Science and Social Communication

Natividad Carpintero-Santamaría

Abstract Social communication has an important sociological and psychological impact; the way scientific developments are transmitted to society can significantly affect the way they are perceived. Scientific findings need to be adequately presented and their interest and value must be stressed if they are to be understood and appreciated by society. In many cases, scientific issues are not satisfactorily transmitted or assessed and are misunderstood or ignored by nonspecialist audiences. Traditional mass media instruments such as newspapers, radio, and TV are being overtaken by the powerful influence of the internet, with its ability to reach remote places and social groups. The transmission of science through social mass media can help people to accept its benefits but may also lead to misapprehensions. The internet is perceived by a large sector of society as a reliable source of information, but this powerful new communication channel requires a greater awareness on the part of its users to avoid the misunderstanding—and, in the worst possible scenario, the misuse—of the information it contains. This paper focuses on a range of areas such as the social perception of science, the role of the internet, limits, and ethics in scientific communication, and the endeavor of the European Union in science transmission.

Keywords Social perception of science · The role of internet · Limits and ethics of scientific communication

Introduction

Human communication is a dynamic, interactive, and intrinsically social phenomenon which involves the development of psychosocial capacities of relationship. Communication is also an important strategic tool in a world

N. Carpintero-Santamaría (✉)
Departamento de Ingeniería Energética, Instituto de Fusión Nuclear,
Universidad Politécnica de Madrid, Madrid, Spain
e-mail: natividad.csantamaria@upm.es

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increasingly accustomed to real-time interaction. Globalization and the internationalization of societies have created a new communication model in which the communication of science has a key role to play. The twenty-first century is an age of near-total dependence on communication technologies whose influence on society has substantially altered the way we see the reality around us, especially in relation to scientific and technological issues.

The right to communication was recognized by the Universal Declaration of Human Rights proclaimed in 1948 after Second World War by the Security Council of the United Nations. Two out of its 30 articles refer to this right:

> Article 19 Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions without interference and to seek, receive, and impart information and ideas through any media and regardless of frontiers.

> Article 27.1. Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits.

Several definitions of science communication have been proposed. According to Burns et al. (2003):

> Science communication (SciCom) is not simply encouraging scientists to talk more about their work, nor is it an offshoot of the discipline of communications. Although people may use the term "science communication" as a synonym for public awareness of science (PAS), public understanding of science (PUS), scientific culture (SC), or scientific literacy (SL)—in fact many of these terms are often used interchangeably—it should not be confused with these important and closely related terms.

Other perspectives can be found by Fujun et al. (2012):

> Science communication is neither a device applied by the scientific community to achieve its own purposes, nor a unilateral one-way dissemination of scientific knowledge by the government but an activity in the formation of culture

The inherent cultural value of science is undeniable, as is its capacity to transcend global borders. Social progress through different civilizations has been made possible by scientific and technological advances. Engineering, for instance, emerged at the time when humans abandoned their nomadic lifestyles and adopted sedentism; in order to survive, they were now obliged to protect their crops, their cattle, their territory, and their possessions with techniques and tools that became ever more sophisticated as the centuries passed.

In spite of its obvious value, it is not always easy for society to understand science; in some cases, science can be seen as harmful and negative. Even when scientists use down-to-earth language, many people confuse fundamental concepts. A good example is the conflation of two completely different concepts, nuclear fission, and nuclear fusion. *Nuclear fission* occurs in the nuclei beyond iron in the Periodic Table when they are bombarded with neutrons, giving rise to two nuclei whose mass is inferior to the initial one. This loss of mass is transformed into energy and each fissioned kilogram gives rise to 24 million kilowatt hours. Nuclear fission is the process via which nuclear reactors produce electric power using uranium, plutonium, and so on, as fuel. *Nuclear fusion* occurs in the light nuclei from hydrogen to iron in the Periodic Table when they are heated to hundreds of millions of degrees giving rise to a lighter nucleus, so that the loss of mass is transformed into energy. The fusion of each kilogram of deuterium–tritium results in 94 million kilowatt hours. Nuclear fusion is the energy that is produced in the stars and, in particular, in the Sun; research is currently underway to produce a future massive source of energy by using lasers, particle beams or magnetic fields in the deuterium and tritium nuclei.

In addition to common confusions of this kind, other factors such as the dissemination of pseudoscientific concepts can produce disinformation and prejudice.

The Internet: Its Impact on Science Communication

When the Spanish engineer and mathematician Leonardo Torres Quevedo presented at the Paris Academy of Sciences in 1920 his electro-mechanical arithmometer, the first digital computer in the world, he could have never imagined the impact that computers would have on human lives within only a few decades. Today, traditional mass media instruments such as newspapers, radio, and TV are being replaced by the internet, which is now the most common form of personal, professional, and social communication. It is a network of networks that interconnects millions of computers, with no borders and without any governance—a decentralized system linking 190 countries. To quote Beal (2016), the total number of websites is currently 1,065,468,807 and "[…] as of August 12, 2016 there was an estimated 3,432,809,100 internet users worldwide. The number of internet users represents nearly 40 percent of the world's population. The largest number of internet users by country is China, followed by the United States and India." The following are the percentages of internet users in the world by regions: Asia (50.2%); Europe (17.1%); Latin America/Caribbean (10.3%); Africa (9.3%), North America (8.6%), Middle East (3.6%), and Oceania/Australia (0.7%) (Internet World Stats 2017).

The Internet has transformed the way we interact with the world and our everyday life, providing virtual applications for banking, hospitals, business, and shopping. It has also changed the way we learn. According to Harley (2013):

> Over two decades many have predicted that models of scholarly communication enabled by emerging technologies will transform how research is conducted, disseminated, and rewarded. The transformation would be driven by new generations of scholars weaned on file sharing, digital piracy, Facebook, Twitter and yet-unrealized social media technologies.

However, although internet provides easy access to information, it is also a platform through which illegal, manipulated, or prejudicial information can be disseminated. As Clarke (2008) points out:

> Internet is full of erroneous and even dangerous information that is difficult for people without a scientific education or training to interpret in context, particularly given the uncertainties inherent in the scientific process.

Since the Internet is a highly effective means of communication, science transmission can quickly reach most corners of the world and opens up an immense field of freedom of expression. It provides accessibility, simplicity, low cost, greater speed, larger data catalogs, continuous updating, and access to new contents in the form of patents and articles. However, though all these features might be considered a priori positive, this is not always the case. The internet requires an infrastructure and traceability is difficult. In addition, the availability of so many opinions or evaluations can lead to misjudgments, misunderstandings, and confusion among the audience who find it difficult to distinguish the true elements from the false or speculative ones. Cyberspace also provides a place for impunity for unethical actions such as plagiarism, the appropriation of intellectual property or the downloading of copyrighted materials for free.

As Dumon (2013) points out:

> By 2000, digital versions of more than 11 million research articles and the first e-books became available and by the end of the first decade of the new century, international sales growth for digital academic content surpassed hard copy. More than 1.5 million research papers are currently generated by over 200 countries and e-marketing of such content through the use of social networks now is the norm.

However, the ready availability of huge numbers of digital publications—with no effective checks on their quality or accuracy—poses a real challenge to the authority of these conventional channels of the transmission of knowledge, and can easily spread unreliable information.

Limits and Ethics of Scientific Communication

Science is social capital. However, scientific communication imposes a series of limits that must be taken into consideration, especially when this information may entail a risk for safety and security. In many countries, national security criteria are applied to scientific information whose dissemination can be harmful or counterproductive. According to the Report of the US National Scientific Foundation (1988):

> There are, however, valid reasons for withholding and controlling information and for allowing limits on open dissemination. Such grounds include national security, the conduct of diplomacy, individual privacy, commercialization of intellectual property and international competitiveness.

Among the factors which are applied to scientific communication are the scientists' own criteria about the sensitivity of their research. This question is difficult to elucidate. In words of Malakoff (2013):

> Every research field has findings so sensitive that scientists can spend countless hours fretting over when, where, and how to publish them—or whether to share them at all. For microbiologists and chemists, it might be a technique that could be misused to create a terrifying weapon. For biomedical and social scientists, huge databases of personal health and behavioral information pose threats to privacy. Archaeologists and wildlife biologists worry about pinpointing some study sites, fearful they could guide looters and poachers to priceless artifacts or vulnerable species.

Disinformation or fraudulent scientific information can cause a great deal of harm to the social perception of science. As Clarke (2008) points out:

> Some scientists and ex scientists are prime movers in promoting disinformation on the internet, and some journalists, are keen to promote causes or angles for their own reasons that have nothing to do with 'pure' science communication. Many scientists have commercial and other vested interests, or strong political ideologies, rather than being dedicated to objective interpretation.

Unsatisfactory transmission of science or inappropriate assessments of scientific issues may lead to misjudgments and social rejection. One of the most significant examples is to be found in the way nuclear energy is often manipulatively presented to society, especially by some mass media, thus eliciting an emotional reaction that has nothing to do with scientific or empirical facts. As Garvey (1979) states:

> Scientific progress could actually be curtailed if mass-media newspapers reports of research findings become a legitimate medium in the communication structure of science. That is, without rigorous scrutiny by qualified scientists a great deal of such information would be unreliable (both in terms of its replicability and relevance to science) and the foundations of scientific knowledge would become enfeebled by "unscientific information".

A relevant example of the distortion of scientific communication occurred in 2011 after the accident in the nuclear power plant of Fukushima in Japan. On 11 March of that year, Japan suffered its largest ever recorded earthquake with a magnitude of 9.0 on the Richter scale. The Japanese nuclear power plants shut down successfully. However, 40 mins afterward, the earthquake generated massive tsunami waves that peaked at heights of 46 m which destroyed the emergency cooling systems of Units 1–3 at the Fukushima Daiichi Power Plant. Reactor cores went into meltdown and released iodine 131 and, in much smaller quantity, caesium 137 radionuclides into the environment. Within the efficient emergency plan developed by the Japanese government to minimize the radiological impact on the population, stable iodine tablets were immediately distributed to saturate the thyroid gland to avoid cancer that would have caused the iodine 131. Inaccurate reports of what had happened at Fukushima provoked further anxiety among the Japanese people who, in the middle of the devastation of the earthquake and the tsunami, received stressful and apocalyptic messages through the Internet.

After the accident, international experts and observers from the World Health Organization (WHO) carried out a comprehensive damage evaluation study by entitled "*Health risk assessment from the nuclear accident after the* (2011) *Great*

East Japan Earthquake and Tsunami based on a preliminary dose estimation". The report included an evaluation of the risks of cancers and other diseases as well as public health considerations. The WHO report (2013) says:

> Cancer data from Fukushima were likely to be comparable to those from other parts of Japan. This determination was made on the basis of the similarity of cancer incidence in two neighboring prefectures for which cancer registries are available (Miyagi and Yamagata) and the other Japanese cancer registries. Also, similarities were found between cancer mortality data in those two neighboring prefectures compared with cancer mortality data in Fukushima and data from the rest of Japan. From a global health perspective, the health risks directly related to radiation exposure are low in Japan and extremely low in neighboring countries and the rest of the world.

Cases of scientific misconduct have triggered a new debate about the ethics of scientific communication. The use of internet has exacerbated the misuse of intellectual property, confidentiality, plagiarism, data falsification, and so on, which has had a negative effect on the social perception of science and science transmission. With respect to research integrity, the first report and recommendations of the Commission High Level Expert Group on the European Open Science Cloud (2016) states:

> [...] there is an alarming lack of reproducibility of current published research, together with scientific fraud, this cause enormous damage to the reputation of science. This is partly due to the lack of deep and rigorous knowledge on how to render data and the associated methodology and tools in a format that allows others to reproduce results.

According to Fang et al. (2012), 6.4% of 2047 retracted biomedical and life sciences research articles were due to misconduct, 43.4% for fraud or suspected fraud, 14.2% due to duplication, and 9.8% for plagiarism; only 21.3% were retracted for errors. These figures are negligible among the very high number of research papers published, but the existence of retractions reflects the potential harm that misconduct may cause.

Before the Internet era, the World Intellectual Property Organization (WIPO) was established as an agency of the United Nations in 1967 in Geneva in order to combat breaches of intellectual property and currently has 189 members. The Law for Intellectual Property currently has four different classification systems to make intellectual property searches easier and faster: (1) *The International Patent Classification*. (2) *The Nice Classification* (for marks). (3) *The Vienna Classification* (for figurative elements of marks). (4) *The Locarno Classification*. Furthermore, five other systems also help to protect intellectual property in its different areas: (1) *The International Patent System*. (2) *Madrid—The International Trademark System*. (3) *The Hague—The International Design System*. (4) *Lisbon—The International System of Appellations of Origin*. (5) *Budapest—The International Microorganism Deposit System*. (6) *Article 6ter on the Paris Convention* (this is a structural search which looks for the 3387 documents contained in its data collection up to March 2017). (WIPO 2017).

In 1931, the International Council for Science (ICSU) was created to promote "the Universality of Science in the basis that science is a common human endeavor that transcends national boundaries and is to be shared by all people". According to the Council, scientific activity for the good of mankind, scientific work should be communicated with integrity, respect, fairness, trustworthiness, and transparency, recognizing its benefits and possible harms. (ICSU 2017).

Improving Scientific Communication

Without scientific transmission, there can be no scientific progress. A poor or inadequate communication technique may mean that a brilliant scientific discovery will not be understood in all its magnitude. The lack of effective communication skills by scientists or engineers has been stressed for decades. Today this drawback in scientific transmission is being increasingly overcome due in part to new technologies that allow versatile means of graphic transmission such as videos, photos, interactive maps, and so on.

Another improvement in scientific communication is due to the focus in the engineering and scientific world on communication skills, acknowledging that learning to communicate should be an integral part of researcher training and of scientific education. Scientific education must overcome communication barriers of many different kinds. As regards psychological barriers, we cannot forget that each person produces and interprets messages based on their values, prejudices, norms, customs, and cultural heritage. The strength of philosophical barriers is revealed when there are different ways of thinking due to the different ways of interpreting both the world and life.

Effective scientific communication also requires scientists to take into consideration the public's needs and views and to try to use a clear and concise style to make their message easily understood. The use of complicated sentences or arguments does not help the general public to understand the essence of the message.

The Social Perception of Science in Spain

Since 2002, the Spanish Foundation for Science and Technology (FECYT) of the Ministry of the Economy has carried out a survey on the Social Perception of Science. The survey analyses various aspects of how science is perceived by the public in Spain, according to sex, age, size of town/city where they reside, and region.

In 2014 the *VII Encuesta de Percepción Social de la Ciencia* survey was carried out throughout the whole of Spain, including the Balearics and the Canary Islands. This quantitative study was based on a semi-structured questionnaire administered in personal and home interviews. Respondents were persons living in Spain for at least 5 years aged 15 and older. A total of 6355 interviews were conducted, distributed by regions (VII Encuesta de Percepción Social de la Ciencia 2014).

The survey was based on the following issues:

- Spontaneous interest in current topics.
- Spontaneous interest in science and technology.
- Reasons for lack of interest in science.
- Social image of science.
- Social image of the scientific profession
- Scientific education.
- Scientific literacy.
- Information deficit on questions of interest.
- Sources of scientific information.
- Sources of scientific information in internet.

Respondents completed a number of multiple choice questions, and some of the results are presented below. The answers may add up to more than 100%.

These percentages show that the world of science still belongs to a relatively small social sector, as has traditionally been the case. To redress the lack of understanding a new and pragmatic approach to scientific communication should be considered so as to make science attractive to the general public (Fig. 1).

The finding that 26.1% of the sample thought that the benefits and harm of science are balanced is a cause for concern. Again, new strategies of communication should be found to overcome this pessimistic and negative result. These strategies should include messages showing how science and technology contribute to social progress in most fields of everyday life, from the eradication of diseases to the improvement in people's standard of living (Fig. 2).

Television continues to be the most common means of social communication. This fact is understandable since there are still large sectors of the population who have not integrated new technologies in their everyday lives (Fig. 3).

The responses show that there are various options for using the internet to obtain scientific information (Fig. 4).

Not arouse my interest:	39.4%
I don't understand it	35.9%
No specific reason:	9.9%
I have never thought about this issue	8.4%
I don't have time	7.7%
I don't need it:	7.1%
Others:	0.9%
No answer	6.5%

Fig. 1 Reasons for lack of interest in science

The benefits of science are greater than its damage	59.5%
The benefits and harms of science are balanced	26.1%
Damages of science and technology outweigh the benefits	5.3 %
I have no opinion on this topic	6.9%
No answer	2.1%

Fig. 2 Social image of science. Contributions of scientific knowledge to the global reality

Internet	56.7%
TV	72.1%
Daily newspapers	28.9%
Free newspapers	15.5%
Radio	31.0%
Books	17.8%
Scientific journals	13.2%
General information journals	6.7%
Other	1.2%
None	0.4%
Don't know	5.9%

Fig. 3 Scientific information sources

Wikipedia	32.7%
General digital media	31.5%
Social networks	30.8%
Videos	29.7%
Blogs	25.4%
Science and technology digital media	22.8%
Radio	7.6%

Fig. 4 The internet as scientific information source

Scientific Communication in the European Union

For centuries, Europe has maintained a great tradition of scientific research that gave birth to pillars of universal main scientific fields. Until the emergence of the new technologies, the scientific exchange was made through traditional means such as the publication of results, verbal communication in meetings, mobility of researchers, and so on. However, as we have seen, in the twenty-first century this way of scientific communication has very much changed. In 2008, the European

Commission adopted the *Strategic European Framework for International Science and Technology Cooperation* in order to establish cooperation between EU countries and the rest of the countries of the world. The Framework looked for factors that could influence research cooperation and identify indicators of appropriate practices.

The EU considers it vital that science should be communicated among EU countries as efficiently as possible. This communication could be encouraged by means of efficient new data exchange mechanisms and platforms for generating an effective flow of information between participants and thus to improve coordination between different scientific communities and countries.

In order to achieve these objectives, several programs are currently being developed by the European Union: (1) *EU Framework Programme for Research and Innovation Horizon* 2020 which aims to improve communication inside the scientific community by providing specific guidelines for project coordinators and scientists. (2) *The European Open Science Cloud (EOSC) for Research* which provides support for dealing with the huge amount of scientific data and creates a tool that will aid scientific computing, storage, and connectivity.

The following are considered key factors for the effective implementation of the EOSC: (1) Core data experts need to be trained and their career perspectives significantly improved; (2) A real stimulus of multidisciplinary collaboration requires specific measures in terms of review, funding, and infrastructure; (3) The transition from scientific insights to innovation needs a dedicated support policy; (4) The EOSC needs to be developed as a data infrastructure commons which is an ecosystem of infrastructures; (5) Where possible, the EOSC should enable automation of data processing; therefore, machine actionability is key; (6) Lightweight but internationally effective guiding governance should be developed.

Effective science communication among European Union member states would help to reinforce the present capacities, enhance research visibility, encourage researcher mobility and open up new research fields of common interest.

Conclusion

Scientific progress is synonymous with social progress. Scientific research is a fundamental pillar of human development and it depends on an open, honest, responsible, and ethical scientific exchange. Communication is the essence of science, a fundamental factor for scientific advance. Science should be communicated with integrity, transparency, and respect; both its benefits and its detrimental effects must be recognized and it should always be accompanied by a sense of social responsibility.

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