Art and Science: Combining Learning Tools

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Abstract. This article presents how the art-works, part of our cultural heritage, can become effective learning tools to be used for the study of scientific subjects, mainly science and mathematics. In particular, it intends to show some preliminary results and works gathered during the piloting phase with Italian secondary school students of the first and second cycle.

Keywords: Mathematics Education, Art, Learning, Teaching.

1 Introduction

A clear break between art and science, scientific and humanistic disciplines, actually took over only in the modern era, from Descartes onwards, with the so-called scientific revolution of the 17th century (Cartesio, 1999). While less than a century before, the universal talent of the Italian Renaissance, Leonardo da Vinci celebrated the maximum coincidence between art and science (Kemp, 2006).

In classical times there was no real contrast between the aesthetic and the scientific dimensions; just think of the Poetics of Aristotle or Pythagoras' doctrines, where the world of nature, that of mathematics and music are intimately interconnected (Olcese, 2004).

Today's cultural horizon bans all dichotomous stereotypes between humanistic and scientific knowledge: these are two distinct forms of knowledge among which, however, there is correlation and interpenetration; two cognitive acts, based respectively on intuition and reason, which correspond to different optics, to different ways of experiencing reality, but among them neither an ideal succession nor a hierarchical order can be established.

However, in 1959, almost sixty years ago, the book, where the Englishman Charles Percy Snow strongly supported the idea of the separation between "the two cultures", the scientific and the humanistic, caused a fuss. Even nowadays, more than ever, we are forced to deal with Snow's provocation, because the cleft between the "two cultures" is still evident, mainly in school education (Snow, 1959).

Many intellectuals, in Italy and outside, were struck by the provocation of Sir Charles Percy Snow by reacting to his entrapments. One of them was Primo Levi, who wrote that if there were indeed a “cleft” between science and art, it was “unnatural”: because “neither Dante, Galileo nor Leonardo, Descartes, Goethe, Einstein, nor the anonymous builders of Gothic cathedrals, nor Michelangelo; neither do the good modern artisans knew it”. This means that these “two cultures” are actually the one.

Thus, Levi's approach states that art and science are different but profoundly interpenetrated manifestations of a single culture, human culture. Art and science intertwine and therefore influence each other: much more than we are led to believe. And the significant ways of their intertwining and their mutual influence are innumerable, impossible even to be summarized (Levi, 1997).

The main dimensions of this dense, articulated and complex relationship between art and science are at least three:

1. Art and science as products of biological and cultural evolution;
2. Art and science as mutual sources of inspiration;
3. Art as a significant channel of science communication.

According to an evolutionary perspective concerning the research in psychology, in all above dimensions, a relevant and crossing feature between art and science is creativity. Therefore, between scientists and artists, there are many common factors.

Jacques Hadamard, at the beginning of the 20th century, identified two models through which the creativity of scientists is exercised: one of an intuitive nature, the other - analytical. The intuitive is basically analogous to the creative model of the artists. It feeds on analogies, metaphors, images and mental experiments. The analytical one is the opposite, based on the rigid application of formal logic, often mathematical, which leaves little room for intuition.

In fact, Jacques Hadamard demonstrated with convincing arguments that even in the most rigorous adherence to the analytical model of scientific creativity the intuition is the origin of this investigation process (Hadamard, 1996).

The greatest theoretical physicist of the last century, Albert Einstein, recognized intuition as the trigger for his extraordinary creativity. The first step in the construction of his theories consisted always in imagining the physical reality he wanted to describe. And, then, only after having guessed it, Einstein gave the necessary formality to a new theory. He is a classic example of how the intuitive model in scientific creativity works (Howard, 2004), (Pais, 1982), (Sayen, 1985).

On the other hand, another great theoretical physicist of the 20th century, Paul Dirac, came to elaborate the quantum theory of the electron and to discover the physical reality of antimatter by purely analytical means through the development of mathematical proofs. From this point of view, Dirac is an example of how the analytical model in scientific creativity works (Dirac, 1987), (Farmelo, 2009).

However, Dirac also became convinced of the goodness of his elaboration when he was able to observe the simple and elegant “beauty” of his equations. In fact, Dirac, as admitted at the conclusion of his theoretical work, recognized it as the result of his aesthetic sense (Farmelo, 2009).

1.1 Art and Science: A Multidisciplinary Vision in a School Curricula

Since the last years' debate on the recovering of the necessity to recognize the unity and complementarity between scientific and humanistic vision, and, more specifically, between art and science, school education has slowly started this revolutionary process based on a multidisciplinary and interdisciplinary vision of national curricula.

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In this context, learning through the Arts assumes a relevant role in the student's cognitive development (Parsad, Spiegelman, & Coopersmith, 2012), and consequently, art becomes a tool to arouse and hold interest in a curriculum of scientific subjects, like science and mathematics.

The art, in its integration in school curricula, is used in different ways with stu-dents: from the art-works production to the analysis of the relevant already existing art-works. In particular, producing a hands-on work, like drawing, or discovering prospective rules in a painting or, simply, playing with digital applications on a mobile phone to turn a simple photo into an original and beautiful creative product. All these activities can stimulate students' creativity and inspiration.

The artistic experience can help students to explore their emotions and to use their own judgment, as summarized by Professor Elliot Eisner from Stanford school, who firmly believed that use of the art in education was one of the essential keys to student learning.

Indeed, art, in its most varied forms (visual arts, music, theatre, dance, narrative), involves all the senses of the young student and reinforces their cognitive, socio-emotional and multisensory skills (Eisner, The role of discipline-based art education in America's schools, 1987), (Eisner, The arts and the creation of mind, 2002).

Actually, from the cognitive point of view, arts teach students:

- To develop problem-solving skills, to understand that problems can have different solutions and each question can have multiple answers. The solutions are rarely fixed but change according to the circumstances and conditions opportunity. In artistic production both the will and the ability to grasp the solutions are indispensably unforeseen events offered by evolving work;
- To elaborate a multiple perspective, influencing the way we observe and interpret reality. During the artistic process, the student's mind is involved in a discovering process of "how" and "why". Exactly like a scientist, who experiments and discovers solutions, a student, when faced with an artistic idea, analyses the various possibilities and works through a dynamic change;
- To think "with" and "through" the materials, teaching them that the turning ideas into reality through arts is possible.

From the point of view of the student's social development, the arts:

- Teach how to develop opinions on "qualitative" and not just "quantitative" relationships. In general, the most of today school educational programs are primarily focused on teaching direct instructions on giving “correct/incorrect answers” and “rules”, whereas opinions and judgments prevail in the art field;

- Promote socio-emotional skills. Through art young students learn how to find a deal with themselves and control on their own efforts. This process, together with the sharing practice, encourages efforts appreciation with their peers and, at the same time, the awareness of the uniqueness of each individual, from which derives a positive self-awareness.
- Can become an effective therapeutic tool for problematic young people, for example in the use of the arts in so-called art therapy;
- Favour the integration of whom and what appears to be “different” when they are used in multicultural contexts (Elster & Ward, 2005).

Therefore, arts play an irreplaceable role in conveying those skills to the young people that will be useful in dealing with real life: “favouring the development of the child's personality, talents, mental and physical abilities to their fullest potential” (Unicef, 1989). In fact, it recognizes that children have the right to participate in art in all its forms and expressions, to be able to enjoy it, to practice cultural experiences and share them with the family, the educational structures, and the community, beyond the economic and social conditions of belonging.

Attempts to bring the world of childhood closer to that of art are becoming more and more frequent. The parents are very attentive to this aspect of the education of their children and many museums have become active in organizing art fruition initiatives for children.

2 The Methodology of Using Art for Discovering a Scientific Topic

One of the methodological procedures on how to introduce the arts into scientific subjects in national school curricula has been undertaken recently with Italian secondary school students (first and second cycles) with 13-16 years-old.

This integration has been introduced through three phases, inspired by Singapore’s method for mathematics study: concrete, pictorial and abstract (Yoong & Hoe, 2009). The proposed teaching method has started from the object manipulation in order to reach the final abstract representation of the formula studied.

During the concrete phase, students had to make the experience and become familiar with the mathematical formula studied through object manipulation (Fig.1). As agreed with teachers, GeoGebra application was utilized for this purpose for several reasons.

First of all, Italian teachers consider it (GeoGebra) user-friendly when used with low ICT skilled students on PC, Mobile, and Tablet.

Secondly, due to students’ previous experience with the software, they were able to concentrate directly on the subject to be explored without first being worried about the tool.

In addition, the software could be used for manipulating both 2D and 3D objects with different types of animation (Tramonti & Paneva-Marinova, 2019).

Fig. 1. Experimentation time - Concrete phase with students at Istituto Tecnico Superiore Bianchini in Terracina (Italy).

The use of the modelling program, during the concrete phase, has allowed students to explore and understand mathematical concepts through the help of visualization and virtual object manipulation (Fig. 2). Therefore, students learn and familiarize themselves with the specific objects' construction on the base, for example, of symmetry concept. This helped students to reinforce their visualization skills, modelling the real world problems and making connections between the real world and mathematics.

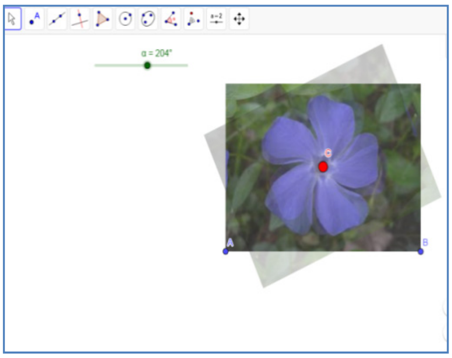

Fig. 2. Visual Modelling Programming – Example of symmetry study – GeoGebra

When students had got familiar with mathematical concepts, they have gone through the pictorial phase by learning to recognize math formula previously studied in the relevant artworks both individually and in team working.

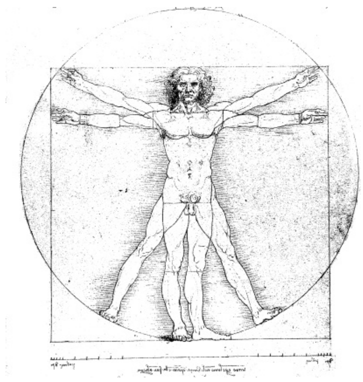

Fig. 3. Experimentation time - Pictorial phase – artwork selected by students at Istituto Tecnico Superiore Bianchini in Terracina (Italy).

The aim was to help students find in the habitual surrounding objects the mathematical concept studied, that, in this case, was the "symmetry". During this phase, they used not only what is strictly known as the art-works but also they have found the mathematical concept in other contexts as well, e.g. in nature.

Finally, on the base of the mathematics concept studied, students have created their own art-works by using their creativity as shown in Fig 4.

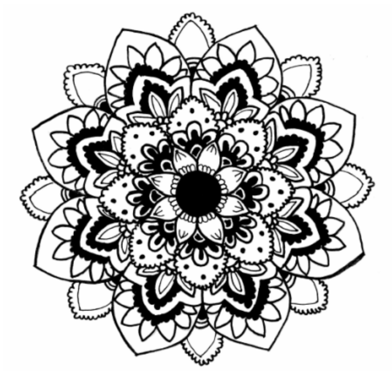

Fig. 4. Experimentation time - Abstract phase – artwork realized by a group of students from Istituto Tecnico Superiore Bianchini in Terracina (Italy).

In the end, 14-15 years old students, due to their lack in the practice and use of technology, have decided to produce their artistic hand-work. On the contrary, younger students (11-13 years old) have created their art-works by using technology, mainly GeoGebra. Finally, a part of these works will be uploaded in a 3D virtual museum (Márkus, et al., 2018), to be produced by Institute for Computer Science and Control, Hungarian Academy of Science in collaboration with Institute of Mathematics and Informatics - Bulgarian Academy of Sciences from Bulgaria (Tramonti & Paneva-Marinova, 2019).

2.1 Preliminary Results

According to the preliminary results, the piloting phase has been realized with a sample of about 125 secondary school students of different age, 11-13 for the first cycle and 14-16 - the second one.

At the beginning and at the end of the experimentation, two types of questionnaires have been administered to define the state of the art and students' expectations on the method proposed. However, the researcher was involved in the observing of all the phases above described to collect both qualitative and quantitative data to assess the effectiveness of the approach.

The preliminary survey has demonstrated that students develop not only their knowledge in mathematics but also reasoning process based on its applicability, imagination, creativity, and problem-solving skills. They learn to deal with the mathematical problem with variations according to the different art-works used for studying the same mathematical concept. Thus, even if the art-works can change the context and the background, the mathematical concept, behind these works, is always recognized and become easier applicable in their everyday life.

The main perception revealed is that the use of the art-works in the mathematics study favours the development of an enhanced learning setting enabling students to enjoy the learning process more with respect to the traditional frontal lessons thanks to the exploitation of different languages, such as visual, graphical, verbal and non-verbal, representational and pictorial.

Currently, the piloting phase is being finalized with 11-13 years old students and the data processing has been started.

3 Conclusions

The preliminary gathered data reveals that the use of art-works, as means and tool of learning of other subjects, like mathematics, offers students the way to go beyond the pure theory and to apply knowledge in the surrounding world. Therefore, it enables them to approach knowledge in a holistic and integral way.

Moreover, art, as a creative element, supports students in the development of the ability to introduce innovations continuously without being afraid of them.

Integrating art into learning not only permits to involve students into the educational process better, thus stimulating their enthusiasm from the perspective of open-minded future employees and out-of-box thinkers, but it also helps to produce citizens of the world with views large enough to embrace all the complexity of the actual reality.

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