Seurat started was a new aesthetic based on the works developed in the 19th century and at the beginning of the 20th by the chemist Eugène Chevreul and the physicist Nicholas Rood on the theories of colour as well as those of James Maxwell on the nature of light. Chevreul developed the "Chevreul's Circle", enabling the active role of the human brain in the formation of colours to be tested by processes of harmony and contrast. For his part, Rood studied colour and optical effects, establishing a distinction between additive and subtractive colour mixture, analysing the mixture of two superimposed pigments. Rood upholds that painters should not mix their colours in the painting, but instead place a great number of tiny dots of two colours very close to one another so that they blend at a distance. According to Duchting (2000) "colours reach the eyes as light of different wavelengths and are mixed in the retina". Seurat applied these ideas on the simultaneous perception of colours and on optical mixing to his paintings, with his ex-libris being the oil-painting "A Sunday Afternoon on the Island of La Grande Jatte" (1886) (Fig. 1); (for an analysis of the painting see Gage, 2006 and Zuccari & Langley, 2004). So the case of Seurat's Pointillism is emblematic of a new way of looking at possibilities of an interdisciplinary dialogue between Art and Science. The example of Seurat is relevant not only from an aesthetic viewpoint but also in terms of an educational exploration. In fact, one of the dilemmas that Education faces at present is how to pass a non-compartmentalized view of knowledge so as to legitimize a more integrative, eclectic and tolerant perspective of the same. The interdisciplinary issue is thus an educational imperative.

In the education field, most of the studies bridging Art and Science explore the educational use of digital technology (virtual worlds, second life…) and focus on teaching (e.g. www.princeton.edu/artofscience/ or www.artic.edu/aic/ or www.si.edu/ohr/). In the science education domain research studies are scarce (particularly research with empirical back-up). For instance, Lerman (2003) explores Art to make Chemistry accessible to everyone. Lima et al. (2004) addresses the link between Poetry and Physics by exploring Fernando Pessoa's "Message"; Joaquim and Mariscal (2006) explore extracts of the work of Don Quixote to construct didactic tools for teaching Mechanics. A common line of these works is that they are aimed at secondary school pupils or students in higher education, no research studies involving young pupils having been found, a somewhat controversial aspect, since it is there – as it is well known– that new attitudes to and relations with knowledge are formed and built on.

Figure 1. Georges Seurat, "*A Sunday Afternoon on the Island of Grande Jatte*" (1884-1886).

This research aims at contributing to a dialogue between Art and Science and an exploration thereof within the framework of Science Education through suitable transpositions of the scientific bases of Seurat's aesthetic. The educational focus of the research is thus on the intersection of three areas of knowledge: Art, Science and Education. The interdisciplinary view is emphasized by the inclusion of the Art component (interdisciplinary studies in science education are usually limited to various science disciplines, an internalist view). In Portugal, an important aim of the Basic Education National Curriculum (2004) is that the "pupils should use languages properly from different areas of cultural, scientific and technological knowledge, to express themselves" (p. 15). Primary school pupils are also requested "to develop a scientific perspective of the artistic phenomenon" (p. 153). However, when transposing these aims to teaching practices, the different dimensions are traditionally explored in a segmented way. According to the rationale of this study, what was at stake was to search for a more holistic approach to science teaching. Thus, the research objective was to design, develop and evaluate an interdisciplinary teaching strategy aiming to promote a better understanding of the relationships between Art and Science by primary school pupils, exploring the concepts of light and colour developed by Seurat's Pointillism.

METHODOLOGY

Based on the criteria presented by Yin (1984, p. 23) a holistic single case study design was chosen with the unit of analysis being the nature of the teaching strategy. The field work involved 23 pupils (15 girls; average age 8 years; mixed level ability) from a typical (medium size, middle class families) semi-urban primary school (North of Portugal) and was carried out from December 2007 to May 2008, interspersed with other curricular activities. The teacher (woman, 29 years old) with secondary schooling in the Arts and five years of professional experience (primary school), was involved in a professional development project aimed at linking the research with innovation exploring the idea of the teacher as a researcher (Stenhouse, 1975). The teaching plan (Table 1) included seven experimental activities of variable complexity (except for the last one). The pedagogical sequence of these activities reflected the "transposition" of the main lines of the historical development of Seurat "scientific" aesthetics. Activity 1 was contextualizing and making the pupils aware of the topic. Activities 2 and 3 were aimed at introducing the young pupils to the issues of light and colour. Activity 4, one at the interface, prepared the pupils for activities 5 and 6, which were ones of synthesis. The aim of activity 7 was solely to assess (in a formative way) what had been learned, although other data on what the pupils had learned had been gathered in every previous activity (continuous assessment). The following were drawn up for each activity: (i) a teacher's manual with methodological guidance on the activity including a scientific note on the content being studied, work strategies, activities and orientating questions for the teacher; (ii) a pupil's worksheet to assist the teaching/learning process and a record of his/her answers (iii) the teacher´ s critical report on the activity with a critical reflection on difficulties encountered, strong and weak points and possible ways to overcome them. A final overall report was done at the end of the whole process. The teaching followed an inquiry approach; pupils were asked to present their ideas about an initial question or situation, for example: (teacher), "Do you think colour is inside objects?" activity 2; or "Do you think the Sun's light is really white?" activity 3) «Prediction (pupil)» «Observation (pupil)» Conclusion, critical reflection and pair-discussion (pupils). The pupils' work was almost invariably organized in groups (3 or 4 pupils). Each group's records represented the group's collective understanding and not just that of the person writing them; if there was a difference of opinion the pupil had to write it in the blackboard (this happened once per activity, on average). At the end each group's results were compared and discussed by the whole group. Technical language was deliberately simplified. For instance, the terms "scientist" and "artist" (instead of the more abstract terms "science" and "art", activity 1); or again "things that give light" (instead of "light source", activity 2); "separation of light" (instead of "light refraction", activity 3); "colours of light" (instead of "frequency" or "wavelength", idem); "mixture by the eyes" (instead of "optical mixture", activity 6). For the same reasons, in addition to the written record the pupils were asked to make illustrative drawings that were then photographed for analysis. Direct evidences of the whole process were obtained through classroom observation (80% of the total time) of the activities carried out. Observations focussed on the incidence of some particular behaviour aspects, namely: the general teaching approach followed; language (particularly technical language) used by teacher and students; how the teacher coped with pupil's expected incorrect ideas about colour and light; organizational classroom tactics used and pupil's participation. Field notes from observation were then inspected for convergent/divergent arguments with the teacher reports. All these data were used to design a semi-structured interview (1.5h) to the teacher at the end of the whole process in order to clarify issues and results obtained, in particular: What was the underlying organization logic of the work plan? What was the criterion followed in the choice of the activities? What was the criterion followed in the choice of the questioning strategies used? What was the impact of the innovation in the school? What were the limitations of the strategy followed? What are the suggestions for improvement? These multiples sources and methods of information (pupils´ answers, teacher´ reports, data from observation and interview) were used to the triangulation of the data, an analytical strategy generally used to increase the reliability and the validity of a case study (Yin, 1984).

Table 1

Teaching plan

Activity	Description	Objective	Record	Validation	Time Date
A1 "The work of the scientist and the artist" (group application)	Pictorial home research on scientists and artists activities; cartoon with questions	To promote understandings of relations between art and science in everyday life	Posters (collage); written replies to cartoon questions	Analysing the replies on the link between art and science; pupil participation	3½ h Dec. 07
A2 "The magic of colour" (individual and group application)	Observation of an object in the shade, natural light and with coloured cellophane paper	To understand (experimental) that colour is not a property of the objects, but of the light/material interaction	Written record of the experience (worksheet)	Comparing the prediction with experimental observation; pupil participation	2 h Jan. 08
A3 "The colour of light" (individual and group application)	Light refraction (using a Newton prism)	To understand (experimental) that visible light is composed of different colours	Written record; poster created	Identifying the visible spectrum; comparing prediction with observation	2 h Feb. 08
A4 "The invention of colours" (individual and group application)	Constructing a sequence of colours starting with primary colours (pigments)	To understand that the mixture of primary colours creates new colours	Representing the new colours in a colour disc; systematizing in writing	Quality of the materials constructed; pupil participation	3 h Mar. 08
A5 "Colour with dots" (individual and group application)	Elementary presentation (teacher) of the Seurat painting; focusing on the pointillist technique	To recognise the pointillist technique (optical mixture) as an example of perceiving new colour	Observing details in Seurat's painting with the naked eye and under a magnifying glass	Application exercises (work sheet); pupil participation	2h Apr. 08
A6 "Painting with Science" (group application)	Reproduction in mosaic of Seurat's painting "A Sunday …"	To apply the pointillist technique	Reconstruction by each group of parts of the painting so as to "reproduce" the original	Relation of reproduced mosaic with the original; inter group co-operation	2½ h May 08
A7 "Assessment" (individual application)	Analysis of suggestive and unknown images art/science	Information on final learning	Worksheet for written record	Relevance of the arguments	1h May 08

RESULTS

Table 2 presents a summary of the main results obtained. The pupils' involvement exceeded the teacher's expectations. In some cases the activities went over the time initially anticipated (Table 1), as it was necessary to clarify pupils' individual difficulties and to respect their learning rhythms (for example, in activity 1, 30 minutes longer).

Table 2

Summary of the main results by activity

Activity no.	Results of the pupils' learning	Difficulties encountered
1	Examples gathered at home during one week: microscope, computers, TV, cars, vaccines…(scientists) and painting and sculptures (artists)	Only after the teacher's presentation was the link between the two areas recognised (e.g. car design, TV art programs)
2	Identifying light sources and various types of light (colours); recognising that light depends on a light source; colour is not inside objects	The idea that colour results from the light/material interaction was only achieved on the empirical level with the aid of the teacher (see text)
3	White light can be decomposed; recognising the example of the rainbow; identifying the colours that make up white light	In the initial prediction of the phenomenon several pupils thought that the light emerging from the prism had to be white, too
4	Forming new colours (secondary colours) from mixtures of colours; skills in handling materials and painting techniques	The link between intensity of the colour of the mixture and different proportions of the initial colours was only achieved on the empirical level.
5	Understanding of the optical mixture process ("mixture by the eyes"); simple exploration of the pointillist technique	Technical limitations (e.g. time the paints took to dry…)
6	Optical experiments with mixing colours successfully carried out; joint reproduction of the Seurat painting (see text)	Technical limitations (idem); some pupils impatient to finish the mosaic of the Seurat painting
7	The link between the work of the scientist and that of the artist was recognised in the two examples presented by the large majority (see text)	One of the two examples presented created greater difficulties for the pupils (see text)

As expected, difficulties arose in interpreting physical phenomena in activities 2 and 3, perhaps because they go against common sense. In activity 2 every pupil initially presented the previous idea of colour as the property of the objects; this notion was subsequently refuted (on the phenomenological level) by the teacher by using a lantern with cellophane paper of different colours and the light falling on the same object; or through a power point slide showing the change in colour of a same building lit by the sun at dawn and at dusk.

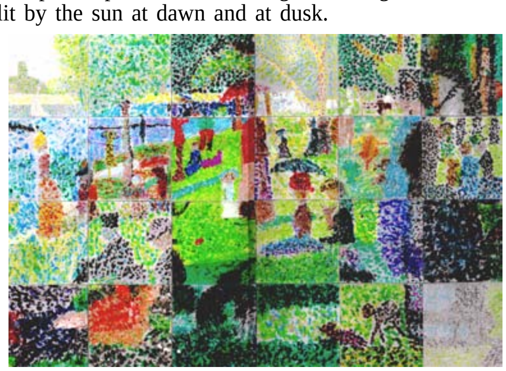

Figure 2. Final mosaic of the collective work of the pupils reproducing the Seurat´s painting

In activity 6, what was most important was not the exactness of the reconstituted painting (Fig. 2) but instead the process developed by the pupils to achieve it in terms of exploring the concepts of colour and light. In the last activity the pupils were asked to identify aspects relating to Art and Science in unknown pictures and to register their responses. In order to make the task more flexible, they were given two options to choose one from: the colour painting "Tree" by Maria Sibylla (the branch of a tree containing floral motifs, butterflies and little earthworms on the leaves, option 1) and the abstract painting by Mondrian "Composition with red, yellow, blue and black" (option 2). The questions the pupils had to answer in writing were: "What do you see in the picture? What do you think the artist's work was? What do you think the scientist's work was? To make it easier for the pupils to register their answers the teacher told them that spelling mistakes would be corrected afterwards. The majority of the pupils (60,8%) opted for the "Tree" picture, perhaps because the Mondrian picture was more abstract. Overall, in 82,6% of the pupils' answers they recognized the work of the artist and the scientist, for example: *"It was the artist that drew and painted the picture. The scientist's work was to study mathematics and discover the geometrical figures"* (pupil, option 2); 52,2% considered that they worked together, e.g.: "*the scientist went to the forest and saw these animals in a tree. The artist painted in colours what the scientist discovered in the forest and they did this work together* (pupil, option 1); 17,4% of the answers were hard to interpret in relation to the questions asked (e.g. *"a photograph taken from high up"*; pupil, option 2). At the end there was a collective discussion of the answers obtained.

CONCLUSIONS

Overall, the results obtained suggest that the main research aim was reached. In our view, the teacher was able to overcome an initial dilemma: on one hand, to work with quite young pupils and, on the other hand, the relevance of promoting an adequate perspective of knowledge from an early age. The careful planning of the strategy, the experimental character of the activities, the spontaneous and creative involvement of the pupils and a good pedagogical relationship with the pupils helped to solve this dilemma.

The study may help other science teachers (and teacher educators) to critically analyse their work and eventually adapt it to their own purposes and contexts. This is an important step in order to establish bridges between research and innovative practices. The work plan (table 1), the teacher's critical reports and the pupils' work sheets are valuable study resources which allow the understanding of the details of the strategy and also analyse the teacher's professional development for whom *"the outcomes of this process substantially helped [her] towards [her] future practice as a teacher and a researcher"*.

In our view, the main limitations of the research were (i) the little impact on the school level (owing to the fact that it was near the end of the school year) (ii) the qualitative nature of the study does not allow statistical generalizations, only analytical ones; more research studies are needed including replication studies (iii) the limited command of the language on the part of some pupils did not allowed the exploration of more sophisticated strategies based on verbal language. Finally, more often than not, both pre service and in service training of science teachers are not geared to develop innovative studies of this kind. Thus a great effort is required on the level of education policies, the institutional organization of initial and ongoing training of science teachers and schools. The question raised is relevant, especially in view of the current challenges raised by the so called Bologna process.

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