Confederación de Sociedades Científicas de España (COSCE)

# Acción CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Science and society

# Summary

The section *Science and society* analyses some of the central problems in the interaction between scientific advances and social structures. In particular, it looks at how individuals and social groups (the public) receive scientific advances in Spain. In addition, it includes a study of the influence that the appreciation of science by the public and society as a whole has on science itself. This summary highlights some of the section's most representative observations, conclusions, and recommendations.

Nowadays, most scientific areas and their social applications are not a problematic issue for the majority of the public. Indeed, many such areas are seen as clearly beneficial. However, an overview of Spanish society's recent perception of science and technology reveals one aspect that is different than that of other European societies. This is important when formulating programmes for bringing science and society closer together and for establishing a dialogue between the scientific community and the public. This aspect is outlined below:

*a)* Studies carried out by the European Commission and private institutions concur in characterising Spanish society as one of the most optimistic, with the least reservations about science.

*b)* Spanish society's optimistic, unproblematic profile is accompanied by a low level of scientific knowledge among the population (knowledge of science's central concepts and ways of operating). It is significantly lower than the level in the majority of advanced European societies. In other words, Spain's open attitude to science is, in fact, passive. It is not linked to personal efforts to take an interest in science or to become informed about it. Science is not seen as an essential aspect of society's culture.

In this respect, the proposals are:

• In Spain, more than in other European societies, lasting and effective initiatives should be introduced to increase society's knowledge and general interest in both the scientific foundations of culture and the contribution of science to cultural development. This would also encourage young people to choose scientific careers.

• Efforts by public and private agents to communicate science to the public should be considerably increased. In addition, the results of these efforts should be scrutinised and assessed. In particular, it should be compulsory to assess the results of implementing public science-related policies.

The number of researchers involved in bringing science closer to society is almost negligible. This activity does not form part of researchers' normal concerns. Many researchers consider that it is outside their role, and even contrary to their interests. Therefore, the following proposal is made:

• The scientific community and scientific institutions with competence in political science should make a clear and explicit commitment to assess and stimulate science communication by researchers.

Obviously, the best results of educational efforts are attained within the formal education system. It is extremely important to dedicate special attention to generating and maintaining university students' interest in research.

- Institutions of higher education should find new ways to support and recognise members who stand out due to their special efforts in stimulating science and reforming the curriculum. The latter will allow phasing out of unimaginative teaching methods that dampen interest in research. In addition, students should be encouraged to find out about research activity of the teaching staff.

- In primary and secondary education, all teaching-staff initiatives directed at increasing interest in science and its applications should receive special attention and support from the universities, the CSIC, and scientific organisations. This would help to draw the attention of the corresponding education authorities to the importance of basic scientific education. There are currently serious shortcomings in this area. Such support would also highlight the lack of encouragement, incentives, and resources of the teaching staff.

Like the rest of Spanish society, the Spanish political class is not in close contact with scientific knowledge, and, unlike the majority of countries in Europe, there are no official and transparent channels for offering scientific and technological advice to the government or parliamentary representatives. Examples of such channels are: scientific advisory offices for the presidency; permanent Parliament and Senate scientific commissions; scientific advisors in embassies, and international organisations.

- It is essential to institutionalise the channels for managing and applying scientific knowledge, so that public interest can be handled on a daily basis, not just in crisis situations.

The scientific community cannot remain indifferent to Spanish society's view of science and its level of acquisition of scientific culture. Thus:

- Spanish researchers have to be aware of those concerns and attitudes in the social environment that are relevant to their work. Likewise, the scientific community should take advantage of any opportunity to inform society about how public concerns, preferences, and requirements are incorporated into research work.

- It should be clear to the scientific community that using public resources entails some indissoluble, inherent principles of reciprocity. Among others, these include explaining the efficient use of resources in terms that can be understood by the society that provides them.

The position of scientific information in the Spanish media is on a par with its situation in the country, in terms of effort and scientific level. It lies somewhere between that of the most advanced countries and the least developed. The small size of the Spanish science and technology system; the lack of leading scientists and authorised spokespeople; the limited social and political influence of scientists; and the absence of a scientific tradition in Spain are factors that have a negative effect on the social appreciation of science, despite the level reached in the last two decades. Thus:

- All agents in the science and technology system should be aware of the importance of keeping society well-informed of their activities through many channels, with a special emphasis on the media. The heads of public institutions should adopt appropriate measures to achieve this aim.

Bridges need to be built, and connections improved, between the scientific community and the media in order to bring about this flow of information. Both groups must play a part in this process. However, science will have to continue to earn its presence in the media by generating interesting news, being open and transparent to the media, and offering quality up-to-date information.

- Specialised personnel or scientific communicators –ideally, journalists with scientific training or scientists with journalistic training– should be involved and work first and foremost in this area. The public system should stimulate training of these professionals.

The most reliable data regarding the amount of science shown on television reveal that science has a relatively low impact on TV programming in Spain (0.001–0.01% on TVE).
Therefore we propose that:

- Public television channels dedicate both more attention and time slots that attract much larger audiences to popular science programmes, even if they are not immediately successful. Children's' programmes with a science content are a clear investment in the future. Meetings between scriptwriters and news and scientific editors should be coordinated so that they views on science and society can be exchanged.

Since the early days of the internet, science has sought and found its place in the resources of the World Wide Web. This has raised the prospects of moving science closer to the interests of society. Scientific organisations and associations, hospitals, universities, companies undertaking research, government departments, museums, etc., have created an enormous arena for learning and communicating science. However, the limited number of internet portals for science communication and information in Spain are often of a low quality and have only marginal influence. If the overall effects are considered, it is clear that the internet has changed the situation, in science as in other fields, from a chronic lack of information and knowledge, to one in which the problem is the individual management of an overabundance of information. In turn, the traditional mechanisms for "filtering" or separating verified from spurious knowledge have been weakened.

- Institutes and scientific organisations should exploit the revolutionary possibilities of new internet resources more professionally and intelligently, in order to communicate their research activities to society. It is vital to educate the population regarding the criteria for selecting and recognising the cognitive value of information available on the internet. Consequently, they will be able to access and use the vast digital library of verified knowledge that currently exists on the internet.

Intellectual access to science and other information is seriously limited by the fact that reading habits have changed for the worse and reading comprehension has decreased, particularly among schoolchildren. Recovering and strengthening these capacities should be compatible with the emergence of new media and formats. In addition, the production of scientific and popular science books is very low in Spain. The major scientific magazines (in all forms and at all levels) have only a limited role. They are better represented and established in other European countries.

- There are very few science books in public libraries, and those that are found tend to be out-dated; thus, sustained plans are needed to increase their availability. In addition, joint publication agreements for popular science works of clear social interest should be reached, and a carefully thought-out plan implemented to provide support for magazines covering popular science and scientific culture.

Currently, Spain has a notable group of centres devoted to the communication of science. These include: museums and interactive science centres, specialised museums, planetariums, aquariums, botanical gardens, and zoos. All of these centres are essential to improving scientific knowledge and the public's perception of science. In addition, they promote public education about the characteristic attitudes and skills of scientific research, aid in understanding scientific concepts linked to current affairs, and suggest ways to incorporate such concepts into culture.

- Society and the authorities should recognise the growing impact and diverse functions of science museums (including planetariums, aquariums, botanical gardens, and zoos) in disseminating scientific knowledge. Human and financial resources as well as museum space should be considerably increased to improve the educational function of the National Museums of Natural Sciences and of Science and Technology. The contribution of these institutions to the dissemination of scientific knowledge should be systematically assessed.

The presence of women in the Spanish education and research system has increased considerably in the last two decades. However, it has not yet had a significant effect on the number of women on the higher rungs of a teaching–research career.

- To address a problem of this complexity, reliable and systematic data should be obtained immediately. Such data would be used to statistically analyse in detail all of the variables involved in gender inequality in the Spanish science and higher-education system.

However, some actions can be taken before the results of these analyses are obtained. A series of measures can be implemented that contribute to halting both the loss of women from the Spanish R+D system and their massive demotivation due to the additional barriers they encounter in pursuing a competitive research career and achieving excellence. The following measures stand out:

- Mechanisms for harmonising professional, private, and family life should be created or strengthened. These could include: flexitime, public social services to look after dependants, tax incentives that favour these mechanisms, and other similar incentives that facilitate researcher mobility and the return to a scientific career or part-time work after periods of maternity leave.

# Science and society at the turn of the century

One of the strongest driving forces in the global and complex society of today's world is the continuous advance of scientific and technological knowledge. Such advances have become a kind of "life-support system". For any society, its collective possibilities, and those of the planet as a whole, are a function of its capacity to continue to expand the scientific image of the world and of its ability to better understand and more effectively design "the artificial", which is the objective of technology and engineering.

Science and technology's current pre-eminence has emerged amid tension with other conceptual constructs and institutions. In the last three decades, indicators of "cultural unease" and resistance to scientific change have appeared. Groups and associations have arisen that fight for greater control or an external orientation of science. They also demand a redefinition of the rules of the "implicit contract" between the scientific community and society (Guston and Keniston, 1994). In recent years, regulators, public officials, and members of the scientific community have formed the view that we are faced with a widespread crisis of confidence in science and its most characteristic institutions. Recommendations and action plans have taken this diagnosis of the science–society relation as a basis for their responses. In reality, neither the diagnosis nor the treatment is entirely new. In fact, they have reoccurred in a cyclical manner since at least the end of the 1970s. A brief look at the course of the science–society relation from the perspective adopted in this report could assist in identifying new factors in this interaction in relation to other periods of time.

Science has been increasingly connected to a large number of institutions and social practices, in the context of a more general process of modernisation. In parallel, it has become formalised as the exclusive activity of a professional group. This has given rise to a sharp demarcation between the scientific and public communities, clearly visible since the end of the nineteenth century. Along with this *scientific–public community* demarcation arose what is known as the *implicit contract*, regulating the interactions of the two communities. This has been in effect since the end of World War II. By virtue of this tacit agreement, the scientific community attained autonomy (in selecting objectives and carrying out research) and an increasing volume of financial and human resources. In exchange, it contributed to the production of a stream of material goods and services (among which those in the field of health care stand out), and the transformation of the average person's education and cultural facilities. Through its spokespeople, society accepted– with little argument– the assumption that material support and non-interference, added to how the scientific community operated, even if this appeared to be esoteric and unnatural, would sooner or later improve the quality of life and create more choices for most of society. There has been unbroken confidence in the existence of this link between scientific theory and material progress (and, less explicitly, cognitive and educational progress) throughout the central period of the modern age. The undesired effects of scientific advances were generally viewed as temporary episodes that could be resolved by more science and more technology (Pardo, 2001).

In areas of the world where the science–industry complex became rooted, the source of legitimisation of science lay more in its practical effects or applications (levels of well-being increase steadily and become widespread) than in its strictly cognitive aspect (a greater capacity to construct representations of the natural and social world, which are constantly revised and have growth potential, unparalleled by other forms of higher culture). This utilitarian function of science was expressed most clearly in modern medicine (Handlin, 1972: 260).

This situation changed dramatically after the demonstration of devastating nuclear power in World War II. It was also affected during the 1970s by the environmental effects of the partnership between science and industry. The visibility of the unwanted consequences of applying scientific knowledge underwent a change of such magnitude that the erudite optimism of the scientific community, and the belief in science-based progress that is characteristic of modern societies, could no longer get around it.

The dramatic confirmation of the dual nature of scientific knowledge, "creating new parameters of risk and danger [while] offering beneficent possibilities for humankind" (Giddens, 1991), led to an erosion in public confidence in the link between scientific advances and social progress (Marx, 1988). The culture of critical and alternative movements at the end of the 1970s attributed a wide spectrum of undesired effects to science and technology, which were criticised for: being a causal agent in the processes of alienation and dehumanisation. Intuitive images of the world supported by common sense were allegedly being replaced with fragmentary and abstract representations unconnected to the way most people visualised the world from daily life. These un turn gave rise to artificial and "unnatural" lifestyles, seriously alterations in the seasons and environmental equilibrium, and support of the nuclear arms industry.

The scientific community viewed outside criticism as inciting regulation by state agencies, or even the direct intervention of the public in matters that were thought to be reserved for scientists. Sensitivity to this criticism led, in the mid-1970s, to a sense of alarm, expressed by media and scientific institutions, who feared for the ability of science to survive the attacks being launched against it. The idea of a *crisis regarding the legitimacy science* took shape, and indirectly contributed to increasing the then modest level of research into public perceptions of science. It also resulted in initiatives to improve "public literacy". Until the end of the 1980s, this task was led by the National Science Foundation in the United States. The NSF analysed a biennial series of science and technology indicators measured since 1972. At the end of the 1980s, the European Commission and other nationally based private institutions joined in the mapping public perceptions of science.

This area of research is known on the other side of the Atlantic as *scientific literacy,* and in Europe as *public understanding of science* (Miller, 1983). The above context helps to understand why the focus of this research agenda has been measurement of the degree of public approval of science and the scientific community, and why it has continued to be the focus of such surveys. The main hypothesis of this research programme is that (favourable) attitudes to science are a function of the public's level of scientific knowledge. The public's cognitive deficit, documented using an extensive series of surveys in advanced countries, has been taken to be the variable that is related to the occurrence of criticism or resistance to certain scientific and technical applications. There is no formal or statistical evidence to support this hypothesis, and it has been subjected to scrutiny only in recent years (Evans and Durant, 1995), with unclear results.

With the perspective of time, the seriousness of the supposed *crisis regarding the legitimacy of science* can be re-evaluated. A second examination of the data gives a more qualified opinion, although we should bear in mind that while the best-documented case is that of the United States., it cannot be directly applied to European societies. Despite this cautionary note, available empirical and historiographic evidence shows that the fears of the scientific community, from the mid-1970s until the end of the following decade, only partially corresponded to reality. More specifically, those fears were mainly based on the attitudes and behaviour of a few, quite active minorities, and on the mass media's disproportionate coverage of a few critical episodes involving science and technology. These were given a weight that was disproportionate to their actual social impact. This disparity illustrates that public opinion cannot be directly inferred from either opinions disseminated by the mass media, or the demonstrations and actions of pressure groups (Pardo, 2001).

According to data from surveys undertaken in the US between the end of the 1950s and the beginning of the 1970s, analysed by Karen Oppenheim and Amitai Etzioni (1974), the public's overall assessment of science's role was positive. People rejected openly anti-scientific viewpoints and had high regard (prestige and trust) for professional scientists. Even so, these positive perceptions were based, above all, on the instrumental (practical effects) rather than the cognitive (explanatory capacity) dimension of science .

The constant dissemination of information regarding the undesired effects of science- and technology-based progress opened the way for sceptical attitudes and criticisms of technological advances. Paradoxically, a higher level of knowledge brings with it a greater awareness of the risk factors, as remains the case today. Thus, a constantly expanding list of risks has been generated that has gradually taken the form of the current culture of *zero tolerance* (at least on a symbolic or declarative level), which frequently conflicts with the fearless, personal acceptance of some preventable risks in daily life.

Therefore, there is a dividing line between the widespread trend of optimism and confidence in science up to the beginning of the 1970s, and the culture of criticism, or at least ambivalence, in the face of progress and science that marked the end of the decade. This occurred in the context of a more general crisis of confidence in modern society's main institutions (Lipset, 1987). Despite this erosion of confidence, the scientific and medical communities continued to be highly favourably viewed. Moreover, in contrast to the conventional idea that the relative loss of confidence in science occurred in the most educated sectors, an analysis of the data shows that the opposite was true.

The emergence of environmental consciousness is one of the changes in modern societies that has had the most enduring effects and the greatest influence on perceptions of science. The historian Leo Marx (MIT) pointed out that the optimistic Euroamerican view of progress has eroded during the last three decades. The main contributing factor to its decline has been growing pessimism about the role of humans in nature; i.e. an awareness of the serious, undesired effects of the industrial productive system and the modern age in general on the global ecosystem. Such effects are sustained by science and technology

(Marx, 1998). Extensive, concurring evidence indicates that late modern age societies are aware of negative environmental developments, such as global warming, the greenhouse effect, and species extinction. Simultaneously, improvements in the standard of living and lifestyles fostered by the transference of scientific and technological advances to society via the productive system are taken for granted, nor does the public seem willing to relinquish these advances. Thus, the public's ambivalence to science at the turn of the century has largely arisen from these two opposing vectors.

An overview of the public's perceptions of science and technology in recent years is typified by the following points. These are useful when formulating programmes for bringing science and society closer together, and for establishing dialogue between the scientific community and the public:

• *Most scientific issues and their social applications are not a source of problems for the majority of the public*. *Many such issues are seen as being clearly beneficial.* Typically, scientific and technological advances are quietly integrated into the basis of the complex manner in which the public's needs are collectively satisfied. To a lesser extent, advances are also incorporated into conceptual schemes used to interpret the world and to order daily experiences.

• In general, outside the scientific community, only limited, brief attention is given to these advances. In other words, *scientific issues must now compete for the attention of a public that can choose between an enormous number of sources of information such that its "interests" multiply beyond the limits of its cognitive capacities and available time*. The population segment referred to as the *attentive public* (satisfying the set of conditions for being "interested in" and "informed" about science) is around 10% of the adult population of more advanced countries.

• *Only limited resistance to scientific and technological change is present in the current climate. As a rule, such resistance does not involve a generalised critical attitude to science.* In the second half of the twentieth century, resistance and controversy were mainly related to the undesired impacts (observable or supposed) of some aspects of science and technology, such as: the natural environment, central cultural values, views on human identity, and the demarcation between species.

• *Studies aimed at determining trends within the general public regarding their attitude to science* (measured, for example, using questions about the expected effects of a wide range of scientific and technological areas over the next 25 years) *show that, overall, it is optimistic.* In addition, analyses of the public's confidence in groups and institutions reveal that there is a favourable opinion of scientific institutions remains, although confidence has decreased since the 1970s.

• *This overview correlates with reserves and anxiety concerning some areas of science,* and some specific applications of biotechnology in particular. These are the focus of concern and debate within a wide range of institutions (e.g. the church), associations (these are often religious, although advocacy groups for patients with specific illnesses –the potential beneficiaries of new biochemical advances– often act as a counterweight to such groups), the general media, the media and institutions representing the scientific community, and, of course, regulatory agencies. The most rigorous studies show that *the level of public understanding of modern genetics is extremely low*, and confusion and erroneous beliefs abound. However, there is also evidence of *legitimate moral concerns* linked to developments in genetics and their applications. The scientific community generally tackles these issues inadequately, making dialogue between researchers, the public, and regulatory agencies difficult.

• It is also clear that the *public distinguishes between degrees of acceptability of different applications, even in the absence of exact information.* The "approval" of a specific application is mainly based on judgement of its end use. However, in other notable cases (such as stem cell research) the *means* are also extremely important (e.g. opinions about embryonic stem cells and cells from adult tissues differ). In general, while there are relatively few conflicts between public attitudes to science and religious beliefs, the latter are much more relevant in cases such as the noted above. Therefore, the scientific community and regulatory agencies should be sensitive to these differences of opinion and be able to approach the moral debate without reservations (Solter *et al.*, 2004; Pardo, Midden and Miller, 2002).

• A series of analyses of public perceptions of science appeared in the second half of the 1990s and at the start of the new century. These questioned the effect of scientific knowledge or familiarity on attitudes (acceptance or resistance) to science. A theory developed in literature until 2 or 3 years ago claimed that, in general, a high level of scientific knowledge has no effect on favourable attitudes to science. Variants of this theory stated that its effect is contrary to previous beliefs, i.e. more knowledge leads to more critical and sceptical attitudes to science. As this theory spread among political leaders, particularly in the European Commission but also in some European countries, it led, after an initial period of disorientation, to a change in strategy, in which the goal of scientific dissemination and communication was replaced by the aim of establishing a dialogue with the public as well as public participation in resolving scientific–technological controversies (using mechanisms such as consensus conferences).

Empirical evidence from the Eurobarometers was used as the basis for criticism of the *scientific literacy* ("knowledge matters") paradigm. A new, more detailed examination of this evidence has helped to re-establish, in a more elegant and unequivocal way, the differential effect of the public's familiarity with science on their inclinations towards it (Pardo and Calvo, 2002; Muñoz, 2003; Sturgis and Allum, 2004). Hardly any significant gaps could be found *in the theory linking higher levels of knowledge and more favourable public attitudes to science.* The few gaps that do exist are confined to science's prospects in areas that could be classified as "science–technology miracles". Logically, together with other matters directly and deeply involving ethical principles, these have been rejected by the well-informed public.

These new analyses have formed the basis for the renewed effort during the last decade at increasing the number of scientific communication activities. At the same time, other general variables (world views), such as those on nature and "natural" and ethical orientations, have played a supporting role in significantly influencing the general population's view of science. Without denying the effect that specific public-participation has on the formation of opinions regarding controversial issues, two conclusions have arisen in this recent period. First, the *public and private efforts to communicate science to the public should be considerably increased. The results of these efforts should be subject to scrutiny or assessment* (i.e. it should be compulsory to assess the results of implementing public policies). The number of researchers involved in bringing science closer to the public is still negligible, as this activity does not form part of researchers' normal concerns and many researchers consider that it is outside their role, and even contrary to their interests. The effectiveness of different approaches and means of communicating science to the public needs to be rigorously evaluated. Second, *the scientific community should pay increased attention to legitimate questions from the public about the ethics and values of its activities*, or the results of these activities. This should lead to: better training of researchers in this area, the drawing-up of guidelines up by scientific institutions, and constant attention being paid to the concerns and sensitivities of pluralistic societies like the Spanish one.

- *Studies carried out by the European Commission and private institutions concur in characterising Spanish society as one of the most optimistic, with the least reservations about science.* This is even the case in areas (such as biotechnology) that are problematic in countries with a similar religious orientation (such as Italy and Poland). The scientific community is highly valued and ranked only just behind another highly valued group, the medical profession. The fast pace of socio-economic change experienced in Spain during the last three decades, the development of a markedly pluralistic democracy, and the country's full incorporation into Europe seem to have eroded or even pushed aside all traditions and principles perceived as obstacles to innovation, pluralism, and greater well-being. Nonetheless, *this optimistic and unproblematic profile –one that distinguishes Spanish society from those with a long scientific and pluralistic tradition– is accompanied by a level of scientific knowledge among the population that is significantly lower than the level in the majority of advanced European societies.* In other words, Spain's open attitude to science is, in fact, passive. It is not linked to personal efforts to take an interest in science or to obtain information about it. Even "second stage" university students have little knowledge of such activities. Thus, more than in other European societies, science in Spain needs to be brought much closer to the interests of its citizens by increasing the amount and accessibility of information and sustaining the public's interest in the dynamics and results of research activities. This is even more urgent than illustrating the benefits of certain areas of research and their applications, which is a worthwhile objective but one that should be carried out in a realistic way, with no "oversell".

These points describe the both the general and Spanish background to the more specific considerations set out in the next sections.

# Science for society: the social responsibility of scientists

Science is an intellectual adventure in which the ideas of creativity and progress are inherent. It is an essential part of modern culture and has revolutionised our notion of the world and of ourselves. The main function of science is to construct verifiable knowledge, which is constantly open to confirmation or rejection. When scientists transmit this knowledge to society they contribute to generating ideas and concepts. These help people to live in the current, changeable, global society with greater rationality, security, and freedom. In addition, the applications of science have profoundly transformed daily life, to the extent that science and technology are now essential components of a country's economic development. For these reasons, *the scientific community cannot remain indifferent to Spanish society's view of science and its level of acquisition of scientific culture.*

It is usually taken for granted that the knowledge characteristic of experimental sciences is ethically and morally neutral. However, some aspects of it go beyond strictly cognitive (theories, empirical evidence) and involve elements related to values and ethics. In advanced democracies, scientific and technological activities can, either directly or indirectly, affect societies' collective ideas, values, interests, preferences, needs, and opportunities, to varying degrees. These activities include the selection of priority areas of research, how research is undertaken, and the technological developments arising from it. In Spanish society, most scientific research is carried out in public institutions or using public funds (universities, PROs, technological centres, regional research institutes, health system centres, etc.). Therefore, scientific researchers have an additional commitment to the social environment they belong to and depend on. At present, the attitude of the Spanish scientific community does not generally appear to recognise society's influence on the direction of its work. It is therefore important to focus on incorporating an attitude of recognition into research culture. We propose some channels by which Spanish scientists can be motivated to accept this social commitment.

In addition, a significant effort in education and the dissemination of science is needed for society to be able to take an interest in and fully appreciate the nature and objectives of science; its applications (generated much more rapidly than in the recent past), and the uncertainties associated with its uses. This effort should be made at all educational levels, and outside of the formal channels of education. The current contribution of Spanish scientists to this effort is minimal. There is ample space for growth and improvement in the effectiveness and visibility of science. These, and other related aspects that typify the relation between scientists and their social environment in Spain are described below.

## The researcher in society

*As mentioned above, most members of Spanish society appreciate that scientific and technological advances contribute to improving their well-being. However, this perception is not linked to a view of science as an essential element of society's or of each individual's culture.* The scientific community should not "overreact" to the uncertainty and even resistance with which society sometimes responds to scientific or technological developments. Instead, it should try to understand the basis and the meaning of such reactions, by creating an open, non-paternalistic dialogue with the public.

Some segments of the public do not appreciate with clarity that there is no absolute certainty in scientific theories and models (i.e. results that are immune to being changed by subsequent theories). Likewise, they do not understand that "zero risk" is unattainable (as much as risk is, and should be, reducible to socially acceptable levels). Scientists, on their part, all too frequently seem to be disconcerted by ethical debates on research, and often attribute them merely to the public's lack of information. The effect of the combination of these two attitudes on controversial science-related subjects could erode the "intangible asset" of the public's confidence in the scientific community.

Spanish researchers have to be aware of concerns and attitudes in the social environment that are relevant to some aspects of their work. They should take advantage of any available opportunities to inform society of how researchers incorporates the public's concerns, preferences, and requirements into its work and decision-making. There are different ways of implementing researchers' social contracts, including numerous European initiatives (such as the European Group on Ethics in Science) and some Spanish ones. These should be acknowledged, evaluated, and generalised as appropriate. Postgraduate and doctoral programmes should include the opportunity to confront young researchers and technologists in training with ethical questions and the importance of social responsibility. Administrations in charge of funding research could, with little extra effort, provide guidelines on general ethical principles for the researcher (such as the well-known pamphlet *On Being a Scientist. Responsible Conduct in Research*, compiled in 1989 by the National Academy of Sciences and the National Institutes of Health, USA). These could be complemented by other, more specific guidelines for those scientific areas of specialisation that have a greater capacity to affect society's values and ethical principles. The state-wide establishment of CSIC has facilitated the important task of raising public awareness, thereby promoting debates and informative meetings on these aspects. Science academies and societies offer a particularly appropriate framework for presenting and debating scientists' social responsibilities.

As mentioned above, another important aspect of researchers' social commitment relates to the public origin of the funds used for their work. It should be clear to the scientific community that using public resources entails certain indissoluble, inherent principles of reciprocity, such as explaining the efficient use of resources in terms that can be understood by the society that provides them. This information task could be carried out by research organisations (universities, CSIC, PROs), through activities such as: open-house days; electronic information resources; disseminating reports of activities undertaken and outlining researchers' principles of conduct. This institutional support would in no way substitute for the responsibility of individual researchers.

## The researcher as a teacher and spokesperson

It is extremely important, even urgent, to make a lasting and effective effort to increase Spanish society's knowledge and general interest in culture's scientific foundations and science's contribution to their development. This may also encourage more young people to choose scientific careers. Initiatives should tackle many aspects, such as:

*a)* Providing an intelligible and attractive description of the creative function of scientific knowledge and the impact of scientific and technological advances on growth and well-being in Spain.

*b)* Stimulating scientific interest and scientific knowledge at all educational levels, according to the specific characteristics of each level (in a programme similar to that developed by the American Association for the Advancement of Science, called *Science for all Americans*. AAAS, 1981, 1993).

*c)* Communicating information about the methods and elements that typify scientific research, such as: curiosity and a desire to understand the world, the role of doubt, attention to empirical evidence, uncertainty, risk, perseverance, and critical analysis of the arguments of others, and, more importantly one's own arguments, etc.

It is true that a growing number of Spanish scientists participate in popular science programmes and initiatives. However, they are not usually given incentives or recognition for this work, and levels of organisation and support are low. Research institutions and government departments themselves do not fully appreciate the value of disseminating information about the scientific advances generated within them. A clear and explicit commitment to valuing and encouraging researchers' work in this area has to be made by the scientific community and the scientific institutions with competence in the area of science policy. They should provide specific, professional, and financial incentives to researchers carrying out this task. These incentives must not impinge on the criteria of selection and excellence in communicating scientific knowledge, as the negative effects of shortcomings in this area are well-known. University institutions and research organisations should make more extensive and efficient use of the opportunities information technologies provide to spread scientific information. Such technologies are generally absent, or the content is limited, in these institutions' Web pages and internet portals.

While the task of communication scientific information is on the official agendas of many Spanish scientific societies and academies, in general, sustained and efficient plans are lacking. Some societies composed of professionals and enthusiasts with the common objectives of research, knowledge preservation, and dissemination have attained a notable and active social presence. They illustrate by example the important role that scientific organisations could assume.

Obviously, educational efforts can attain the best results within the formal education system. At the university level, it is essential to dedicate particular attention to generating and maintaining students' interest in research. Judging by some recent studies, the framework of higher education brings students into only limited contact with the research world. This is a matter for concern, as they are thus deprived of one of the strongest incentives for choosing a research career. In addition, this approach does not help to transfer information about the central core of research activity (which is not just its results). This is such an important issue that it is dealt with in a separate point, based on the Fundación BBVA study *Los estudiantes universitarios españoles* (Spanish University students) (Fundación BBVA, 2004).

According to this study, 35% of "second stage" university students considered the possibility of a research career at some time. This percentage dropped to 11% if only those students who actually mentioned research as the career they would most like to pursue after their studies were included.

An important aspect of Spanish university students' perception of science is the image they have of the researcher. This is true of students as a whole, and the subset planning on pursuing a research career. It is interesting to confirm that all university students perceive a career in research as demanding and not financially attractive. They also believe that the authorities do not support researchers. Among the positive aspects is the belief that researchers are increasingly necessary for social and economic development, and that it is a prestigious career (Fig. 1).

The 11% of students who mentioned research as the career they would most like to pursue had the same image of the researcher. However, the difficulties did not seem to affect their choice of profession. The reasons and motives for their choice seemed to be based on other factors, such as their university experience, their general attitude to science, their motives and interests at the beginning of their studies (significantly influenced by their experience during secondary education, family influences, and their "reference group" during that time).

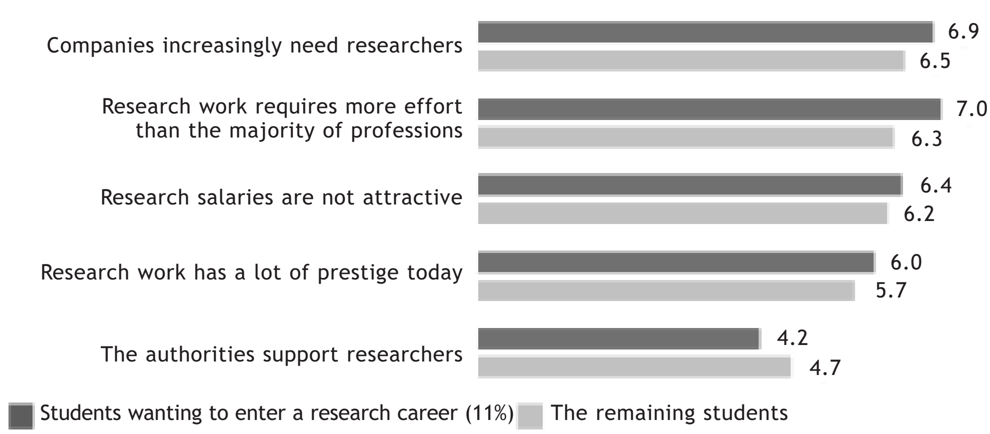


**Figure 1.** Level of agreement with each phrase

*Base:* Total cases (3000) average on a scale of 0 to 10 (0 indicates total disagreement and 10 total agreement)
*Source:* Fundación BBVA

**Table 1.** Evaluation of research

| | Want to pursue a research career (11%) | Remaining students |
|---|---|---|
| ***Do you know of any research programmes or projects being carried out in your faculty?*** | | |
| Affirmative response | **46%** | 20% |
| ***Evaluation of research being carried out in your university*** | | |
| Average (on a scale of 1 to 10) | **6.7** | 5.9 |
| Very positive evaluation (scores of 7 to 10) | **57.3** | 36.2 |
| ***Agreement with statements about research in your university (average on a scale of 1 to 10)*** | | |
| Research has nothing to do with me or my studies | 2.6 | **4.5** |
| Professors encourage students to go into research | **4.8** | 4.1 |
| Professors usually talk about their research in class | **4.5** | 3.9 |
| My university offers resources so that students can do research | 4.7 | 4.5 |

*Base:* Total number of cases (3000). *Source:* Fundación BBVA

This study of Spanish university students suggests that university experience has a significant effect on students' expectations of research. Those who wish to go into research when they finish their studies are more familiar with research carried out by their faculty (46% knew about a research project of their faculty). They have a more favourable view of the development of such projects (57% considered that it is very positive). In contrast to those who are not interested in a research career, they more highly value the contact they have with professors on research topics (Table 1).

It is also important to note the perception (shared by students who want to pursue a research career and by most students in general) that lecturers do not encourage research and that there is a lack of university resources for students to carry out research.

An analysis by branch of knowledge shows that students of experimental sciences are clearly differentiated by their greater familiarity, interest, and career orientation towards research. Forty-five percent of experimental science students knew of a particular research programme or project by their facility, compared to 23% of the total university student group. In addition, experimental science students are the most aware of the relation between their studies and research. Students of social sciences and law are the least aware of this link.

Likewise, 67% of experimental science students had at some time considered pursuing a research career, and 35% stated that research was the career they would most like to pursue when they finished their studies. Among the remaining students, this percentage was no higher than 11%.

The segment of students wishing to pursue a career in research after graduating tends to have different plans than the group of university students as a whole. The most notable difference is that those students in the research group planned to complete a doctorate, which they viewed as the "ticket" to enter a professional research (25% compared to 5% in the rest of the student group).

TABLE 2. Contact with and evaluation of science according to a profile of subject area and professional orientation

| | Scientific area (experimental and health sciences) | | Other areas (humanities, social, legal and technical sciences) | |
|---|---|---|---|---|
| | Want to pursue a research career (5%) | Remaining students (13%) | Want to pursue a research career (6%) | Remaining students (76%) |
| Watches TV programmes on scientific and technological topics | **71** | 54 | 49 | 40 |
| Reads popular science magazines every month | **31** | 17 | 23 1 | 0 |
| Watches videos about scientific and technological subjects | **55** | 41 | 40 | 27 |
| Scientific and technological subjects are frequently and quite often part of their conversations | **60** | 42 | 49 | 27 |
| Has been to a natural science museum in the last 12 months | **49** | 36 | 33 | 27 |
| Interest in scientific subjects (on a scale of 0 to 10) | **8.2** | 7.1 | 7.2 | 6.0 |
| Information on scientific topics (on a scale of 0 to 10) | **6.3** | 5.8 | 5.8 | 5.0 |

*Source*: Fundación BBVA

Moreover, the group who declared their interest in a research career also clearly held more favourable attitudes to science. There are two significant differences between students in terms of those attitudes:

- The first of these is related to *the different fields of study.* Students of experimental and health sciences are the most involved in science. Not surprisingly, they have the most favourable attitudes to science and the most favourable image of scientists.

- The second is related to *professional orientation.* There is a more favourable attitude to science among students who are more interested in academic careers, such as research.

The interaction between the two variables produces the subset of students with the most positive inclinations towards science, i.e. the group of health and experimental science students who intend to pursue a research career. The indicators in Table 2 show that these differences can also be observed in other forms of contact with science and research.

The above results provide evidence of the shortcomings in students' awareness of the research work of lecturers-researchers. Academic institutions should thus find new ways to support and recognise members who stand out due to the special efforts they make in stimulating science and reforming the curriculum. The latter aids in eliminating unimaginative and demotivating teaching methods. The process of adapting Spanish qualifications to the European Higher Education Area began recently, and offers unique opportunities for this reform process. Maximum advantage must be taken of these opportunities, such as collaboration between university teaching staff, CSIC scientists, and other research organisations.

In primary and secondary education, all teaching staff initiatives directed at increasing interest in science and its applications should receive special attention and support from the universities, the CSIC, and scientific organisations. This would help to draw the attention of the corresponding education authorities to the importance of scientific education at these basic levels –an area in which there are currently serious shortfalls. This support would also help to eliminate the difficulties affecting teachers in such areas. The Spanish scientific community has a rich variety of opportunities to contribute, in an effective, structured, and systematic way, to updating and disseminating scientific knowledge and technological advances to primary and secondary school teachers. These opportunities have not been fully exploited to date. In addition, the department responsible for education should stimulate interaction of teaching staff with research professionals through participation in joint research projects. facilitating the inclusion of teaching staff in scientific societies, etc. Direct contact between students and scientists should also be promoted through a variety of methods, such as opportunities for young researchers to offer seminars in secondary education centres. Presenting the history of science and technology at these educational levels could also contribute to transmitting a view of science as a fascinating adventure in search of knowledge. The consequences of science in terms of increasing opportunities for individuals would also be communicated through such presentations.

## The researcher as advisor in public matters

Traditionally, only limited resources have been allocated to scientific research in Spain. This is a symptom of the political and governing classes' lack of interest in this essential component of the country's development and culture. Paradoxically, in an industrially advanced state like Spain, an increasing number of political decisions affecting the country's development are closely linked to scientific and technological issues. On a daily basis, the governing classes are confronted (at the national and European levels) by problems in allocating resources, creating normative frameworks, and devising public policies that directly or indirectly have a strong scientific component. Unlike the majority of European countries, Spain has no official and transparent channels for offering scientific and technological advice to either the government or parliamentary representatives. Examples of such channels are: scientific advisory offices for the presidency, permanent scientific commissions in Parliament and the Senate, and scientific advisors in embassies and international organisations. Spanish political representatives rarely resort to scientific advice, despite the fact that a large community of scientists with a wide range of competencies are accountable to the administration. In an advanced country like Spain such an anomaly must be corrected. The number of channels for managing and applying scientific knowledge should be increased. Channels should be formalised and made transparent (or "institutionalised"). They should not only be available in crisis situations, but also for the daily management of the public's interests.

# Science and society: the role of the media

## Introduction

"For most people, the reality of science is what they read in the press", wrote Dorothy Nelkin. This statement is accurate, particularly if we substitute the media for the press. Once individuals leave school, the media are their main channels for remaining informed about scientific advances and their consequences, particularly in the current context of rapid scientific change. As a result, public decision-makers and the scientific community itself have frequently focussed on the role of the media in communicating science activities and news and, consequently, its role in creating the image society has of science and scientists.

This attitude has led to efforts to promote public communication of science through the media. On occasion, scientists have been encouraged to communicate their work directly or through intermediary journalists. However, these initiatives have tended to ignore the essential characteristics of journalism, leading to results that fall short of the effort undertaken. In particular, an attempt has been made to give, *de facto*, the informative media the role of actors in the science and technology system, whereas their function can be none other than transmitting what occurs in the scientific domain. An extreme example illustrates the requirements of the media's information task: if there is an absence or low level of scientific activity, then there is no information to transmit, or only articles of little content can be written.

Another deception can be found in initiatives and proposals on the media's role in communicating science to society, in which the press, radio, and television have been assigned a direct educational role. Thus, confusion arises between the public media's official communication role– a remnant of their function several decades ago, when they were obliged to broadcast and publish whatever those controlling their funds wanted– and the current situation, in which most of the media is privately owned and competes in the market economy. The media need to attract recipients, i.e. audiences, for their business to work. And since they are not subsidised, they cannot ignore the rule of the market: "your worth is equal to the number of times you reach the public". Furthermore, since their core activity must be compatible with making profits to be distributed among shareholders, they resemble, despite their specific characteristics, any other company. Some publicly owned media (notably in television) can and should have greater liberty, even though they cannot completely ignore the above rule. In other words, the regular presence of some contents, such as science, can be required of them, even when this does not result in gaining television audience share.

In general, regardless of whether media are public or private, one of their roles should be to report on science as they do on any other activity. The information should be put into its social or economic context, and according to the target audience's estimated level of knowledge, it should be popularised and made more accessible.

Two types of news items can be distinguished in Spanish science journalism: current science news from any country (including Spain); and news about the science world, the science and technology system, and science policy in Spain and other countries. Information about the science world varies greatly from one country to another and is a result of each country's social image of science, among other factors.

In recent years, a new area of specialisation has emerged in journalism. It focuses on the environment and ecology, has its own space in some media, and is covered by specialised professionals. Nevertheless, it is closely linked to science journalism.

Current science news comes from many sources, including scientific conferences, scientific journals, and researchers themselves. Such news is treated like information about current affairs, which entails certain conditions, such as immediacy. However, science news also needs to be treated with rigour, which makes it difficult to compile news items with the speed journalistic work requires. The origin of information (in Spain or anywhere else in the world) does not affect the way it is communicated, although recipients are more interested in news that has greater proximity.

Science journalism in Spain has recently been roused from a long period of lethargy, in parallel with events in scientific research. Above all, in Spain, it is now –at the beginning of the twenty-first century– also taking into account other people's advances, creations. and research. Both fields i.e. research and journalism, have to communicate with each other for the benefit of all involved, including recipients of the information. The efforts of researchers and spokespeople in this area should be emphasised. Researchers have created communications offices, and journalists are trying to specialise and to be as rigorous in their coverage as possible. The main printed media have special pages; for example, *El País* dedicates one day a week to publishing scientific information; *El Mundo* has a daily section on science; *ABC* has daily coverage of science news; *Heraldo de Aragón* is a pioneer in this area and recently received an award; *La Vanguardia*, etc. In contrast, despite its importance, television is the medium in which scientific information occupies the most precarious position.

## Problems in scientific communication

The position of scientific information in the Spanish media is on a par with its situation in the country, in terms of effort and scientific level. It lies somewhere between that of the most advanced countries and the least developed. The small size of the Spanish science and technology system, the lack of prominent scientists and authorised spokespeople (resulting from a lack of organisation), the limited social and political influence of scientists, and the absence of a scientific tradition in Spain negatively effect social appreciation of science. Thus, there is little sense, on the public's part, of current scientific research and what it means for society.

However, all existing studies concur in indicating medium to high levels of interest in scientific subjects, far from the existing level of information on such topics. In Spain, as in other countries, there is notable interest in biotechnical and health topics. *Interest in science policy and technology seems to be significantly lower than in other European countries, which is parallel to the limi-*

*ted interest shown by the political class and (with some exceptions) the business world*. As indicated earlier, the low level of scientific knowledge in Spain is accompanied by a favourable evaluation of science and a high level of confidence in the scientific community. There are no strong barriers of beliefs or morals that could slow down scientific research. Nonetheless, knowledge about Spanish scientists and their institutions is extremely low, and most Spaniards cannot even cite the name of a single living Spanish scientist.

In the "Spanish case" a series of specific factors have a negative effect on the relation between science and society. Some of most notable of these include:

- *The Spanish scientific community is small and lacks cohesion. Apart from some exceptions (such as that of young researchers), it is poorly organised and lacks a united voice*. Scientists rarely become involved in public debates. When they do, it is in the context of catastrophic crises (such as the *Prestige* or Doñana disasters) (Nombela, 2004).

- *It is difficult to find researchers willing to make statements about issues that are not entirely scientific but affect society;* i.e. questions that combine science with other issues related to the economy or politics.

- *Debates and controversies rarely arise between scientists; instead they develop between scientists and groups outside of research defending religious beliefs, morals, or social interests.*

- *The principle of excellence is not well-recognised or encouraged.*

- *Scientific information in Spain is not subject to differences in opinion, or to debates or conflicts. These are all essential components of information. The lack of critique is reflected by the observation that the scientific community often provides a sweetened version of information, in which only the successes (real or assumed –a distinction that it is very difficult for non-specialised journalists to make) and assumed positive consequences for society are communicated. There are very few established information channels, pressure groups, or scientists who are well-known outside of their specialised milieu.*

- A very important determining factor in communication is that *most Spanish scientists work in the public system, and have very little influence in companies carrying out research.* Thus, sources of information are distorted and are not countered by sources of information, as is the case in those societies with a greater scientific tradition and higher scientific level. Sources should also be more varied and more open to communication.

- *Another factor that distorts scientific communication in Spain is the fact that a lengthy tradition of science journalism exists only in the Anglo-Saxon world.* This is, in part, a reflection of the US's global scientific leadership. Much of the information about space or biotechnology, to mention just two areas, comes from the US. The Spanish media sometimes take greater notice of a news item because editors have seen it in the Anglo-Saxon media. It has a good headline, excellent photos, and editors know in advance that it will most likely be interesting to readers. The consequence is that a news item previously published in *The New York Times* is communicated more readily than a news item from a Spanish scientific journal.

In addition to these issues, scientific information in Spain has the same problems as in other developed countries. These are reflected in various reports on the subject produced by different countries. The greatest obstacle everywhere is the difficulty the scientific world and journalists have in communicating with each other. However, this is a problem that has diminished considerably in the last few decades. Both scientists and journalists are convinced that the situation could further improve, if a clear framework of collaboration is established in which both sides benefit. The dialogue must be constant and honest. The scientific world has to recognise that the media have their own way of working –which is not going to change– and also that the science cannot be treated any differently than any other field that generates information. This should be accompanied by a media effort to publish or broadcast information that is as rigorous as possible.

The interests behind science news are a growing problem. Any possible conflict in this area is the same as in other informative areas, such as the economy or culture. Identifying these interests and taking the necessary action is a journalistic problem, and does not involve scientists.

The objective should not be to improve the image of science and scientists, but to give people information about topics that directly concern them, increasing their ability to make or influence decisions in the public (with greater knowledge, and therefore greater liberty) and private arenas. Such information enables people to approach the domain of science as they do culture. The final objective of providing more information through the media can be expressed by the following classification, proposed by the astronomer Shen (1975). The first type of *literacy* or scientific information is of a *practical* nature and include scientific knowledge related to health, the environment, work, and consumption. The second type is *civic* and deals with the knowledge needed for public participation in science and technology public policies, in particular those that could causing alarm or lead to controversies. The last is *cultural* and refers to the symbolic nature of humans, who seek knowledge regardless of its short-term practical usefulness. This type of literacy responds to the curiosity that most individuals have. Half way between types 1 and 2 is the communication of *risk,* in which the media exercise an extremely important role, influencing the type and levels of risk perceived by society. For example, issues such as mad cow disease, pollution, and even driving cars have a scientific basis that should be correctly communicated so that society has an adequate perception of the risks.

*The freedom to carry out research in areas susceptible to controversy, such as biomedicine, depends, at least in part, on the existence of an appropriate social and cultural climate.* This is true today in the case of embryonic stem cell research or the use of a preimplantation genetic diagnosis. This diagnostic method is used to select embryos that are free from defective genes that increase the risk of suffering from neurodegenerative diseases. Scientific and technological advances are putting pressure on the ethical criteria, values, and beliefs from the very recent past. The opportunities opened up by genetic manipulation or manipulating matter's atomic structure (nanotechnology) give rise to challenges of great magnitude and importance for all of society, including the scientific community itself. In such matters, a higher level of scientific information is essential, as are ethical criteria and the rational, moral debates of a pluralistic society.

There is another area of interest in the science–society relation: the influence and regulations of governments over the research activities they fund. Governments, in turn, are pressured by groups of people fighting for the inclusion of their concerns or interests in the publicly funded science agenda. Another matter of social relevance, at least for some population segments, is the effect that biomedical research's economic interests could have –and are having– on orienting research towards fields that are not priorities from a scientific perspective, nor are they relevant to improving public health.

There is no simple solution to these problems. They require constant guidance. The effectiveness of any measures should be assessed periodically, as should any undesired effects. In any case, what seems clear is the need to encourage and facilitate an open dialogue between the population, political representatives, business, and the scientific community. This dialogue could take a number of different forms, and address themes central to the science –society relationship:. The net result would be a considerable increase in the amount of scientific information targeted to the general population, and an appreciation of the scientific aspects of many public policies (energy, water, environmental policies, nutrition, communications, etc.).

## Proposals

All agents in the science and technology system should be aware of the importance of keeping society well-informed of their activities through many channels, with a special emphasis on the media. The heads of public institutions should adopt appropriate measures to achieve this aim.

Scientists' main task has been, and will continue to be, to advance the frontiers of knowledge. However, this priority can be made compatible with the task of communicating directly with the public and, more frequently, the media. In any case, it should be the role of specialised professionals or scientific communicators, journalists with scientific training, or scientists with journalistic training who work in communication to communicate scientific information to society. Accordingly, the public system should support training for these communicators.

Bridges need to be laid down, and connections improved, between the scientific community and the media in order to bring about this flow of information, and both groups must play their part in this process.

Ideally, given the current position of scientific information in the mass media, and particularly on television, the scientific community should use contacts, press releases, basic documentation, availability of sources, images, etc., to do at least half the groundwork. Internet tools are now essential to modern means of communication. However, even if a Web page is well-designed and has a rich content, it should be complemented by other channels, all of which would then constitute a communication policy of scientific institutions and organisations targeted at the media.

A corollary of the above is that all scientific institutions need to have scientific communicators, as these professionals are in the best position to transmit scientific results and to explain to non-specialised journalists how scientists work.

The scientific communicators' tasks should also extend to communicating with specialised journalists, and scientific, pharmaceutical, technological, or innovative companies in general. They would also provide information on science policy.

Although scientific information quotas cannot be imposed on the private media, a more receptive attitude to science than the present one could be requested. Authorities could begin a dialogue on this topic with the media. Similarly, the public media should considerably increase the amount of attention paid to science and technology, even if this does not lead, in the short-term, to increases in readers, listeners, or television viewers.

With the universities' agreement, the administration should introduce improvements in scientific education at each stage of university education.

It is important to remember that in the current context, science will have to continue to earn its presence in the media by generating interesting news, being open and transparent to the media, and offering quality up-to-date information.

One way to obtain greater media coverage would undoubtedly be to increase the influence of science in the political arena. Top public officials frequently rely on scientific advisors. However, in general, these advisors are totally unknown to both the scientific community itself and to society. Such experts have the capacity to influence decision-making as well as the transparency of guidelines and advice given to public decision-makers. If they were more visible, the interest of the media and the general population in science policy would increase.

# Science on TV, in publications, and on the internet

## Textual dissemination of knowledge

Advanced societies are currently moving from an information culture to a knowledge culture, with vast and ever-increasing amounts of available information. Channels of communication are sought to enable this information to reach its final destination: the population. These pathways to knowledge are increasingly rapid, which makes any incipient process of cultural adaptation difficult, and hinders the generation of "ordered" access routes to the prospects of information.

As a result of the enormous development that science has undergone in recent decades, a considerable proportion of this information is scientific. Therefore, increasing efforts have to be undertaken to disseminate scientific information, if it is to reach large population segments. However, once this objective is achieved, the problem no longer lies in an excess information supply, and the resulting differences in individual and group preferences. Instead, the main issue becomes the growing difficulty the population has in accessing the information. This is due to the increasingly high threshold of knowledge needed to access introductory, informative, and even educational scientific texts. This extreme situation is well-documented in the first part of this section.

Each society has approached this problem according to its own resources and characteristics. In Spain, shortcomings have accumulated. As a result, levels of knowledge transfer between the science world and society continue to be particularly low, even though Spanish society adopts the different communication channels quite rapidly as they emerge. *However, there are notable shortfalls in the depth and intensity of use of the new communication channels by both recipients and disseminators.*

Regarding the characteristics of dissemination channels, once a cluster of scientific information has obtained the form of contents that can be published or broadcast. its base and organisation are *textual* and it can be expressed in different formats (print, sound, and image) that can be quickly communicated through technological media, from the printed word to TV and the internet.

Communication "products" that are able to transmit scientific and any other information could be organised into the following categories:

*a*) Printed texts: books and publications that are updated with very limited or no periodicity; periodical publications and magazines.
*b*) Digital text: internet portals containing information and documentation; some are updated with periodicity, some not. Web pages can be developed by the system or consist of a replica of the printed edition, in which case it is only a change in format.
c) Oral communication: broadcasting and stage productions based on pre-established scripts.
*d*) Audiovisual communication: audiovisual programmes, TV (news programmes, series, and

dramas) and cinema, in which the script also forms the basis and structure of the contents.

## The relation of science to different communication channels

### *Books and publications*

Science has maintained a clichéd, almost mythical and historical relation with the printed word. Libraries have been science's reservoir for centuries. From its enlightened beginnings to the present, science has essentially been *written science.* The major classic scientific theories have been forged in the written word, expressed on printed paper, and bound. In turn, such theories have been deeply conditioned by this format. If books had had a different form, the major classic scientific theories (Newton and Darwin are paradigms of these) would have had different formulations to those that we now consider to be standards.

Therefore the book is a mature format; it is both highly developed and "tailor made" for science. It is also tailor made for society –or at least for those that have been at the receiving end of scientific advances over the last two centuries.

While the prominence of the book in the current scientific arena is limited in comparison to the volume of science in circulation, it does not lack importance. Books detailing scientific theories continue to be published, and many such books have been written, particularly during the last two decades of the twentieth century –for example by Lovelock, Margulis, Dawkins, Gould, and Kauffman). More recently, there seems to have been a certain resurgence of this genre by unconventional scientists such as Hawkins (*On Intelligence*) and Luca Turin (*The Emperor of Scent*). In these books, the authors provide first-hand accounts of scientific theories in order to spread information and to present it in a way that can be accessed by a wider public. A slight resurgence of popular science books is also taking place. These books are written by authors (scientists and specialised communicators) who are not the creators of the theories they describe. Such books have attained a certain degree of success with the public.

The different kinds of science books described above have at least one characteristic in common: they have all been profoundly influenced by literary norms, both in their form and formulation. The science book has therefore become a crossover of cultural expressions, and a graphic illustration of the existence of a connection between these two forms of expression.

Due to its own cultural nature, the book is usually much longer-lasting than the formats created by new technologies. Thus, the book has become "science to keep", allowing readers to return to it again and again.

### *Magazines*

The magazine is a contemporary format for communication compared to the thousand-year-old tradition of the book. Magazines have brought to published science its well-known characteristics: access, brevity, and the development of a non-literary language, culminating in the "technical report" style of scientific journals. Magazines are, almost by definition, also introduced "multi-authored, but in a very different way than found in encyclopaedias.

Scientific magazines are, to the same extent as books, essentially written science. However, "illustration" (a double-edged word in publishing) acquires a relevance in magazines that it does not have in books. It is the seed of the "viewed science" that has developed in association with advances in representation technologies.

For many reasons, as magazines have flourished and their influence expanded, scientists have largely abandoned directing their writings at society and instead focused them at their colleagues. As a result, many scientific magazines stopped trying to keep the general public among their readers. Scientific journals were founded that have become increasingly prestigious and inaccessible to most of the population –and to some scientists themselves. Such journals have constructed a wall from which science is imparted and thus frequently control what is newsworthy by rationing out advances to the main media organisations. In response to the exclusivity of journals, other magazines have taken over the task of informing wide segments of society about science, with notable success. These have developed from a strictly textual format with simple illustrations (*Scientific American*) to the visually oriented magazine dominated by photographs, computer graphics, and 2D/3D (e.g. *Muy Interesante* in Spain). However, the origin and splendour (both past and present) of both types of magazines resides in the Anglo-Saxon world.

Magazines in the category of "scientific culture", such as those published by some scientific societies and universities, deserve special attention. Their content looks at society from a scientific perspective (either generally or in part). Good examples are: *Revista de Física,* published by the Real Sociedad Española de Física (Spanish Royal Society of Physics); *SEBBM,* published by the Sociedad Española de Bioquímica y Biología Molecular (Spanish Society of Biochemistry and Molecular Biology); and *Quark,* published by the Universidad Pompeu Fabra. By allowing scientists to disseminate science information in the first person, these magazines provide a fertile breeding ground for science professionals' to become science communicators.

Magazines have therefore become a powerful format to which science has adapted perfectly and have in the process become science's "official version".

In Spain, hardly any scientific journals stand out as capable of competing with major international publications. To do so, their content has to be published entirely in English, which contributes to distancing them from a position of cultural proximity to Spanish society. Apart from the notable exceptions mentioned above, popular science magazines have become short-term projects (they arise, shine, and then either disappear or survive), incapable of finding the tone and the accent required by Spanish society.

Due to their periodic nature, magazines are culturally "perishable" and their contents are not normally re-read. Popular science publications use an increasingly journalistic style of writing, while specialised scientific journals have developed a form resembling technical reports, which their bleak lack of literary style.

***Internet Portals***

The information structures on the internet, particularly those that have arisen due to the popularisation of the World Wide Web, represent a significant change in format. However, this change is not as radical as it may at first appear. It is true that some of the main characteristics of the internet, such as the interactivity between issuer and recipient and the ease with which anybody can send a message, have made this new medium a revolutionary form of communication. However, this radicalism has not yet been paralleled by a dramatic change in content or format. The page, i.e. a surface area that confines a determined amount of text, continues to be the conceptual unit of the Web. In fact, the main characteristic, in terms of content, is that such digital pages impose functional brevity. Moreover, there is a social factor that acts as a preliminary barrier: the extent of widespread access to the internet.

Since the early days of the internet, science has sought and found its place in the resources of the Web. This has raised its prospects of moving closer to society. Nevertheless, these prospects seen to be taking a long time to be completely fulfilled. Internet portals have a unique, attractive form, and open up interactive opportunities. However, their structure and presentation continue to be too similar to that of printed publications (books, magazines, newspapers), and the discourse and origin of their texts are too closely based on those of publications with traditional formats. As the creators and editors working on the internet become capable of adding new formats to the novelty of contents, and abandon the continuous direct and indirect reference to the printed page, the potential of this new medium will be released and inevitably pervade science.

Considering the immediacy and the interactivity of the internet, it is plausible that we are not far from the day when a scientific theory will initially be expressed on an internet portal, with a formulation that is essentially different from those used to date. Certain structural parallels can be drawn between new formats found on the internet, such as blogs and tags, and the (laboratory and field) notebooks and notes that scientists have used to express their theories first-hand. These new structures could be the source of the first steps in this long-awaited revolution. The prospects of scientific theories constructed in real time on the internet, with the attentive observation and interaction of an infinite number of spectators-followers-collaborators, could bring about a resurgence of the interaction between the scientific community and society. (This would be a new and powerful version of Benjamin Franklin's practice of hanging the proofs of his books in the window of the printer's shop so that passers-by could correct them according to their criteria).

There are many examples of internet portals for science. All large scientific institutions have developed and maintain their own spaces on the internet. However, the most well-known and frequently visited sites tend to be those created by the major scientific journals and popular science magazines. Scientific organisations, hospitals, universities, science academies and societies, companies carrying out research, government departments, foundations, museums, libraries and databases, the media, associations of science enthusiasts in any field, and an increasing number of organisations and individuals are creating –in most cases independently though sometimes in collaboration– a vast space for learning and communicating about science. As stated at the beginning of this section, an emerging problem, multiplied by the development of the internet, is how to move from the previous chronic lack of scientific information to *the overabundance of information and resulting cognitive overload* for individuals. In addition, it is relatively difficult to find a system that can qualify knowledge as valid (that is, validated by peer review, according to the strict formal protocols of printed journals) on the public space of the internet. It is increasingly difficult for the end user to distinguish between *authentic* and spurious, or at least non-validated, knowledge. This is particularly true when information does not come from a publicly and scientifically prestigious and verified source. Thus, it is difficult to ascribe appropriate relevance to the information about specific scientific fields that is available on the internet. (This can have direct, undesired consequences on the end user of the information, particularly in cases such as biomedicine and health care). In Spain, it is essential and urgent to provide *training for society on how to filter scientific information and recognise its validity.* This should be done within the frame of plans for promoting the information society. Such measures would prevent a large population segment from assuming that relevant and verified knowledge means those pages that are presented at the top of a search engine's list. The internet is, without doubt, a space and a group of tools that have unknown potential. Both creators and users of scientific information need to have a good command of it (acquiring a new kind of "*literacy*" or capacity) and use it intensively. Without losing the spontaneity and the degree of freedom that creators and users have had on the Web to date, giving it its shape, it is clear that the education system, government departments, and the scientific community itself should contribute to teach the public how to surf this ocean of information with minimum risk and the greatest benefits.

***Television***

Television is by far the most widely disseminated media form, with the largest audiences. TV's visual component has generated its own language, which prevails over its textual references (the almost indispensable script). Despite the fact that the content is often far from spectacular or interesting, it is clear that TV is an excellent medium for science communication (not science in its strictest sense, which has not found its place in this medium). Broadcasts classified as "science" programmes often have a report or magazine format. There are a certain number of broadcasts on Spanish television channels that could be labelled as "science" programmes in some way. However, their audience is small and they are usually broadcast at inconvenient times; this feeds back into their lack of viewers. The number of documentary series about the natural world stands out. Many of these are about animal ethology, and most have been made outside of Spain. Clearly, the barriers to entering TV are high, due to the substantial financial resources required.

There are very few landmark science communication TV programmes (two emblematic ones would be the Carl Sagan series and the work of the singular Rodríguez de la Fuente). In its process of specialisation, TV has generated channels whose content is focused on providing quality information (Discovery, NatGeo). Although these channels provide many examples of how science can be communicated on TV, the dissemination of such programmes continues to be limited. One internationally broadcast TV series, *CSI*, should be highlighted. Its plot is based on applying scientific techniques, and the traditional image of a researcher is replaced by an unusual kind of policeman. The series' success in the US has given rise to various franchises, but is producing the disturbing effect of identifying scientists with detectives and scientific activity with the plot of a detective novel. We should stress that the series' internet portal contains abundant scientific material at a level that goes beyond strictly popular science.

After reports, dramas (and hybrids between the two) are the best option TV has found for disseminating scientific information. It is clear that the nature documentaries rely heavily on simulation and preparation. This is probably the key to their success. TV as a vehicle for scientific knowledge has strengths and weaknesses. The written text (the book) is ideal for transmitting/creating abstract thought, whereas television is best at transmitting/creating emotion. It is a poor transmitter of data, due to the fact that an accumulation of data saturates viewers' receptive capacities. As a result, they will either change channel or simply switch off their TVs. In both cases, the attempt at communication is aborted by errors in the approach to and execution of the message (this does not only occur in science programmes, but also in some television treatments of history). Nonetheless, some televised works have managed to transmit highly complex concepts using appropriate language.

An analysis of the most reliable data on the presence of science on television (audience data compiled by Sofres) reveals a relative lack of science content in Spanish TV programming. For example, data for the period 2000–2004 confirmed science's marginal presence in TV programming. In 2004, TVE 1 broadcast 19 hours of science programmes, and a few hours were also broadcast on TVE 2. Together, this represents 0.001% of the total annual broadcast time of each channel (both broadcast 24 hours a day, i.e. 8784 hours/year). These data are far from being complete, and were drawn up using a specific classification of what does and does not constitute science content (e.g. the TVE magazine *Redes* does not appear in the list of science programmes). Therefore, the actual science content may be higher. But even if this leads to a correction factor of 10, the annual percentage would still only be 0.01%, which is modest, and far from the desired level.

If the presence and influence of scientists in "page" formats is limited, in the audiovisual media it is negligible. This has helped to contribute to the "invisibility" in many social sectors of not only science but also scientists.

## Proposals

### *General proposals*

*Actions should be created and supported to maintain interest not only in newsworthy science but also in scientists.*

Periodically focus attention on a scientist and his/her work. This could contribute to "humanising" science and to perceiving the diversity of its contents through the diversity of its protagonists.

Propose a *"scientist of the month (or quarter)"* to the media. Continuously highlighting the importance of the profession through its most distinguished members and their current projects could contribute to increasing society's interest. COSCE should assume the lead in this initiative.

From an institutional perspective, there is a lack of reference bodies (institutes, agencies) with enough prestige and communicational capacity to stimulate the appearance of scientific topics with multimedia material that can be used in the media. These bodies are indispensable during times of crisis (such as the recent case of "ice meteorites"), when society needs a voice that is capable of giving satisfactory responses.

*Scientific institutions that undertake science communication should be strengthened.*

Although there are professionals of unquestionable value on both sides of the science–communication interface, it appears to be necessary to strengthen professionalism in the "transactional space". *To this end, the profile of a profession-*

*al scientific communicator, someone who is integrated in both worlds* and is equipped with more effective tools to avoid scientific reticence and the population's incomprehension, should be increased.

An agency assigned with disseminating science news and capable of providing an overall view of science current affairs in Spain should be created. This agency would integrate and coordinate information from the many university offices, public and private research centres, companies engaged in biomedical research, etc.

*Provide a science news agency that brings together and organises Spanish scientific-technical current affairs.*

Finally, the greatest problem found along the path that leads scientific information from its origins to society does not lie in the creation of products (whether they are printed or in visual or digital formats) but in their dissemination and distribution. Therefore, *the dissemination of scientific information should be taken into account when it comes to appraising, encouraging, or attending to any project or scientific proposal.* Experience shows that wonderful science-communication projects have not reached their destination due to a lack of an appropriate distribution plan (and funding).

## Specific proposals

### *Books*

Intellectual access to science and other information has been seriously jeopardised due to the fact that reading habits and comprehension have seriously deteriorated, particularly among schoolchildren. Recovering and strengthening these capacities should be compatible with the emergence of new media and formats.

An increase in science education is essential if science is to become more important to society and involve greater activity on behalf of the population. Such education should be promoted and structured with the rigour that a conceptual structure like that of science requires. One of the steps to promoting science education is to increase the availability and quality of published products.

The publishing industry in Spain is suffering the same crisis of identity as in the rest of the world. It deserves the attention and resources needed to overcome this situation. There are very few science publishers in Spain. Thus, considering the level of scientific activity, the production of science books is less than desired, and that by Spanish science authors is particularly rare.

Joint-publication agreements concerning science communication and dissemination of works of clear social interest should be drawn up with those institutions that have a direct or indirect interest in science.

*Specifically promote scientific publications through joint-publication agreements.*

In their capacity as social (and also cultural and commercial) objects, books should be made readily available to the public through libraries. However, the presence of science books in libraries is negligible, and those books that are available are often out of date.

*Increase the presence of science books, in particular new titles, in public libraries.*

Commercial access to science books is restricted by the lack of facilities the retail book system offers. Competitiveness for space in bookshops and the rapid stock rotation imposed by distributors of popular books place science books at a serious disadvantage, as they are usually not impulsive purchases and thus require a longer shelf-life.

*There should be a dialogue between the publishing world and bookshops so that science books are treated in a different and favourable way, enabling readers to have better access to them.*

Finally, the culture of science books is linked to the culture of reading, and reading is not sufficiently encouraged in the education system. At present, books are undervalued in schools and rarely take the leading role in the education process. This situation is even worse in the case of science books.

*Fully incorporate science books into the learning experience.*

An undesired consequence of the limited presence of books in schools is that the population's reading comprehension is decreasing. As a result, people lose access to one of the most powerful channels for acquiring information about science. It is important to stop the idea that the computer is a "natural substitute" for books.

***Magazines***

The seemingly unstoppable plunge in the status of popular science magazines and the rapidly growing interest in new formulations should be analysed to identify the changes that are occurring in society's perception of science. Such analyses would also indicate whether new forms of popular science magazines are replacing older forms in the public's preferences, or reaching sectors of society that have previously shown no interest in science.

There has been a spectacular increase in the number and quality of illustrations in the new popular science magazines. This seems to indicate that these publications are emphasising visual communication and minimising textual information. While the objective of this approach is to satisfy the population's preferences, it is not clear whether scientific information presented in this way retains the accuracy and completeness obtained from a "textual" format.

As a consequence of trying to mimic "television language", popular science magazines are becoming expensive projects that cannot be financed by the publishing sector alone.

There is a lack of major science magazines in Spain (for both popular science and scientific reflection), whilst they are common in other European countries. It is hard to overcome this shortfall without an enormous increase in the efforts of both private bodies and public institutions.

*Multiple collaborations need to be coordinated to provide Spain with major popular science and scientific culture magazines.*

A careful approach, in which, for example, financial backing is made available to popular science and scientific culture magazines, will help serious projects to be created and to last. This would put an end to the socio-economic and cultural shortfalls caused by the limited presence or complete absence of such magazines in Spain.

***Internet portals***

The first and most urgent measure should be to foster and increase internet use by the general population. To achieve this goal, decisive actions need to be taken by all interested parties. There is no need to be creative or original in this task;

Spain can simply adopt measures similar to those implemented in other countries.

As mentioned above, the internet is a medium with enormous potential for communicating science. However, such prospects are affected by the fact that, apart from sites concerning health, science communication portals –in the strict sense of the term– are almost nonexistent and have only marginal influence. If a lack of professionalism can be seen in the traditional means of science communication, it is even more noticeable on the internet. In response, all scientific institutions should engage in social communication initiatives, using both consolidated and emerging formats. The contents of those initiatives should include explanations of research activity carried out in the institutes, presented in a form that is intelligible to the population.

***TV***

Due to the lack of science content in TV programming, it is essential to ensure that each new broadcasting opportunity exploits this medium's potential to the maximum. There is little point in investing resources (public or private) in series or popular science campaigns if the transmitted messages make poor or mistaken use of TV.

"Ghetto" strategy ,infiltration, or both? The following need to be increased to raise the presence of science on TV:

*a)* Communication: already-acquired knowledge; biographies
*b)* Debate: on scientific and moral opinions, such as stem cells
*c)* Information: new scientific ideas, science policy
*d) T*he influence of science in the public imagination: real or fictitious characters
*e)* Science in children's programming

The first three items are related to the treatment or reflection of "reality", as presented in news programmes, reports, magazines, documentaries. TV stations (whose programmes are, by definition, aimed at large audiences) tend to consider that such contents interest only a minority of viewers, and should therefore be relegated to secondary channels and broadcast at times other than prime time. This situation should be improved by aiming to increase the quantity and quality of this kind of science programme. This is the "ghetto" strategy: increase the amount of products for the small audience that already consumes them.

The infiltration strategy involves introducing science contents into non-science genres and formats. Examples of this can be seen in characters from several fictitious series, such as *Siete Vidas, Aquí no hay quien viva, El Comisario,* etc.

The advantage of infiltration is that it helps science to reach a much wider public, as the "carrier" genre has a large audience. The disadvantage is that a greater degree of compromise has to be accepted. In fact, the plots of these series are usually centred on relationships between characters rather than on the professional aspects of their lives. But stressing the latter also entails a compromise, as the activity is made more glamorous than it is in reality.

Including science content in children's' programmes or offering science-oriented programmes during children's viewing times is a clear investment in the future. The practical aspect of science (experiments) enables programmes to be created that, using appropriate language, aim to stimulate children's' interest in the fascination of discovery (e.g. *Beakman's World*, broadcast on some regional channels in Spain). Private channels should be encouraged to broadcast these kinds of programmes, and they should be obligatory for publicly owned channels.

*Promote the strong presence of science programmes during children's' and young peoples' viewing times, particularly on public channels.*

In considering science programmes, the issue of language arises. In any format, it is difficult to adapt scientific language to the language of the media. This is particularly true when the medium is television. However, (more or less pure) fiction seems to be the road to success. The first conclusion is that writers for television should receive enough information to stimulate the inclusion of science in their scripts. A clichéd view is that TV recreates real society. However, "only" police, medics, journalists, and lawyers exist in this TV world. There are no signs of scientists, and scriptwriters do not know how to incorporate them.

To rectify this situation, *a common platform should be created (forums, meetings) where scriptwriters and scientists can work together to improve the science content of* TV *programmes.* This type of platform can also be exploited by scientists and TV news editors.

*Generate fixed platforms where scientists, scriptwriters, and TV news editors can work together.*

Positive examples of this improving the relationship between science and television includes: the recruitment of science editors by officials responsible for those news programmes with the largest TV audience; a report on the science topic of the month, based on a science debate moderated by the science editor.

A negative aspect is the low profile of events in which major science prizes are awarded. News programmes do not seem to have found the tone or the way to make either the award winners or the research that led to the award accessible to the public.

It is clear that the success of audiovisual scientific productions has wide-ranging political and social repercussions, as demonstrated by the aforementioned programme *CSI* and the recent film *The Day After Tomorrow.* This film aroused debate over climate change (despite its being a dramatisation, the film was sufficiently rigorous and well-documented) and contributed to establishing a more sensitive context for climate research.

Public TV should make a decisive, medium-term commitment to increase popular science programmes, even if they are not initially as successful as a programme needs to be to continue being aired. There are many cases in which a programme's culture keeps it on the TV screen.

The advice of consumer motivators should be sought in choosing the science content of programmes. These kinds of actions need to be taken to bring science closer to popular modes of communication.

# Science museums and their role in the relationship between science and society

The number of centres devoted to science communication in Spain is now substantial and currently includes: interactive science museums and centres as well as specialised museums, such as planetariums, aquariums, botanical gardens, and zoos. The definition of a science-communication centre remains controversial; for example, should an institution containing a dolphinarium be included? There are also various examples of joint centres, such as an aquarium/museum (Casa de los Peces) and a planetarium/Imax cinema (Hemisfèric).

The most important development in recent years has been the appearance of new museums and planetariums, including about twenty distributed around Spain. The initiative to create these centres, their funding, and their active maintenance have come from foundations linked to financial institutions (CosmoCaixa, Kutxaespacio de la Ciencia); town councils (Museos Científicos Coruñeses, Planetario de Madrid); regional governments (Planetario de Pamplona, Museo de las Ciencias de Castilla-La Mancha); and consortiums bringing different bodies together (Parque de las Ciencias de Granada). Society's recognition of the financial contribution of these institutions to popularising science is richly deserved. Currently, the number of visitors and people involved in the activities of these museums is over 10 million per year. The number of visitors to the Museo de las Ciencias Príncipe Felipe in Valencia stands out in particular.

In general, the new museums and planetaria present exhibitions and undertake activities that are related to aspects of contemporary science and the social impact of science and technology. Such exhibitions do not necessarily use collection items; instead, they often use exhibition components of a different nature (interactive, audiovisual, computer-based, models, etc.) that are specially designed to demonstrate a phenomenon, explain a concept, or provoke ideas and responses in general.

One of the most notable characteristics of the new museums is the opportunity they offer for interaction. This arises from a concept of exhibition items as educational elements (regardless of whether they are part of the collection or not). The importance of interaction has been emphasised by the popular statement that contains four invitations: "Forbidden not to touch, forbidden not to think, forbidden not to feel, forbidden not to dream".

Traditional science and technology museums have also undergone a transformation, incorporating some interactive elements into their exhibitions. However, it has to be said that both the Museo Nacional de Ciencias Naturales and the Museo Nacional de Ciencia y Tecnología lack the resources required to carry out their educational tasks at the level one would expect from such important institutions, and from the research activity they undertake. The Museo Nacional de

Ciencia y Tecnología de Cataluña is a unique model of an integrated and coordinated network of interesting installations in the field of industrial archaeology.

The new science museums have an extensive social task. They play a key role in improving the public perception of science, contributing to a positive evaluation of science and its technological developments. In addition, they stimulate the population's education about the characteristic activities and abilities of science. They also help people to understand scientific concepts linked to the present day and propose steps for integrating them into culture.

Science museums also play a role in supporting and complementing formal education. They are therefore visited by numerous schoolchildren every year and present aspects of science that differ in content and form from those of educational centres. Such aspects are more closely related to current affairs and interdisciplinarity and are linked to situations involving play, happiness, and freedom of initiative. Other activities, such as science workshops, have a more didactic focus, or are oriented towards specifically teaching certain topics specified in the school curriculum.

Annual meetings of the managers of science centres and planetarium have been held since 1997, to exchange experiences and establish guidelines for collaboration. In the first of these meetings, held in La Coruña, a manifesto was signed (see Bibliography) linking the activity of these centres to the cultural needs of the population that arise from scientific and technical developments.

The atmosphere among Spanish museums is one of a community with common objectives. This has led to the joint production of exhibitions (one that stands out is "Madera del Ayre", which travelled all over Spain and was brought about by collaboration between the Museo Nacional de Ciencias Naturales and the Casa de las Ciencias). It has also resulted in audiovisual planetarium programmes (such as *Vía Láctea* -the Milky Way- that premiered simultaneously in planetariums in Madrid, Pamplona, and La Coruña). There are many other shared projects, including publications, conferences, and general activities.

Science museums not only carry out activities within their facilities, they also frequently present their exhibitions in other non-specialised locations, or even move around in the form of "travelling museums", as did the Fundación La Caixa's *Carpa de la Ciencia* (Science Marquee). Another notable example of this is the portable planetarium, which was a private initiative.

Science museums have taken the lead in carrying out actions such as producing publications with a wide circulation, and holding conferences, debates or exhibitions to inform the public about alarming or worrying social situations related to science and technology (mad cow disease, mobile phone antenna, black tides, human cloning, etc.).

Since 1988, the Museos Científicos Coruñeses have held annual awards for the best science communication work (audiovisuals, books, unpublished texts, journalistic articles). These awards are currently linked to the European Commission's Descartes Prize for Science Communication. Likewise, there are prizes to encourage scientific research among young people, including those directed at secondary education students, such as the "Luis Freire" prize, held annually since 1998.
Science museums have particular importance, as organisers or major participants, in a wide range of initiatives, including science fairs, science days, and similar events. Those held in Madrid (*Madrid por la Ciencia*, Madrid for Science), La Coruña (*Día de la Ciencia en la calle*, Day of science in the

street), Seville, and the Balearic Islands are particularly noteworthy.

We should also highlight museums' concern for the task of public communication of science and technology. Their involvement in this task is demonstrated by the three *Comunicación Social de la Ciencia* congresses that have been held by the Parque de las Ciencias de Granada (1999), the Museo de las Ciencias Príncipe Felipe de Valencia (2001), and the Museos Científicos Coruñeses (2005).

In addition, science museums participate in organising (alone or in collaboration with universities, CSIC institutes, and other bodies) days, courses, and conference cycles. Museum conference halls have become the most appropriate place for meetings between scientists and the general population.

Planetaria are an exceptional tools for teaching concepts related to astronomy and geography. Above all, they make it possible for people of all ages to become enthusiastic about the marvellous spectacle of the night sky, through the learning process. The trend of creating public planetaria should be supported, until there is at least one per regional government.

The development of zoos and aquariums must enable them to combine, in an increasingly effective way, the task of environmental education with a philosophy of respect for living beings and biodiversity conservation.

# A central aspect of the relationship between science and society: women and science

This section outlines some of the issues comprising the complex problem of the professional development of women within the scientific community. European data show that, despite numerous European Commission initiatives to promote gender equality in the area of research and teaching, progress has been very slow. This was also recognised in a recent document (*Women and Science: Excellence and innovation-Gender Equality in Science. European Commission,* SEC 2005: 370). In Spain, the progress of women in education in the last two decades has been spectacular. According to data provided by the *Conferencia de Rectores de Universidades Españolas* (the Conference of Spanish University Rectors) from 71 universities (www.ujaen.es/serv/gerencia/images/webestudio-crue04/index.htm), women make up 53% of enrolled students and 59% of graduates; Seventy-five percent of the students enrolled in health sciences are women, compared with 65% in the humanities, 63% in social sciences and law, 59% in experimental sciences, and 28% in engineering and technical careers. For the first time in Spain, 51% of doctoral theses were defended by women. However, as women move higher up the teacher-researcher career ladder, they become a minority. Only 35% of permanent teaching staff are women, and they only occupy 13% of professorships or 15% of the equivalent rank in the CSIC.

The gender differences seen today are partly due to clearly discriminatory trends that belong to a Spain from earlier times. They are also the result of the interaction of an extensive series of variables from different domains: from "private" life and the distribution of roles and expectations in the family, to the influence of intangible cultural aspects that still exist in Spanish society and institutions. These aspects converge to give priority to men when high levels of responsibility are assigned (in this case, in research and/or teaching).

In addition to the absence of equal opportunities in past decades, one of the main reasons for the near absence of women at high levels of the R+D system is that they have not been given incentives to be group leaders. This socio-cultural condition is not, of course, specific to scientists – it affects all professions. In research, another significant factor applies: there are many more men than women on panels and evaluation committees. The *Asociación de Mujeres Investigadoras y Tecnólogas*, AMIT (Association of Women Researchers and Technologists) has been fighting for measures to be taken to redress this imbalance. Such measures should be carefully considered by the different agents in the Spanish science and technology system.

To tackle a problem of this complexity, the first and most urgent recommendation is to *encourage more reliable and systematic information to be obtained. This can be used to undertake precise* *statistical analyses of the source of the current situation of inequality in the Spanish science and higher education systems*. The availability of standardised quantitative indicators and rigorous statistical analyses should help to identify the different variables that contribute to generating a combined effect of inequality. Variables may be from the past and/or the present; private or public; easily supported or intangible. This information would provide more effective tools for correcting inequalities in a decisive and sustained way. At the same time, analyses would help to avoid the undesired effects of measures that are not based on evidence obtained in accordance with the protocols used in the social sciences.

Some measures, several of which were recommended by AMIT, can be applied before these analyses are undertaken. . Among them is the recent creation of the *Unidad de Mujer y Ciencia*, UMYC (Women and Science Unit), which is dependent on the Ministry of Education and Science. Other measures do not need further analysis, as it is easy to predict that they will have clearly beneficial effects. These include:

1. Create or strengthen mechanisms to harmonise professional, private, and family life, such as flexitime, public social services to look after dependents; tax incentives that promote these mechanisms.
2. Encourage non-sexist education at all educational levels, and raise the awareness of the entire society regarding this issue.
3. Communicate European policies that promote equal opportunities for the sexes in the science and technology system.
4. Urge the different administrations and public organisations to unify their criteria for drawing up itemised gender indicators.
5. Publish and disseminate statistics and indicators annually.

In the Nordic countries in particular, numerous initiatives have been put into practice that facilitate researcher mobility and a return to a scientific career or part-time work after periods of maternity leave. Many of these can be transferred to Spain. They would contribute to stemming the loss of women from the fragile Spanish R+D system, and prevent their serious demotivation, caused by the additional barriers they encounter in seeking a competitive career in research excellence. This is clearly a problem that has a detrimental effect on progress in Spain.

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