WHAT IS SCIENCE MADE OF

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Abstract

Science education, which deals with the sharing and communication of science contents, processes, and results with people not belonging to scientific communities, is being increasingly considered a priority in the educational agendas of several countries. Promoting and enhancing scientific literacy of citizens is currently a major mission to modern societies, as it is believed that it will contribute to support and train for a better informed, conscious and committed citizenship. However, the education for this scientific literacy is also a great challenge as target individuals may be very diverse, either in terms of age or in what concerns knowledge backgrounds, ranging from children to adults within the general public. The language, the format and the way this communication/ education is made should take into consideration the public profiles to which is addressed, being as clear, accurate and demystified as possible.

Although science and technology are ubiquitous in our everyday lives, their role and impacts are not perceived equally by all citizens. For a large part of the population, science, in particular, is still something unknown, often complex, strange and distant - being understood as something intangible for those not directly related to the scientific arena. For others, scientists are still seen as a distracted figure wearing a white tap and glasses fully dedicated to the pursuit of knowledge, though this image is gradually disappearing from the nowadays collective imagination.

And what is Science made of? Is it possible to get a clear, precise and instantaneous response? Probably not! Much of what happens in science and in scientific research is still seen by many as pure magic, something transcendental. However it is important to discredit such stereotypes, throwing light on scientists´ work, science tools as well as on the human skills and qualities that make science happens. With this goal, we idealized and prepared an exhibition entitled "What is Science made of", aiming to create a new relationship between science and the general public, in an appealing, innovative and challenging way. "What is Science made of" is a set of twelve images, each one starting from a common laboratory object. The images represent a group of words expressing concepts and values that ideally mirror the relationship between science and scientists. In this work we justify the choice of the twelve words, describe the design and assembly of the set of images as well as its exhibition and the public receptiveness and reactions to such initiative.

Keywords: Science, scientific literacy, science communication, laboratory objects.

1 SCIENCE, TECHNOLOGY AND SOCIETY

The impact of science and technology is unquestionable in our everyday lives. The scientific knowledge accumulated over the last three centuries, and its application in the form of technology have made huge progresses in agriculture, telecommunications, transportation, medicine and health care, among other essential fields, leading to dramatic changes in the way we live and communicate, on the length and quality of life, as well as in moral values and basic philosophies of mankind. In spite of this visible impact, the role and impacts of science and technology are not perceived equally by all citizens. For a large part of the population, science, in particular, is still something unknown, often complex, strange and distant — being understood as something intangible for those not directly related to the scientific arena. For others, scientists are still seen as a distracted figure wearing a white tap and thick glasses fully dedicated to the pursuit of knowledge, though this image is gradually disappearing from the nowadays collective imagination.

But, if science and technology benefits are unparallel in human history, it is also true that in some cases the impact was clearly harmful or the long-term effects raise serious concerns. Thus, there is also a certain measure of mistrust and even a feeling of fear of science and technology within the general public. According to the Report of the North American Meeting held in advance of the World Conference on Science (http://www.unesco.org/science/wcs/meetings/eur_alberta_98_e.htm), promoted by UNESCO [1], there are many reasons for such attitudes: public ignorance or misunderstanding of science, inaccurate or biased media coverage, uneven distribution of the costs and benefits of science among different sub-groups in society, lack of public control over the applications of science and technology, and the inability of some scientists to communicate ideas in plain language. There is a gap between scientific findings and public opinion, largely a consequence of a significant communication gap between scientists and society.

2 SCIENTIFIC LITERACY AND SCIENCE EDUCATION

Developing scientific literacy is often defined as the knowledge and understanding of scientific concepts useful for daily living [2] and science education - which deals with the sharing and communication of science contents, processes, and results with people not belonging to scientific communities - contributes to the goal of scientific literacy [3-5]. Scientific literacy enables people to use not only scientific principles and processes in making decisions in the real world but also to participate in discussions of scientific issues which affect society.

The role of science in society and governance has never been more important and science education is being increasingly considered a matter of national concern and a priority in the educational agendas of several countries. In recent years, national and international institutions have been providing direction and recommendations for achieving scientific and technological literacy for all. The promotion and enhancement of citizens´ scientific literacy is currently considered a major mission and a great responsibility to modern societies, as it is believed that it will contribute to promote and train for a better informed, as well as to a more conscious, critical and committed citizenship [6]. However, the education for this scientific literacy also represents a great challenge as target individuals may be very diverse, either in terms of age - ranging from children to elderly people -, or in what concerns knowledge backgrounds - from students of different levels to people within the general public. The language, the format and the way this communication/ education is made should obviously take into consideration the public profiles to which it is addressed, being as clear, accurate and demystified as possible. Also, several studies have geared to the view that scientific literacy is best taught by seeing science education as “education through science” as opposed to “science through education” [7].

2.1 Strategies to Promote Citizenship Scientific Literacy

The power of science in bringing change places a duty on scientists to proceed with great caution both in how they do science, in what science they do and on what they say concerning it. A good scientific communication via mass media is of upmost importance, especially in areas that directly and strongly affect people’s lives. Scientific production and public understanding of science are linked but unfortunately public images of science are not always realistic. Scientific work is mostly pictured in the media as an in-lab activity and evolving in big steps, overlooking the "extra-lab" work and all the daily small-step contributions to scientific progress. And misconceptions in public awareness of science may seriously hinder scientific progress. Journalists play a role in building a more realistic image of science, contributing to the science education of public in general. Unbiased communication between journalists and scientists is thus crucial, though such communication is not always simple [8].

Apart this communication process, which is mainly unidirectional and assumes that people read newspapers and/ or watch television, another kind of communication is also needed - a “dialogue” between non-peers: scientists, public, and policy-makers. In what concerns to the two first mentioned groups, this dialogue may take several formats, namely: science fairs, interactive exhibits, hands-on sessions, science exhibitions and contests, and public information services provided by universities, research institutes and private companies. As the demand for transparency and accountability in science grows, this type of communication becomes imperative but, unfortunately, resources for such dialogue are lacking, both among scientific institutions and in groups who have a particular stake in scientific developments [1].

Nowadays we are witnessing a growing convergence between art, culture, science, technology and entrepreneurship, which has been leading to deep changes in the role of creativity in society. Culture (in a holistic sense) and creativity are becoming the main driving force of the moving forward for every single field where man puts a hand on. Competitiveness of regions/ countries and businesses, economic development, personal enhancement, social cohesion and urban regeneration - all of them having roots more or less profound in the science development and scientific achievements - feed on new ideas and innovative strategies of engaging people and spreading the message.

Communicating clearly and efficiently with the general public is of extreme importance as misunderstood words may lead to the most unpredictable and ungovernable reactions, like those witnessed in the destruction of genetically manipulated corn fields all over Europe few years ago [9, 10]. In fact, words are generally coined with several senses, often understood with different meanings by different persons, depending on several factors (age, beliefs, cultural background and so on). In the words of Giovanni Carrada [11] "Probably, scientists and researchers can also still improve their skills and practice in interfacing with the media, elaborating and presenting information in a way that non initiated persons can easily and rapidly understand." For that reason, science communication between scientists (or professionals responsible for it) and general public should be as plain and clear as possible, as well as compelling, motivating and universal. And which is the most universal language we can think of? Probably the language perceived by each one of our senses when stimulated by Arts either in performing (theater, cinema, music, dance) or in representational types/forms (painting, sculpture, photography, illustration, digital art).

2.1.1 Performing Art

In Portugal there are several projects that fuse the passion for science with live theatre activities (street theater, standup comedy, speed-dating at a coffee table with scientists and other types of live events), encouraging and stimulating learning for all ages through active participation. In these events the performing groups come to the agreed places, usually with little more besides themselves and a few artifacts (no special staging is needed) and, for a certain period of time, amuse the audience with their sayings, mimics and performing. Usually these public engagement events are rewarding because of the immediate feedback from the audience. "Cientistas de Pé" and "Circo Matemático" are only two highlighted examples.

Cientistas de Pé (roughly translated as "Standing up Scientists") (http://cientistasdepe.blogspot.pt/) is a project of stand-up comedy with scientists, created in 2009 by Nuno Marçal in the scope of European Researchers' Night, an initiative of the European Commission. At present, the group is composed of eight elements with different scientific backgrounds but which primary professional activity is scientific investigation. Since the first performance, they have acted in a range of science communication events and places namely Fundação Calouste Gulbenkian, Teatro Municipal de Bragança, Teatro Experimental de Cascais, The Lx Factory, Jardim Botânico Tropical, European Researchers' Night and Feira do Livro de Lisboa (just to refer a few).

Circo Matemático (Maths Circus) (http://ludicum.org/cm/), a name that carries the wonder and fascination of mathematics, is another interesting project which aims attracting the general curiosity for mathematics by conducting recreational activities in daily environments. It was born by converging the efforts of a multidisciplinary team, formerly composed professors of university and other levels of education and now relying also on university students´ enthusiasm and help, that, over the years, were dedicated to individual projects either integrated into universities (University of Lisbon, Minho, Coimbra, Aveiro), or to the mathematics outreach activities in various other contexts (teacher training, extracurricular activities, ATLs, interactive exhibits, mathematical games, etc). The educational success and the positive impact that these ideas recorded from teachers, students, parents and the public in general has led to consider the convergence of efforts in a major project of national scope.

2.1.2 Representational Art

Since long ago, both scientists and artists have been inspired by science from different angles. Patterns, symmetries, fractals, living things and science phenomena, all are inspiration to our senses and a driving force for our curiosity. Da Vinci's drawings, Bohr's atom, Galileo's phases of the moon, Newton's rainbow, Darwin's plants and animals, Bentley's snow crystals are only a handful of examples. New tools of technology that upgrade the unaided eye like microscopes, telescopes, cameras or electronic digital techniques allow to explore the nano-, micro-, and macromolecular world, raising the inspirational possibilities to levels never imagined. Artists and scientists collaborations enhance science communication to general public. For example, visual imagery helps to teach science, ask questions, to communicate what is going on in an image – in short, to experience science process and to understand scientific principles. Exhibitions combine conceptual, visual (passive viewing exhibits) and, sometimes, tactile experiences (interacting exhibits) of all kinds of formats like illustrations, paintings, drawings, sculpture and photographs of objects from the natural and built world, multi-media, science/art craft projects.

Scientists are aware that engaging with people about research (why it matters and what it means) is now an essential activity both for their careers and for the future of research. The FP7 project funded by the European Commission called ISWA (Immersion in the Science Worlds through Arts) (http://iswa.fisica.unina.it/) that aims to encourage and promote Science through various concepts of art and that involves 16 partners, is being developed in partnership with the Portuguese excellence 3B's Research Group from Universidade do Minho. In the mentors own words “The aim of the project is to engage young people in science through arts. Scientists, researchers and artists involved in the project have collaborated to create artworks based on scientific phenomena and to design educational and artistic paths in scientific institutions, science centers, museums and schools. The idea is to present science with its creative and emotional aspects, showing the links between the arts and science.” The ISWA project is organizing artistic events based for example, on Contemporary art and Imaging.

Museums and science centers, but also several new spaces that are emerging, are considered non-formal education spaces open to a quite diverse public, a characteristic that requires the use of strategies to involve them emotionally and intellectually [12]. The activities promoted in exhibitions integrate different devices in order to explore scientific themes on a playful and interactive way. Depending on the theme, the human mediation may be privileged or not, being conditioned by the pedagogical approach and methodological options of the designers at the moment of conception and planning of the exhibitions

3 WHAT IS SCIENCE MADE OF?

A focus on the relationship among science, technology, and society is considered essential for achieving basic science literacy. It is important to make people understand the relevance of science-based issues in their everyday lives, and to understand that scientific endeavors are actually governed by social values [2; 13]. The requirement to link many of these aspects has led the members of the STOL project to discuss what would be the best approach and strategy to start a productive relationship with the public. The best way to do it was considered to be trying to answer the question: what is science made of?

And what is science made of? Is it possible to get a clear, precise and instantaneous response? Probably not! Much of what happens in science and in scientific research is still seen by many as pure magic, something transcendental. It is important to discredit such stereotypes, throwing light on scientists´ work, on science tools as well as on the human skills and qualities that make science happens. It should be noted that science is made by scientists - human beings just like other human beings, which perform a human activity like any other. Science should be brought to the general public, engaging people to be more involved in discussing science and its applications. Yet, science needs to be demystified — that is, presented in an attractive, innovative, stimulating way, preferably linked to everyday life.

To reply the question “What is Science made of?” the STOL team recognized that there are words that harmonize the concept of science and the spirit of its performers, the scientists, and that the presentation of these words to the public through a representational art would be an interesting and innovative way to generate a new dialogue. Listed a set of words, an acceptable number has to be chosen to be the target of a "transformation", in order they could reach the public. The STOL considered that a set of images would be one possible and interesting way to do it, combining science, art, and communication. Together with the design team DLYB, it was decided that the implementation of the concept would be through a set of images that replicate the initially chosen words, which would be built with common science laboratory materials, and finally represented as photographs.

The photo exhibition “What is science made of” has emerged as an answer to the task of translating 12 concepts, which are part of the scientific process, into 12 images. After being analysed a set of possible approaches to address the challenge proposed, the most appropriate option has been considered to be the production of a group of picture alphabets based on objects of current use in laboratories. A picture alphabet is a creation of forms that try to be similar to the typographical drawings that compose the letters of the alphabet, based on elements that are often out of the context an fall apart from its primary function, being moulded/ tailored to the shape that it purports to represent. The choice of the laboratory objects was made by taking into account the possibilities and limitations that each piece could lead, conducting to the final composition of the image. The final choice resulted in the use of stoppers, test tubes, metallic caps, microplates, pompetes, eppendorf tubes, Erlenmeyer flasks, microscope slides, Petri dishes, alcohol lamps, rubber teats and volumetric flasks as raw material in order to form the words knowledge, curiosity, creativity, communication, challenge, choice, method, persistence, power, accuracy, validation and shrewdness (Fig. 1). The collection of images represents a group of words expressing concepts and values that ideally mirror the relationship between science and scientists.

Each word was structured according to the photographic record of each one of the letters that composed it, on a black background. Subsequently it has been created a document from an image processing program to be carried out the final finishing, in order to be built the whole word. All the photographic shoots were made with the same guidelines, with a Canon EOS D5 machine. Each picture had the final dimension of 70x100cm and 300dpi of resolution.

Fig. 1 – Examples of the pictures prepared for the exhibition “What is Science made of”

The set of images was in exhibition during two weeks in a central local of the city, in order to make it accessible to all the community and transpose the University walls. In the opening day, a colloquium under the same theme was held with academic researchers from different fields of science, which shared with the audience their views about what is the nature, the paradigms, and the beliefs of science.

3.1 Public receptiveness to “What is Science made of”

In an attempt to evaluate public receptiveness and some impacts of the exhibition and colloquium, two questionnaires were designed.

A first Questionnaire was filled in by the public attending the colloquium and was set to characterize the targeted public, namely in what concerns some personal data, and to evaluate the reaction and receptiveness to the initiative.

Another Questionnaire was developed and delivered at the exhibition, during the opening day, in order to ask the visitors about the most impacting image and the reasons for such choice.

3.1.1 Colloquium "What is Science made of"

The colloquium was attended by 119 persons, 70% of which were females. Five group ages were represented: under 19 (79.8% of the attendees), between 20 and 30 years old (12.7%), between 31 and 40 (2.5%), between 41 and 50 (1.6%) and over 50 years old (3.4%). In terms of educational qualifications, the two first groups were composed by undergraduate students whereas the group aged between 31 and 40 years had a undergraduate student, a student with a degree and a person with a PhD. The two elements aged between 41 and 50 and the 4 of the group over 50 had all a PhD. As the far most representative group was that with younger people, the following results derive from the analysis of all the attendees as a single sample, unless otherwise stated.

The public was asked if initiatives like the one they were attended could stimulate the interest in science and 89% of the respondents were positive about such hypothesis. However, just 39% of the public said that there were issues particularly interesting in the colloquium, like the relationship between mathematics and several other sciences, art and architecture, or the fact that science is in continuous evolution, or else the forces between science and power. Even though, 58% of the attendees stated that events of the same kind and nature should be repeated, either they considered to have listened to issues of particular interest or not.

And concerning the words illustrated in the exhibition, the ones that best define science and scientists for these attendees were: curiosity (60.5%), knowledge (55%), persistence (52%), method (32.7%), creativity (26.9%), challenge (26.9%), accuracy (22.7%), communication (12.6%), shrewdness (5.9%), choice (4.2%), power (3.4%) and validation (3.4%).

3.1.2 Exhibition "What is Science made of"

Exhibitions are complex information spaces, which can lead to rich and positive experiences, but not always understood as learning. To create conditions for learning has been the concern of museums, and achieving this goal can only be checked if some form of evaluation is performed. However, specific features of these institutions have offered difficulties in the evaluation process [14], which should take into account that these spaces are "play" areas promoting interaction, that work, in general, cross-cutting themes that relate different kinds of languages. Thus, some issues become prominent. What can be learnt during a single visit? What is the influence of a visit in the learning process? Considering the continuous learning process, slow and non-linear, the task of assessing 'if' and 'how' it occurs in museums and similar exhibition spaces is quite challenging, which is why the topic is widely discussed and studied by researchers of non-formal education. According to Falcão et al. [15], research on learning in museums/ exhibitions has been intensified and has gained specific contours, but the educational potential of museums/ photograph exhibitions needs to be evaluated through more specific, i.e., with strategies more clearly defined.

In an attempt to evaluate the impact of the exhibition on its visitors, twenty two groups of five students each were challenged to select a photograph of the collection and to explain why it has caused impact. Groups have mainly chosen the images with the words knowledge (4 groups), persistence (4 groups), curiosity (3 groups), challenge (3 groups), choice (3 groups), creativity (1 group), power (1 group), accuracy (2 groups) and shrewdness (1 group), invoking mainly aesthetic reasons for the choice made. Indeed, if we compare this selection with the words chosen by the same persons as the ones best defining science and scientists (see 3.1.1), we conclude the two processes were different.

The fact of trying to involve the public in an affectionate, playful, creative and interactive way can provide the learner interest in the content to be learned. Therefore, a subject of no interest to the visitor, into another space or format can attract his attention and thus facilitate the capture and sharing of meanings. This seems to be the crucial stage that precedes the significant or meaningful learning.

4 FINAL REMARKS

As previously referred, the main objective of the exhibition "What is Science made of" was to create a new relationship between science and the general public, in an appealing, innovative and challenging way. However we believe that new ideas and information can be learned and retained if relevant and inclusive concepts are properly structured and may serve as anchor points. From this proposition, we assume that the ideas put forward using different forms of communication during a visit are depending of the nature of prior knowledge of the visitor, and when assimilated, they can improve the cognitive structure. It is noteworthy that we are dealing with learning, a procedural phenomenon; in which time and intentionality of the persons to learn significantly is an essential factor for it to occur. The theory of meaningful learning (Ausubel, cited in [16]), focusing on primarily cognitive learning, takes into consideration these emotional and contextual aspects of its process. There is a cognitive structure formed from prior knowledge, in which new information is integrated.

Different ways of communicating science, even though about the same subject, yet with different strategies, were explored in the present work. The analysis of public responses and reactions suggest a quite different impact in public receptiveness, engagement and, ultimately, in learning. As all the student groups said in their inquiry, these were two more different ways of learning. They consider that these two “styles”, as they named, were much more interesting than the traditional manner they are used to learn. They consider they have learnt in a more creative way and that they were able to explain and relate the discussed issues with the subjects that they are already aware of, which indicates that their learning was meaningful.

Certain approaches would certainly be more effective than others but public own preferences and motivation will undoubtedly influence such results. In this particular case, the respondents think that the most effective initiatives towards an enlarged and more effective science communication will be practical workshops (43.7% of students preferences), science festivals (40%), exhibitions (31.1%), science contests (16%); lectures (12.7%), tertulias (11.8%) and interviews (5.9%).

From the above exposed, we dare to conclude that, somehow, the STOL group's goals were achieved.

REFERENCES

[1] UNESCO (1998). The Role of Science and Technology in Society and Governance: Toward a New Contract between Science and Society. Report (available at http://www.unesco.org/science/wcs/meetings/eur_alberta_98_e.htm)

[2] National Research Council (NRC) (1996) National science education standards. National Academic Press, Washington, DC.

[3] Mbajiorgu, N. M. and Ali, A. (2003) Relationship between STS approach, scientific literacy and achievement in biology. Sci Educ 87(1), 31–39.

[4] National Science Teachers Association (2007) Science-technology society (NSTA position statement). National Science Teachers Association, Washington, DC

[5] Lee, Y. C. (2009). Science-technology-society or technology-society-science? Insights from an ancient technology. International Journal Science Education, pp. 1464–5289.

[6] Fiolhais, C. (2011). A Ciência em Portugal. Fundação Francisco Manuel dos Santos, Lisboa.

[7] Holbrook, J. and Rannikmae, M. (2009). The Meaning of Scientific Literacy. International Journal of Environmental & Science Education 4(3), pp 275-288.

[8] Castanho, M. A.R.B. (2003). Pop-Science: Facts or Fiction? Friend or Foe? *INCI* 28(11), pp.665-668.

[9] Gaskell, G., Allum, N., and Stares S. (2003). ‘Europeans and Biotechnology in 2002: A Report to the EC Directorate General for Research from the Project “Life Sciences in European Society”’, QLG7-CT-1999–00286, *Euro- barometer 58.0,* 2nd edn, 21 March.

[10] Huff, E. A. (2011). Hungary destroys illegal GM corn fields, plans to make distributing GMO seeds a felony, Natural News.com. Retrieved May 10, 2012, from http://www.naturalnews.com/033098_Hungary_GMOs.html

[11] Carrada, G. (2006). Science Communication. A scientist's survival kit. DG RTD. ISBN : 92-79-01947-3. Available at: http://ec.europa.eu/research/science-society/pdf/communicating-science_en.pdf.

[12] Cazelli, S., Marandino, M., Studart, D. (2003). Educação e comunicação em museus de ciência: aspectos históricos, pesquisa e prática. In: Gouvêa, G.; Marandino, M.; Leal, M. C. (Org.). *Educação e museu*: a construção social do caráter educativo dos museus de ciências. Rio de Janeiro: Access. pp.83-106.

[13] deBettencourt, K. B. (2000). Science technology society and the environment: scientific literacy for the future. In: Kumar D. D., Chubin D. E. (eds) Science technology and society: a sourcebook on research and practice. Kluwer Academic Publishers, New York, pp. 141–164.

[14] Gaspar, A. (1993) *Museus e centros de ciência*: conceituação e proposta de um referencial teórico. Tese (Doutorado) - Faculdade de Educação, Universidade de São Paulo, São Paulo.

[15] Falcão, D., Alves, F., Krapas, S., & Colinvaux, D. (2003). Museus de ciências, aprendizagem e modelos mentais: identificando relações. In: Gouvêa, G., Marandino, M., Leal, M. C. (Org.). *Educação e museu*: a construção social do caráter educativo dos museus de ciência. Rio de Janeiro: Access. pp.185-206.

[16] Moreira, M. A. (1999). *Teorias de aprendizagem*. São Paulo: Editora Pedagógica Universitária.