Journal of Modern Education Review, ISSN 2155-7993, USA
May 2019, Volume 9, No. 5, pp. 385–398
Doi: 10.15341/jmer(2155-7993)/05.09.2019/009

http://www.academicstar.us

Scenarios and Scenes of Opera for STEAM Creative Learning: Spain Experiences for Classroom Implementation

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Abstract: The Scientific Opera into classroom promote creativity and STEM knowledge together with Art and cross-disciplinary work. The Opera brings together diverse forms of artistic expression and also allows teachers to introduce innovative ways of directing science classrooms. An approximation to the scientific elements at the Opera from the presence of the Moon in the History makes easier to understand the Opera in the context of STEM content.

The Global Science Opera Project (GSO) proposes and develops scenarios and scenes from Opera for STEAM Creative Learning. The four editions of GSO provide brief cases of the Spanish experience that illustrate pedagogical, methodological and didactic opportunities, composition and artistic participation (composition, performance, design of costumes and sets). There is also evidence of the acquisition of key competences. We end up highlighting some of the specific achievements of collaborative interaction of public organisms, companies and research centres with the participating schools.

Key words: community for science, creative learning, cross-disciplinary, IBSE, STEAM, Science Opera

1. Introduction: Opera into Classroom

Opera is a play that incorporates multiple elements: singing, acting, dancing, script, costuming, pictures, and body expression. The Scientific Opera into classroom promotes creativity and STEM knowledge (sciences, technology, engineering and mathematics) together with Art.

Opera gathers diverse forms of artistic expression and also allows teachers to introduce innovative ways of conducting their science classrooms.

Scientist Opera scenarios make up an interdisciplinary work, mobilize and educate in emotions, train communication and language skills, and develop scientist subjects in today's society (Snowman, 2016) with IBSE (Inquiry Based Science Education) methodology (Minstrel J. & van Zee E. H., 2000).

Questions that students pose to themselves are the principal thread of STEM contents and concepts in creative scenarios. In this way, classrooms change into labs to experience emotionsand space that surrounds us, and improve communication skills. We assist students in building knowledge by the use of bodily expressions, verbal and non-

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verbal. Communication and individual uncertainty lead them to assertiveness, because creative work enhances the validity of all contributions; disruptive participation could be a value in our classrooms.

There are numerous governments that include in the curriculum since childhood initiatives to foster individual and collective creativity, some of this through STEAM activity. In this context A. Craft (2003) opens the question if creativity is always situated within a cultural context and into may be challenged the existence or not of a cultural universalism.

Several studies and personal opinions of important artists, from Hemingway to Marisa Meyer (former CEO of Yahoo), the creators of MediaLab from MIT, or Frank Gehry (the architect of Guggenheim Museum), support the counterintuitive idea that limits trigger creativity; Yi-Ming, Lin & Sun (2008) tackle the study of this counterintuitive idea, developing address studying that enabling students to think outside of concept boundaries in hope of enhancing creative potential with an integrated concept mapping system (ICMSys) the role of computer support for building conceptual self-awareness — that is, enabling students to think outside of concept boundaries in hope of enhancing creative potential. Based on meta-cognition theory, we developed an integrated concept mapping system (ICMSys) (Yi-Ming Kao et al., 2008).

Creations Project (Home Creations, 2019) establishes a pan-European network, with the objective of building a Global Science Opera each year, GSO. Cultural universalism is one of the objectives of GSO. The project provides teachers training and resources (Figure 1).

Figure 1 Training Activity Creations Summer School, 2015

Creations Project is funded by the European Union. The goal is to develop creative approaches based on art, trying to engage young people in science classroom. The Project achieves the goal to promote new strategies and methodologies to guide the student's creative learning process (Jeffrey B. & Craft A., 2006) in the curricular context and involving around 30 countries of the world in Global Science Opera, GSO ("The Global Science Opera", n.d.). It's one of the projects Scientix Community ("The community for science education in Europe", n.d.).

The incorporation of professionals specialized in artistic disciplines, the participation of image, sound and technology technicians (Figure 2), recognized researchers, management organizations and Universities collaboration open the limits at the classrooms beyond classical borders. Art and Science are sometimes far away. The combination of these two areas can enhance cross-disciplinary thinking and raise students' interest in both STEM and art subjects. There are no bonders, no frontiers in knowledge with STEAM activity.

Figure 2 Image Created In Collaboration With Technical Professionals in Assembly Work, 2017

2. STEAM Approximation through the Elements of the Opera

The term opera literally translates into “labour” or “work”. Certainly it contains very complex processes in every step of the creation way. Opera is essentially a play in which music and sung predominate over spoken word. This singing is combined with the other theatrical elements of drama, dancing, costumes, sets, staging, lighting, title, libretto, musical composition, “recitative”, “aria”, argument, social context, scenic proposals, instrumentation, choreography, choirs and expression of emotions (Figure 3). The work of professionals in image design and assembly technologies combines different elements mentioned above and makes them evident.

Figure 3 Ghost Particles Performance 2016

Nevertheless, STEM contents are present throughout the History of the Opera.

A timeline history opera (“Contemporary timeline”, n.d.) is always a good resource to know Opera and find STEM presence in this context. We can find an Opera approaching Einstein, *Einstein on the Beach,* as described a mind that revolutionizes the world, with questionable success, in 1976.

Among the most unique and ancient it can be found, *The Elements*, published around 1713, with allegorical characters such as Air, Water, Fire, Earth, Time and Aurora.

2.1 The Moon Presence in Opera

The main goal of this section is to propose resources to prepare the draft of a scientific Opera.

We provide evidence of STEM topics in operas containing the Moon as a protagonist in some of the elements

cited previously that we can identify on the development of the plot.

The presence of science contents is more common than we thought. We will track the appearance of the Moon in historical operas. The Moon is an astronomical body that orbits planet Earth as its only permanent natural satellite. It is the fifth-largest natural satellite in the Solar System; also is reference subject in poetry, novel, cinema, painting, and other artistic manifestations.

We have studied the Moon presence in different Opera, and listed the year, the composer, the type of Opera related to the social context, and the scientific content specifying, if possible, the time in which we can find it in the referenced version.

- 1777. Josep Haydn. Il mondo della luna. Singspiel. Opera bufa. Titile, Il mondo de la lluna, introduces singular arias (O luccente moon). We find astronomy contents (Only Mozart1, 2016) focus on Moon (min 6), the description (min 11:03), presentation a avant-garde artefact telescope (min 12:50), physical laws (min 58:45).
- 1791. Wolfgang Amadeus Mozart. In The Magic flute, a folkloric and popular drama, the Moon is present with The Queen of the night (flautamaracay, n.d.).
- 1831 Vinzenzo Bellini. Norma, drama, with a prayer to the goddess Luna asking for peace and help against the evil of the druids in (min 24) (Clasical Related, 2008).
- 1875. Charles Offenbach, Le Voyage dans la Lune, bufa, inspired by the Earth and the Moon by Jules Verne; present an Astronomical Observatory (min 28:) (cellcoat, n.d.).
- 2008. Kaija Saariaho, drama. History and Society. The life of the Marchioness Èmilie du Châtelet (1706-1749), mathematician, physicist and lover of Voltaire reveal personality of a scientific woman and nobility in the eighteenth century, and her letters to Voltaire inspire the argument of the Opera Emilie. An example is Scene VIII developing contents: the orbit of the moon, the gravity, the ebb and flow of the tides and more (Saariaho, Kaija, 2013)

3. Global Science Opera Experiences

Creations, a project funded by the European Union, develops creative approaches based on art for an engaging science classroom.The experiences implemented in the classroom with Creations Project, produce annual editions of scientific opera with the participation of countries from all over the world, GSO: Skylight in 2015 International Year of Light (Hoegskolenstorhaug, 2015), Ghost Particles that make up the universe in 2016 (Hoegskolenstorhaug, 2015), Moon Village to survive Earth in 2017 (TV Haugaland, 2017) and One Ocean saving the seas in 2018 (Høgskulen på Vestlandet – HVL 2018). Engage students in international scientific projects, promotes a truly global cooperation.

Spain has participated in the successive editions, different schools of the different Autonomous Communities (Figure 4): the Community of Madrid (2015), the Autonomy of Catalonia (2016), Basque Country Euskadi and Community of Valencia in 2017, and Community of Andalucia in 2018 This provides the added value of a wide representation of the whole country.

Figure 4 Spain Autonomous Communities Participants

3.1 Global Science Opera Editions

The GSO's first production, *SkyLight*, was the first ever opera to be written and performed by a global community. It was endorsed by the International Astronomical Union (IAU) as an official project of the International Year of Light 2015.

We can consider that this first edition provides the pillars of the design of GSO project. A sponsor network of international organizations was initiated and selection of musical compositions in network sessions was coordinated. Unification of costumes, format of the final assembly, and adjustment of times of scenes were other valuable experiences.

Second edition, *Ghost Particles*, worked with the support of CERN, International Organization established in 1954. CERN works to uncover what the universe is made of and how it works. The project followed a similar improved structure.

In the third edition, *Moon Village*, Hands on Universe (HOU) had a special prominence. The mission of HOU is to train teachers on the use of modern tools and provide material and resources for science education (Figure 5).

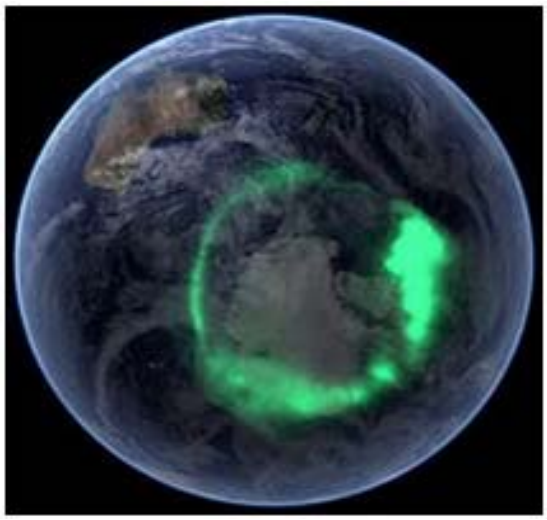

Figure 5 Earth Observation from Moon. One of Image' Resources Cortesy of NASA and HOU Collaboration for Science Education

Finally in 4th edition, the recent premiere of Opera *One Ocean* was developed in collaboration with the Norwegian Institute for Marine Research and the Integrated Marine Biosphere Research (IMBeR). In Spainhas received support of the Oceanographic Institute of Malaga and the CICEROM Project created in this Institute to feed the interest in young people on study of the sea and its resources. Among many other educational actions Cicerom made two webinars, one directed to students and another aimed at teachers; the objective was to motivate concerns about the health of the seas and oceans. Webinars were developed in the Scientix online meeting room. Webinar, an online conference (Figure 6), amplifies the information channels, brings the experience of researchers to the students and provides the added value of the interaction.

Figure 6 Promotional Poster of Webinars Ocean Health

Schools, universities, scientists, teachers, artists and students are engaged in a collaborative work. Scientix Community provides resources facilitating interaction among the participants.

Each edition has been publicized with a poster that encourages participation (Figure 7).

Figure 7 Global Science Opera Productions

3.2 Classroom Situations in Different Editions of GSO

We approach classroom situations experienced throughout the creation of the different GSO.

These experiences are short and illustrative cases of the pedagogical, methodological and didactic opportunities presented. We do not pretend to offer direct examples all the Opera elements, but to capture and describe evidences

of the work (Figure 8).

Figure 8 Primary and Secundary Students Activity

A long list of elements (Figure 9), give form to the Opera: opera's script, the social context, scenography proposals, instrumentation, choreography, choirs, recitative text, musical composition, musical interpretation and song, dance, characters, costume design, scenic pictures.

Figure 9 STEAM Learning Scenarios, Global Science Opera, Elements

- The Synopsis. Synopsis of each GSO collects a small story that becomes the guiding thread of the STEM concepts that make up the GSO.

Ghost Particles, GSO 2016, is loosely based on the story of Joao, a ten year old boy.

Joao discusses various cultures' and ages' concept of matter with his father. He is excited about the story of W. Pauli, who imagined the existence of a particle, leading to an exploration spanning decades. Joao wants to discover a particle, but he is rejected by his father, and told that it would take many years before that would be possible. Desperate to realize his dream, he invites friends from around the globe to help. Together, they study the Ghost

Particles photons, neutrinos, and Higgs Boson, and finally, they consider a way of discovering the new particle. They seek the help of the CMS experiment in order to describe it, and then send a message to the world, inspired by Pauli's "radioactive" speech: "Dear Creative Ladies and Gentlemen….".

- The Libretto. Libretto collects and sequences the scenes of the participating countries

Ghost Particles Spain scene is surprising because it involves 4th grade Primary School boys and girls in the explanation to the world of the participation of Higgs field in the acquisition of Quarks mass; they succeed. The protagonist Joao explains it to us accompanied by his friend Little girl you can read in the script (Figure 10).

Video 17 Quarks

(Spain)

Several children stretched out on the ground like a spider-web are "the sea" that "hosts" Higgs bosons. Quarks colored (red, green and blue), slide between "Higgs field" with agility, they want to acquire their mass.

Chorus. Singers children- "Elementary particles that make up matter have mass: they are leptons and quarks. Look at the quarks taking its mass. Higgs bosons give that. Higgs Boson is there, like a Ghost particle.

Chorus. UAB Coral - "Ah quarks amagats, que mostreu aquest ordre tan lògic i bell"

João- (speaking) I found ...quarks keeping on mass... Higgs bosons give that.

Little Girl - (speaking) Hi Joao, but look that! The matter has no colour, but the matter has mass!

João- Higgs Boson exists, but I have not seen it....

Figure 10 Quarks and Higgs Field. Montserrat School "scene. Barcelona. Spain"

- The Characters. Characters in opera can be historical personalities, fictional persons, abstract or fictional subjects that represents parts of the society, or even figurative objects.

Ghost Particles includes alongside historical fictional characters (Wolfgang Ernst Pauli), imaginary characters (Firefly), representatives of everyday society (Joao and Little Girl) and objects (Higgs Bosson, Quarks) on their journey around the Earth looking for ghost particles.

- The Costumes. Costumes inspiration are based on a simple design for the protagonists of each edition. This is important to facilitate visual coherence between the scenes filmed in different countries (Figure 11). There are too proposals of great sumptuousness in dance choreography of some scenes. Costumes must to cover technical, artistic and budget needs and too complete information related to the action, highlight information represented on scene, and also transmits non-verbal language codes for the script.

For example, in the Spain's scene Quarks, *in Ghost Particles*, represent their colour' property with appropriate colour shirt.

The design proposed for Sophie (Figure 11A) in *Moon Village*, GSO 2017, incorporates the creativity of Spanish students (Figure 11B) in the scene recorded in Bilbo_Bizkaia scene.

Figure 11 Sophia Character Costume Original Proposed (A) and Made by Spanish Students (B)

Methodology. Creation of each Spain' scene in the script and STEM content is based on the Inquiry Learning methodology (Minstrel J. & van Zee E. H., 2000). Some studies conclude significant differences in the results throughout the schooling: students who have been educated by inquiry-based instruction supported learning cycle method have become more successful than the students who have been educated by the traditional teaching methods (Ali A., 2014).

At Moon Village, GSO 2017, 5th grade elementary school children ask themselves questions about the sustainability of the Earth and what would happen if they settle on the Moon and build a school there. The classroom situation scenario is the projection of photos of the vision of the planet Earth from the Moon. Because children are supposed to be looking from a dome in the Moon. Photos were supplied by HOU and NASA.

Here there is a extract of the list of questions children asked. Some of them are repeated; we also include answers that enrich the discussion:

Why there are so many blue things?
I think that's the water.
But why can not we live there?
It seems that humans destroy and ruin the resources of planet Earth.
Why are we not on Earth?
Our parents left the Earth looking for a better place.
Why are there such hot and cold areas on earth?
I think it's something from the heat.
Why there is not a big dome there?
There is the oxygen we need to live and there is a gravity force.
Can we go hiking to the Earth?
What is that white stuff?
Those white things are clouds and icy things.
What is in the centre of the Earth?
A lava ball smaller than the Earth called a core, which is like a magnet. Gravity prevents floating in the air. Gravity is an invisible force that attracts objects near other objects.
Gravity is a force that allows you to be on the ground
Why can't there be oxygen on the moon and on earth?
Why is there no atmosphere in the moon?
Following the questions phase students created drafts to build the scene (Figure 12).

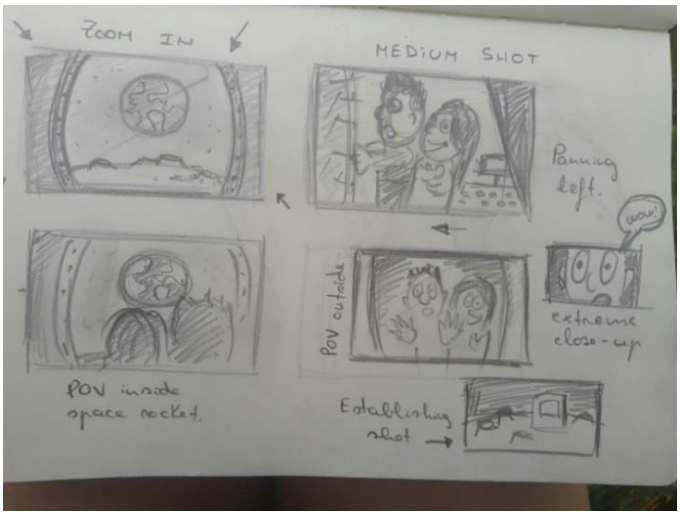

Figure 12 Draft Scene Designed for Primary School Students Who Observe the Earth from the Dome. Euskadi. Spain.

We also want to illustrate the interest of the Inquire phase with questions One Ocean from the working students GSO 2018.

Are there heat flows, but are there also cold flows?
It is not too late to do anything to stop climate change.
What do you mean by the state of health of the sea?
What does thermohaline circulation mean?
How is it possible for salinity and temperature to increase each year?
Are the forecasts of the evolution of the climate 100% reliable?
How can climate change affect the sea?
If all the damage that is generated in the Mediterranean Sea is distributed throughout this area?
Is it true that climate change influences marine plants? If so, in what way?
How is the length and depth of the sea measured?
Why is the Mediterranean an ideal area for studying the effects of climate change?
Is it possible for the species that live in the Mediterranean Sea to evolve to adapt to the new temperatures?
Are tests conducted to see the state of the oceans? If so, how often do they take place?

In both lists of questions, the generation of interests and related concepts is evident and analyzing them we highlight the conceptualization that there is a diverse climate, the relationship of oxygen and life, gravity, atmosphere, structure of planet Earth, depletion of resources of planet Earth, marine currents, climate change and marine resources, parameters and measurement techniques, ecosystem of waters, adaptation of species to environmental changes is a sign of achievements.

Music. In this section we highlight the diversity of contributions in the four editions, not only of the scenes recorded in Spain as a participating country, but also the universality that it has attending the operas of the four editions.

Instrumental complexity, creations of musical composition, instrumental interpretations, voices in the different forms that are designed in the opera, individual interventions, duets, trios, choirs, recitative. All this with the richness of the starting point: science is added to art, science is enlarged with art.

Our students find here the opportunity to identify themselves from their own abilities and stimulate higher level connections for learning. Campbello, O'Neill & Vacek (2002) describe that in addition to the increase in memory there is greater emotional participation, and a transfer of skills to other areas and to life thinking is simultaneous, as Hickey & Webster (2001) also expose. Skylight marks the beginning of organization for the future and introduces the sum of creations of the countries. Ghost Particles is especially unique in the contribution of Spain: the composer of the UAB choir performs a musical creation for the poem by Dr. David Jou Quarks and the chorus of the Autonomous University adds their voices and the piano interpretation with the voices of elementary students And One Ocean offers the tremolo of a Spanish guitar that cries the deterioration of the seas; the lyric is completed with an aria, chorus and recitative very well solved by the students. Exercises of dramatization, improvisation, body movement and voice training have been carried out to complete the lyric interpretation.

Closing of this section it is essential to quote Fischer-Dieskau's (1990) work as reference. For those who intend to highlight the opera as a reference of culture, art, sensitivity and universality is a source of knowledge from which emanates the ability to teach.

4. Opera for STEAM Creative Learning and curricular competencies

Competences have been included in one or other way in all the curriculum of the European Union countries since the beginning of this century (Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning, 2006) and we extract some concretions from the interpretation of Gábor & Key (2011). The need to master the abilities needed to adapt to a highly interconnected and rapidly changing world is capital in current educational systems.

Among the 8 key competences that are established at European level, two of them (labeled with numbers 7 and 8) find in GSO their own space:

- Sense of initiative and entrepreneurship. Refereed as individual's ability to turn ideas into action. It includes creativity, innovation and risk-taking, as well as the ability to plan and manage projects in order to achieve objectives
- Cultural awareness and expression. Appreciation of the importance of the creative expression of ideas, experiences and emotions in a range of media, including music, performing arts, literature, and the visual arts.

We also highlight some GSO content learning that contribute to competence training. Some of them:

- The development of critical thinking and reasoning.

-The emphasis in effective communication.

-The relationship established between students' own knowledge in the daily life and the interests they have when they think about their future.

-The ability to construct arguments and use them in interventions included in improvisation activities.

-The recognition of the emotions related with music and images in all its dimensions.

-The artistic represent of a model for a content.

-The dynamic creative collaborations established between school and social institutions.

- The comment and analysis of literary texts, taking into account the historical and socio cultural context.

-The structuring of ideas needed when taking into account the different parts of a text that must be produced.

- The identification of the main and secondary ideas of a communication and the correct linguistic expression of them.

-The participation in social media.

- The interdisciplinary bridges established between characters interpretation, musical texts and STEAM content.

- The use of strategies that plan and develop ideas, and summarize and evaluate them in a written text.

5. GSO2018 and Spanish Institute of Oceanography: A Collaborative Experience

In accordance with the responsible research and innovation (RRI) approach, science and technology are transformative forces that have allowed humans to alter ecosystems, the Earth's climate or life itself. One of the six politics agenda of the Responsible Research and Innovation is the Scientific Education, whose main purposes are:

(1) the improvement of the actual educational process to provide citizens the necessary abilities and knowledge in order to participate in discussions on research and innovation; and

(2) promote the scientific vocations.

In recent years, many initiatives have attempted to reduce the distance between science and society, and in this sense GSO is a useful tool to bring science and students together.

The Spanish Institute of Oceanography (IEO, Spanish acronym) has participated in 2018 GSO. IEO is a public

research organism, founded in 1914 depending on the Ministry of Science, Innovation and Universities. It's devoted to the multidisciplinary study of the sea (marine circulation, climate change, marine geology...) mainly to those problems derived of the fisheries exploitation and contamination. It also participates as scientific advisory in international negotiations on bilateral or multilateral agreements in different international commissions.

IEO makes important scientific communication efforts, participating in outreach activities like guided tours in its installations, conferences, direction of research works in secondary school students... It pays special attention to the promotion of scientific vocations in girls. For this purpose, among other projects, Oceanicas[1] is a project that tries to valorise the role of women in oceanography. The principal aim of Oceanicas is to make visible the work that women have done (and do) in marine research, showing students real examples of real women that work in science in a classically male environment. It's very important to show students that science is done by real and close women (and men), and that scientist can be their neighbours, friends, family...

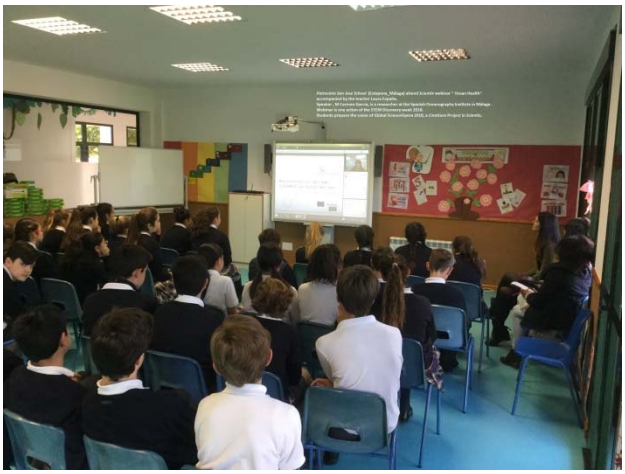

Figure 13 Oceanographic Institute of Malaga. Advice and Development of Webinar

The preparation of the Spanish scene for the GSO2018 is a perfect example of collaboration between school and research. It has been useful to establish communication bridges connecting two different social actors as research organism and schools. The scene by itself has been the objective followed up in this collaboration, but in order to get it, many different actions have been developed to ensure the purpose of promoting scientific vocations in boys and girls. To provide context to the research work related to the oceans carried out by the IEO, two conferences (webimars) were given: "Oceans Health" and "Cuidamos la salud del mar" in English and Spanish, respectively. These conferences were open to students and teachers, being of special interest for the students who were participating in the Spanish scene (Figure 13).

In addition, the participating schools were visited by researchers of the IEO, so the students had the opportunity of have a direct contact with female scientists. The idea is to bring the students closer to the research and vice versa. This perspective must be general, not only aimed at children and young people. The society must be seen as the stakeholder of the investigation as it is the main funders of the research projects. The obligation of the research community is to return to society the results of their investigations, and in this sense GSO has demonstrated to be a very effective tool.

[1] http://www.oceanicas.ieo.es.

6. Summarizing

Project starts with a challenge: inspiring young people to choose for science and technology careers, and we can affirm that working on this path we achieve it. And also we have the opportunity educate a new generation of scientifically literate European citizens at the same time that they develop artistic skills.

We defend that one important contribution of the Global Science Opera project is facilitating the development of IIMM multiple intelligences. Also project reduces school failure because it gives space to diversity developing English abilities.

A consideration relevant is to highlight the achievements of the work within the Global Science Opera project in the methodological aspects, the STEAM context, competence and collaboration of different structures of society.

7. Acknowledgements

This work was funded by Spanish Institute of Oceanography project, CICEROM. The authors thanks all students and teachers and schools (Madrid, Barcelone, Bilbo,Valencia, Málaga) and musical composers, entities and organizations research and university institutions (Cultura en Viu UAB, Space Astronomy UCM, Oceanographic Institute of Malaga), for their active participation in each edition GSO, Creations management team, and Scientix Community for promote collaborative actions for Science Education in Europe.

In the near future the project will design each scene with the joint work of two countries. This implies an interconnection of cultures and a challenge that we propose to face from Spain.

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