Use of Art in Scientific Education

Margarita Cimadevila and Wolfgang Trettnak

Creativity and imagination are basic qualities for a scientist, since science, in reality, is an art.
Ángeles Alvariño. Oceanographer

Abstract A magnificent channel of scientific dissemination that excites the curiosity of the public, especially the young, is art. Art and science are similar in that both involve inspiration, creativity, research, meditation, and experimentation. Their combination can lead to novel results in both fields and reach the public in a subtle way, as beauty, poetry, and creativity are mixed with scientific facts or investigative methods. An example of this is the work of artists M. Cimadevila and W. Trettnak through which they will make a brief tour. In this chapter, we will see how the two artists make use of the art to approach topics from the world of physics as diverse as luminescence or particle physics, as well as incorporating other topics of social interest such as the role of women in science or ecological topics such as marine pollution by plastic. In their work, they mix and intertwine these themes, showing their beauty or even the problems related to them, disseminating them in many ways in artistic proposals in which they combine art, science, physics, ecology, sustainability, equality, didactics, and dissemination.

Keywords Physics · Art and science · Education · Didactics · Dissemination · Gender equality · Sustainability · Ecology · Young audience · Scientific culture

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1 Science and Art: An Introduction

Art and science are similar in that they involve inspiration, creativity, research, meditation, and experimentation. Their combination can lead to novel results in both fields and reach the public in a subtle way, as beauty, poetry, and creativity can be mixed with scientific information or even uncomfortable facts. Throughout the ages, art and science have been intimately linked. However, today's societies have perceived them as different areas with little in common. The digital revolution and the new technological means at our disposal open fields that are explored by art and science together within a new universe of scientific-artistic creation, in such a way that it is becoming difficult to conceive art without the world of science and vice versa.

Art, with its chameleon-like character, and its ability to amaze and reach all kinds of audiences, can be used as a powerful tool for communicating science and scientific culture, not only directly in schools and classrooms but subliminally in all kinds of media and environments (Miller 2014). According to our personal experience, art can show science in a direct, attractive, visual, and immediate way, causing an impact difficult to forget in the viewer, which can last in his imagination for a long time since "an image says more than a thousand words". It is an excellent way to make problems known (in a simple, clear, and impacting way), a valuable tool to fight against them and a magnificent channel of scientific dissemination that awakens the curiosity of the public, especially that of young people (see Chap. 4) (Cimadevila and Trettnak 2020).

The artistic work can take different forms: sculpture, painting, video, installation, performance… and can deal with scientific topics as diverse as particle physics, luminescence, or wave equations; the limit is really the artist's inspiration (Fig. 1) (Miller 2014). Through making scientific dissemination, it can become an exciting and highly rewarding work.

The combination "science and art" has an attractive *innovative and universal* character, breaking barriers, and crossing cultures, ideas, and borders. Its *transversality* allows it to address scientific issues combined with other topics such as gender equality, eco-art, and research, being also *interdisciplinary* since its materials can be used at all levels of other areas, such as environmental education, citizenship education, humanities, social sciences, or languages (see Chap. 4).

2 Goals and Target Audience

The main goals of the science and art combination that we have been pursuing are:

- Disseminate the world of science and art, showing their relationship.
- To promote scientific and artistic vocations.
- To promote creativity and the scientific method in the students.
- To create innovative materials in the field of science and art.

Fig. 1 **a** Cimadevila exhibiting at a physics conference at the University of Santiago de Compostela, Spain. **b** Trettnak at the exhibition *Licht und Schatten* at Graz University, Austria. *Photographs* © Cimadevila and Trettnak 2017, 2015. All rights reserved

Young people are the most important target audience since they are the future of our society, and their training in science is necessary and essential. For this, the artists depend on the teachers who are the second most important target audience, not in vain their work is the one that guides and orients young people. The activities that combine science and art are very well received by students and teachers, who actively participate in them through workshops, competitions, science fairs, and conferences (Fig. 2).

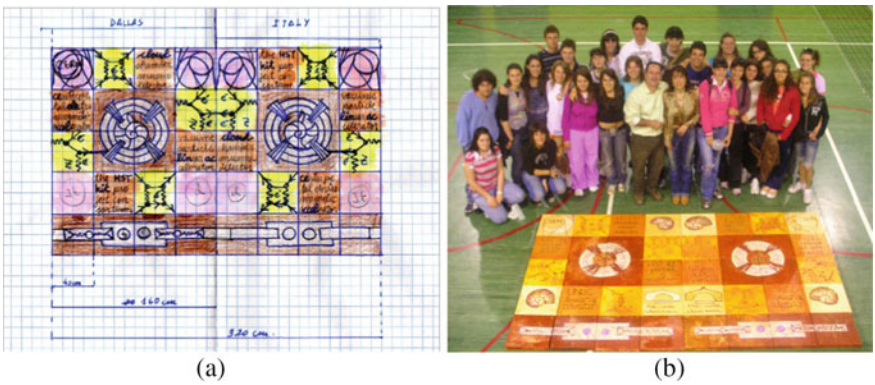

Fig. 2 Cimadevila conducted a particle physics workshop in the international course *The World Classroom* for high school students from Bologna, Italy, and Dallas, Texas: **a** The sketch for a mural and **b** the final product. *Photographs* © Cimadevila 2007. All rights reserved

The approach to classrooms at all levels is essential in the dissemination of the binomial art and science, from universities, institutes, and secondary education to preschool classrooms of the smallest schools. It is very important to sow the seed of curiosity in the small viewers.

One must not forget the policymakers, politicians, and disseminators since they are the actors who translate into rules and laws the needs of science and the public. Ultimately, the public is the target audience, who, with its taxes, finances a large part of the world of science and art.

3 Dissemination

Popularizing science can be done also through artistic work and using very different paths. The first and most obvious is the exhibition of the work in art galleries and museums; however, its exhibition in places outside the artistic circuit, such as a science contest, a school institution, a shopping mall, social networks, or a leisure place, often reaches a wider and more varied audience. But we must never lose sight of the fact that it is not only necessary to reach the public with an artistic proposal, but also to attract its attention to the scientific theme on which the work is based.

A very important point of dissemination is the creation of teaching materials, which should be oriented to both students and teachers. On the basis of photos or videos of the artistic work countless "traditional" materials such as books, brochures, and posters can be created. Special mention should be made of the new interactive digital materials that combine science and art, which are fantastic and an inexhaustible source of fun and learning for students. Their possibilities are endless: games, puzzles, brainteasers, riddles, and didactic units. However, not all are positive points, since their ephemeral nature, due to the rapid evolution of technologies and software, makes very interesting materials of recent creation disappear or stop working. This fact is worthy of careful reflection, not only on the ephemeral nature of the materials but also on the fragility of our digital culture and its possible difficulty of transmission in the distant future.

A Digital Paradox

In 2013, I found my grandfather's doctoral thesis from the early twentieth century on the Internet, which was a great joy for me. However, incredibly, it is no longer possible to access the digital materials *Ciencia y Arte 1 and 2*, created by me in 2014/15 for secondary school students to enjoy science and art, and subsidized by the government of Galicia (Fig. 3).

Fig. 3 Cimadevila, *Ciencia y Arte 1*, the cover of CD casing. © M. Cimadevila 2014. All right reserved

What is the reason? A program used in the creation of the materials is no longer operational and no longer supported. It has certainly upset me to see a work, to which I have devoted a lot of time and effort, disappear without a trace or to see that recovering it might be costly, time-consuming, and difficult.

Maybe stone would have been a better support material!

Margarita Cimadevila

4 Linking Science and Art

Let us now move on to the practical, showing how linking science and art has been realized by us, Margarita Cimadevila[1] (Cimadevila 2023), and Wolfgang Trettnak[2] (Trettnak 2023), artists with scientific training whose artwork has among its objectives to raise awareness of the world of science.

The source of inspiration for our individual work is science, contemplated from such different points of view as teaching (Cimadevila) and research (Trettnak). The artwork has been created on subjects as diverse as particle physics, discoveries of *CERN* (*European Organization for Nuclear Research*), luminescence, bionics, or

[1] The artist, Margarita Cimadevila has a degree in Chemistry from the University of Santiago de Compostela and worked as a Physics/Chemistry teacher and director in different institutes of Galicia.

[2] Wolfgang Trettnak received a Ph.D. in Chemistry from the University of Graz. He undertook applied research on sensors and biosensors for several years and published a number of scientific articles. In 2002 he became a freelance artist.

electric fish, and has a strong informative and didactic charge. Never losing the scientific point of view, the work of both of us also evolved incorporating other themes, both social and environmental.

4.1 Margarita Cimadevila

The artwork, deeply influenced by the roots of her land Galicia and her experience as a science teacher, pursues since many years now a triple objective: *didactic, informative, and artistic*, as well as fighting for *gender equality* and the *defense of the environment*. Science and art are mixed and intertwined in her artistic proposal, in which, from a feminist and always didactic perspective, she

- disseminates the world of science,
- gives visibility to the role of women in science,
- denounces environmental problems.

Through the artworks, she shows the problems of these issues and disseminates them by combining *science, didactics, equality, ecology, sustainability, recycling, dissemination, and art.*

4.1.1 Science and Art, CERN

As a result of her participation in the *Teachers' School (HST 2003)* at the *CERN* in Geneva, her artistic work underwent a radical change and focused on mixing her two worlds: science and art. In 2004, she showed at *CERN* her first painting exhibition with this double theme (*Particle physics I*), being her sources of inspiration the *HST* conferences and the *CERN* facilities (Fig. 4) (High School Teachers at CERN 2004). Her artwork has been shown in different events related to *CERN* and particle physics, such as the *International Particle Accelerator Conference 2011* and she has organized multiple events and programs to introduce the world of *CERN* to students and teachers.

4.1.2 Equality, Science, and Art

Making visible the role of women in science and fighting for gender equality in science and in life have been the fundamental objectives of two of her exhibitions:

- *CIENCIA EX AEQUO* (Cimadevila 2009; López Díaz and Cimadevila 2013) shows and values the work of women in science throughout time. It pays tribute to the unjustly forgotten women scientists, who, by doing magnificent work and

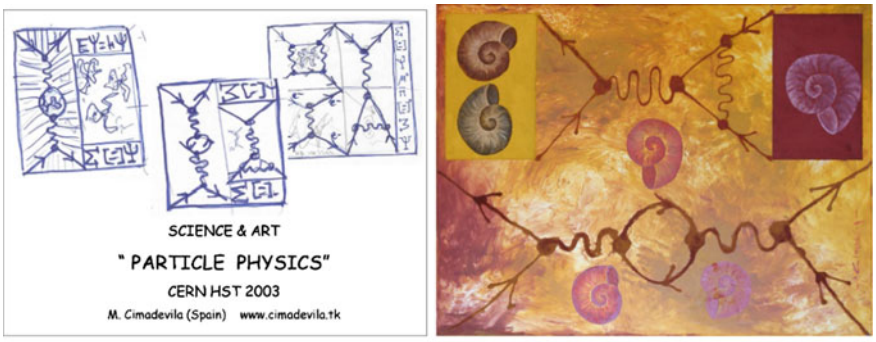

Fig. 4 Cimadevila, *Feynman diagrams*, **a** sketches and **b** final painting. *Photographs* © Cimadevila 2003, 2006. All rights reserved

deserving recognition for it, were ignored, forgotten, or relegated to the background. The exhibition is based on the scientific work of twelve pioneering women scientists of the last century (Fig. 5).

- *Avant-garde in Science* is about men and women who were at the forefront of science and life, working in equality in the early twentieth century. It gives recognition to those men who rose above pettiness, recognized the intelligence of women, and favored their incorporation into science, working with them on an equal basis.

The source of inspiration has been the scientific field on which these scientists worked, which makes that, although all the paintings deal with science, they touch on topics as different as pulsars, *Escherichia coli*, or tryptophan or nummulites, accompanied by brief scientific and biographical explanations (Fig. 5).

Fig. 5 Exhibition *CIENCIA EX AEQUO* of Cimadevila at the *Innovation Convention 2014* organized by the European Commission at Brussels, Belgium. *Photographs* © Cimadevila 2014. All rights reserved

Recycling and reuse of materials are always present in her works, and many of the paintings have been made with leftover textile materials and worn-out clothes, which give them an imprint difficult to achieve with new materials.

4.2 Wolfgang Trettnak

Trettnak draws much of his inspiration from the work done as a research scientist. For many years, he worked on the use of fluorescent and phosphorescent dyes in sensor applications (Trettnak and Wolfbeis 1993; Trettnak et al. 1991), which also deeply influenced his artistic work and resulted in the creation of luminescent objects and installations. Luminescent dyes are not only fascinating, because of their uncommon color behavior, but also allow to play with our visual perception. This makes them very attractive for catching the attention of the spectator (Fig. 6). Similar fascination results from living bioluminescent organisms, which he tries to imitate not only by using luminescent materials but also by light-emitting diodes as light sources.

Sensors play an important role in clinical applications, implants, and artificial limps. The developments in these fields and in robotics were the inspiration for Trettnak to introduce electronic components in his artwork, thus resulting in series of paintings showing "bionic" men and animals. Animals, especially fish, which use bioelectricity as a means of communication, for hunting or defense, were the basis for the creation of a whole series of paintings on "*Electronic fishes*" (Fig. 7).

Many of these works have been presented with information aside, which give hints on the background and short scientific explanations. In addition, Trettnak has given lectures with a popular science character on all these subjects combined with his artwork. For example, he lectured in schools and at universities (Trettnak 2015),

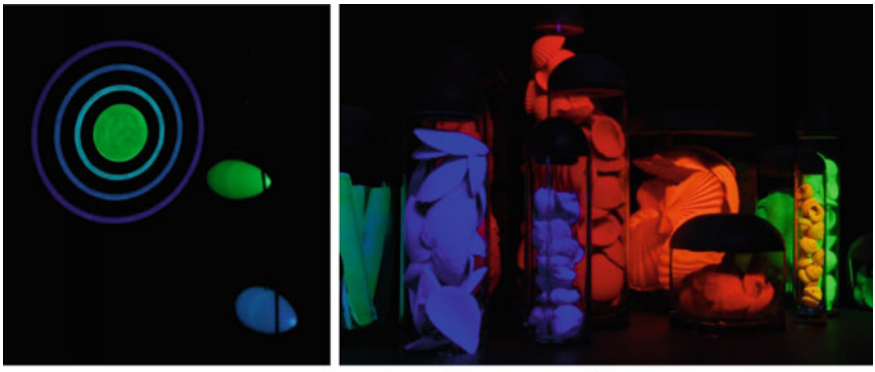

Fig. 6 Trettnak, luminescent objects **a** *Particles hitting the target* (hanging mobile) and **b** In vitro *III*. Details. © Trettnak. 2014, 2015. All rights reserved

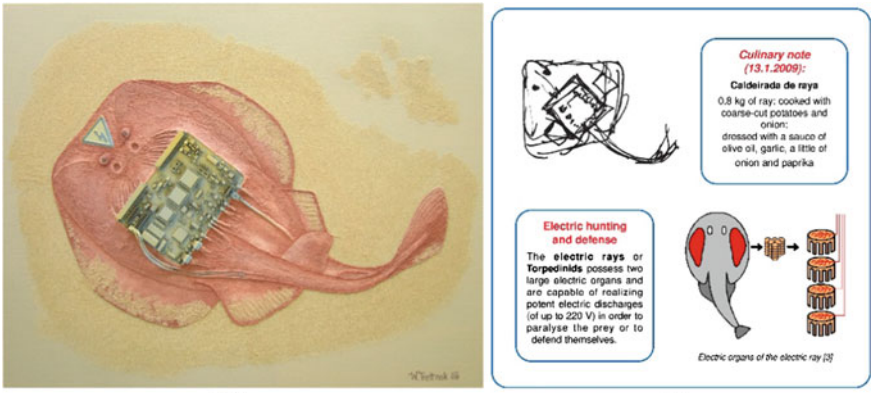

Fig. 7 Trettnak, **a** painting *Electra* and **b** short scientific explanation and cooking recipe (Graetz 2006). © Trettnak 2008, 2009. All rights reserved

at science and art courses for teachers (Dialogue between Science and Art 2023), or at scientific conferences.

Another issue, which is addressed by him, is linking with environmental topics. Recycling and reuse of materials play an important role in his work, not only reuse of electronic components, but also, for example, of textile waste. The problems of electronic or textile wastes are very serious and still need to be resolved. A special problem of concern has been marine plastic pollution and its consequences, which stands in the focus of the joint work of Cimadevila and Trettnak with their eco-art exhibition *MARE PLASTICUM* (Cimadevila and Trettnak 2020; ARSCIENCIA 2023).

But how to win the attention of the spectator or visitor of an exhibition, which may have a scientific background or contain even worrying information? Here humor can help, an aspect which is often present in Trettnak's work.

4.3 Cimadevila/Trettnak—Eco-Art: MARE PLASTICUM

Since 2011, Cimadevila and Trettnak worked, with four hands and two heads, on the exhibition *MARE PLASTICUM* (Cimadevila and Trettnak 2020; ARSCIENCIA 2023) about the pollution of the oceans by plastic and its environmental consequences: entanglement, plastic ingestion, species mortality, and toxicity. Its aim is to inform about the problem and raise public awareness (Streit-Bianchi et al. 2020; Verany 2015; Del Rosso 2015). The exhibition with their artwork and scientific

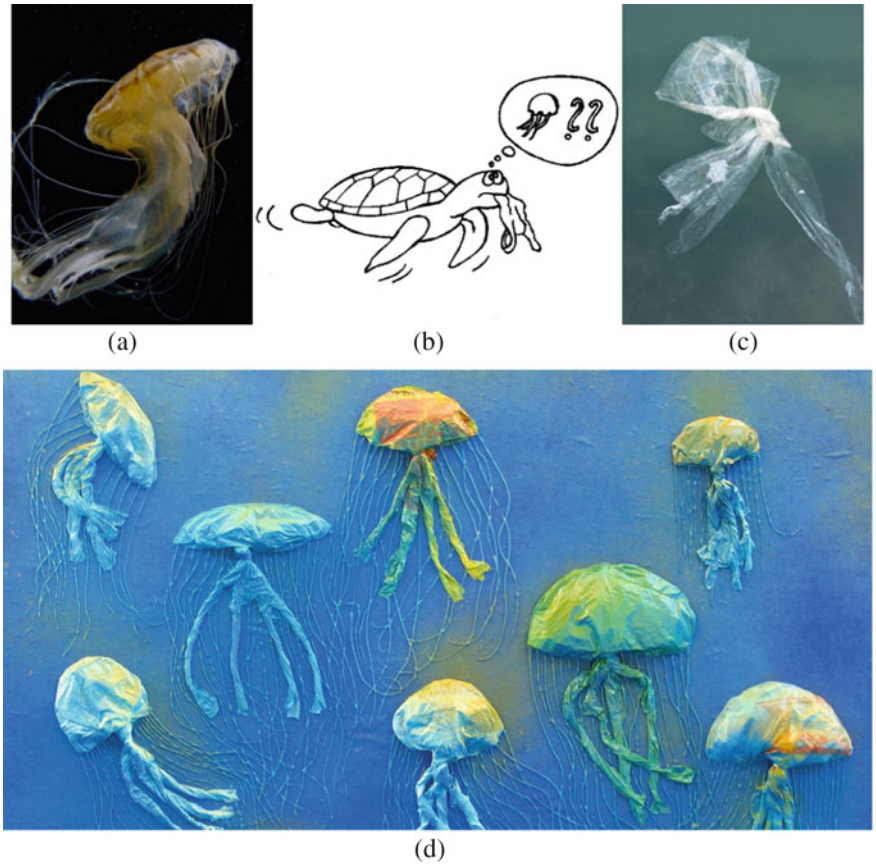

Fig. 8 *MARE PLASTICUM*. Sea turtles eat plastic bags because they mistake them for jellyfish. **a** Jellyfish, **b** turtle, **c** plastic bag, **d** *Jellyfish*, painting made with plastic bags (Detail). *Photographs* **a** public domain (Thurner 2023); **b–d** © Cimadevila and Trettnak 2017. All rights reserved

explanations offers a vision that is both real and imaginary and raises a cry of alarm: *It's time to act!*

The artworks made with plastics collected by them on the beaches of Galicia (Fig. 8) and the scientific information, comics, posters, mobiles, and videos that complete the exhibition, have been shown, for example, at: World Congress *Our Ocean 2017 Malta*, *MUNCYT* (*Museo Nacional de Ciencia y Tecnología de España*) A Coruña, *CONAMA 2016* (National Environmental Congress) Madrid, *CERN* Geneva, and *National Museum China* in Beijing (Cimadevila and Trettnak 2020).

For the originality in showing a pressing problem in a creative way, but without losing sight of the scientific rigor, the 1st prize for sustainability is awarded to the work:

MARE PLASTICUM—PLASTIC FISHES by Margarita Cimadevila and Wolfgang Trettnak from ARSCIENCIA of a Coruña.

Translated from: *Acta de la comisión de CIENCIA EN ACCIÓN* (Ciencia en accion 2023)

28 de mayo al 15 de julio 2015

4.4 Exhibitions

Exhibitions have been organized in all types of museums, centers, schools, universities, events, and national and international forums. It is intended that the public is not limited to static contemplation, but actively participates through guided tours, lectures, and workshops, or even by using on occasion "augmented reality" to include virtual objects through the mobile phone, in order to make the exhibition more interactive.

They have had wide dissemination and reach, thanks to the relevance and high public attendance of centers such as the *Oceanographic Museum of Monaco.* This has made it possible for their message to reach a wide and diverse public. But they have also been shown in modest halls, local meetings, and educational centers, whenever the authors have been invited to spread their message.

4.5 Conferences, Congresses, and Fairs

Events such as conferences, congresses, or fairs, national such as *CONAMA 2016*, or global ones such as the *Our Ocean 2017* Congress, both face-to-face and virtual, are a good way to reach more specific audiences, in addition to opening new forms of collaboration and dissemination. The authors have participated in a wide range of such events: conferences on physics and particle physics, environmental congresses, congresses related to gender equality in science and technology, teacher´s congresses, science fairs, and many more.

4.6 Courses

Another important role is played by courses for teachers and students. For example, both authors were involved in the organization of the course *Science and Art: so similar, so different!* in Galicia (2014) and participated in the course *Dialogue between Science and Art* organized by Michal Giboda in the Czech Republic (Dialogue between Science and Art 2023).

International course for teachers
Science and Art: So Similar, so Different!
(*Comenius-Grundtvig Course* of the Europ. Union; 2011–2014)

The organization of courses for teachers on science and art are a magnificent and enriching experience, where the exchange of ideas and points of view of teachers of different nationalities, levels, subjects, ideologies, and countries give rise to new projects that contribute to promote the popularization of science through art, creating links between different cultures difficult to forget and that remain through time (Fig. 9).

Fig. 9 Teachers in the course *Science and Art: so similar, so different! Photographs* © Niki Alexakou 2012. All rights reserved

Fig. 10 **a** Workshop for students in Sada, Spain and **b** conference at a primary school in Betanzos, Spain. *Photographs* © Cimadevila and Trettnak 2011, 2020. All rights reserved

4.7 Educational Activities

Educational activities intended for primary schools, secondary schools, and university are lectures, guided tours, workshops, participation in competitions, and traveling exhibitions. They are very gratifying for their good reception by teachers and students. Good examples are the participation in competitions such as *Ciencia en acción (Science on Stage)* (Ciencia en accion 2023; Science on Stage Europe 2023), or in educational awareness raising events, such as the *European Maritime Day* (2023). The creation of artistic work with students and teachers also belongs to these kinds of activities (Figs. 2 and 10).

4.8 Didactic Materials

Some didactic materials have been created for students, teachers, and the public such as videos, games, posters, comics, bookmarks, and brochures without forgetting the incorporation of new technologies through interactive digital materials (Fig. 3), all of them in several languages: English, Galician, Spanish, French, German, and Chinese. Books, catalogs, and other publications were edited, such as *CIENCIA EX AEQUO* in collaboration with the *Office for Gender Equality of the University of A Coruña* (Cimadevila 2009) or the book *Mare Plasticum—The Plastic Sea* with Springer publishing house (Streit-Bianchi et al. 2020).

4.9 Media Presence

The exhibitions of the authors have been echoed by various media such as: television and radio programs dedicated to art, equality, science, and environment, reports on

websites, scientific journals, and non-specialized press. Their work has been present also in various social networks, websites, blogs, etc., and, of course, in their own websites and social media (Cimadevila 2023; Trettnak 2023; ARSCIENCIA 2023). Although this might seem a trivial issue in today's multimedia culture, it is still of importance and should not be ignored, since, consequently, resulted contacts to schools, museums, and other institutions. On the other hand, events such as the *European Maritime Day* were completely organized with schools via the own websites (ARSCIENCIA 2023; European Maritime Day 2023).

5 Final Remarks

It should be noted that all activities presented here have been done so far with very limited funds without special financial support, sponsors, or subsidies from the public sector. In general, more important than money is the enthusiasm and personal engagement of the people involved in organizing art and science events. Art and science are efficient means to spread science in society as demonstrated by some of our examples and even more by the interest now important scientific institutions such as *CERN*, *ESO* (*European Southern Observatory*, Chile), *INFN* (*Istituto Nazionale di Fisica Nucleare*, Italy), or *Ars Electronica* (2023) (Austria), and many other institutions around the globe have demonstrated in setting up science and art events for the general public or collaborations between scientists and artists. Furthermore, also universities are moving forward, to give just one example, in Linz (Austria), the *Johannes Kepler University* and the *University of Applied Arts Vienna* have created an inter-university called *Art x Science School for Transformation* (Transformation Studies 2023).

Many of the activities and events presented in Chap. 4 have been channeled through the association *ARSCIENCIA*. The international association ARSCIENCIA (ARSCIENCIA (2023) founded in 2013, is a nonprofit socio-cultural entity, whose purpose is to promote and organize all kinds of activities on science and art, showing the relationship between these two worlds and paying special attention to the presence of women in science.

Their long trajectory in the world of science and art makes Cimadevila and Trettnak firmly convinced that art is a powerful tool for promoting scientific culture and to raise awareness in scientific topics. They both consider as magic to allow students to see science through art and to create art because of science.

The authors hope that their journey is a convincing example to encourage in the classroom the collaboration between artists, art teachers, science teachers, and students to make up projects on topics such as, e.g., the climate change or environmental pollution, where the students can profitably and leisurely deepen their scientific knowledge on physics, chemistry, ecology, biology, mathematics, etc., by using creative methods based not only on traditional methods, but also on the most appealing available digital tools.

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