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Public communication of science in Mexico: Past, present and future of a profession

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Abstract
In this article, we offer an analysis of the evolution of the professional field of public communication of science in Mexico, particularly at the National Autonomous University of Mexico, the influences it has received from other countries, the impact it has on Mexican society and some of its relationships with other Latin American countries. We present examples of successful programmes in different mass media and an analysis of the evolution and diversification of science communicators over the last four decades.

Keywords
Mexican programmes in science communication, professional field evolution, public communication of science in Mexico, science communication in Latin American countries, training in science communication

1. A framework for public communication of science in Mexico

Over a period of almost four decades, public communication of science (PCS) in Mexico has changed from an act of 'social volunteering' into a full-time profession. Socially there is no longer any doubt as to the importance of this activity, and although the internal debate concerning issues such as the nature of PCS, its objectives and who should popularize science continues, complaints concerning the scant number of science communicators,[1] the sporadic presence of science in the media, the lack of basic research papers on PCS and the absence of any formal training are a thing of the past. Present-day discussions in the field have to do with the socio-political role of PCS, its

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theoretical and methodological foundations, modalities and usefulness of research in the field, the professionalization of science communicators, evaluations performed with the purpose of increasing the communicative potential of products and activities and the criteria for evaluating those who develop them.

The Public Understanding of Science (PUS) movement emerged originally in the United States during the post-war years (Lewenstein, 1992), with the purpose of increasing the public's scientific knowledge as well as a greater appreciation for science. Backed up by the scientific establishment, it received financial support from research institutes and government agencies. Towards the end of the 1950s, Dr Luis Estrada (see ahead), the pioneer of PCS in Mexico, returned from his studies in the Massachusetts Institute of Technology (MIT) bringing with him this approach. The PUS movement was taken up in Great Britain in the 1980s and flourished in the 1990s when public disenchantment with science generated, among other reactions, the impression that the credibility in science was rapidly diminishing due to social criticism. The need for popular acceptance became a matter of deep concern in scientific circles. The movement, which spread to other countries, is principally based on the original assumption that the public will have a greater respect both for science and scientists if they have a better understanding of the nature and methods of science (see Bauer et al., 2006). Unidirectional communication from experts to lay society, the now so-called deficit model (Lewenstein, 2003), was the preferred approach. It was not a novel scheme, used worldwide since the 1950s, it was also adopted in the early days of science communication in Mexico. Research in the field became high priority and received generous patronage. Both PUS and the opposing movement that arose in the 1960s, first as Science, Technology and Society (STS) (Medina, 2013) and later as Communication Scientifique Publique (CSP), and which was adopted in Spain as Comunicación Pública de la Ciencia, lean entirely towards the democratization of knowledge and the empowering of citizens in scientific and technological matters. PUS research has gradually been shifting its views towards those of CSP. This is definitely the case in Mexico and the rest of Latin America, where this approach has been significantly displacing that of the 'deficit model', as can be seen in articles and thesis written by professionals in this region such as Merino and Roncoroni (2000), Caue (2002), Lozano (2005), Cevallos (2008) and Reynoso-Haynes (2012).

In this article, we present an analysis of the evolution of the field of PCS, both in Mexico and abroad, with the purpose of strengthening our profession as well as offering a departure point for the exploration of the challenges we face. In order to do so, we considered the different points of view found in literature over the last four decades; examined work documents, projects, thesis, data in annual institutional reports (see references) and interviewed leading figures of science communication in Mexico. The purpose of the interviews was to assess the knowledge, attitudes, opinions and concerns underlying science communication projects between 1975 and 1985. Our sample consisted of 6 leading figures and 12 individuals who played important roles during that period. The interviews were semi-structured with the purpose of promoting conversations rather than interrogations.

Three broad questions were asked: Why is PCS an important professional field in Mexico? Which were the goals 30 years ago? What do you consider is lacking today in this discipline?

To carry out the field work and data analysis, five dimensions were identified: actors, practices, scenarios, outcomes and impact. The information was grouped in a database that can be consulted in website of the SOMEDICyT (Mexican Society for the Popularization of Science and Technology).[2]

The information collected of the five mentioned dimensions was crossed with that of four categories: objectives, intentions, styles and approaches.

The trends, objectives and reasons given by the interviewees were of particular interest in terms of this qualitative analysis. It was assumed that the objectives and the strategies used to develop

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projects and concrete actions during those early years were consistent with the goals expressed by these leading figures.

In this article, the detected perspectives which served as guidelines for the original science communication projects are discussed. Over the years, we observe strikingly different approaches which have given way to a diversity of theoretical and methodological frameworks for research and production in the field.

Although we attempt to be neutral on the subject, it is important to mention that we the authors are also part of this history.

2. The professional field and profile of science communicators in Mexico

Mexico, with a population of over 113 million, is a highly diverse country[3] of social and economic contrasts with unequal educational opportunities. In this context, PCS is seen as an invaluable cultural strategy aimed at increasing the level of scientific culture of the population as an essential ingredient for the development of science and technology and the much needed social and economic transformation of the country.

An analysis of the profile of members of the SOMEDICyT shows that approximately 56% of its members work in higher education and research institutions; 33% in government and private institutions and newspapers and 11% are freelancers who work, for example, on museum projects and in the electronic and mass media.[4]

To this day, a wide range of programmes and activities are offered to different sectors of society. Exhibitions, science workshops for children and teachers, visits to laboratories, summer courses for children, television and radio programmes with scientific content, and an increasing number of interactive science museums, books, journals and newspaper items on scientific topics are part of the Mexican offer. Several examples will be presented further ahead.

Due to this variety, professional profiles of science communicators in Mexico differ greatly. For some, it is a full-time profession, and for others, it is a secondary or complementary activity to their main occupation. This second group includes scientists and also persons who work in the media. Fortunately, the number of full-time science communicators in Mexico has increased significantly over the past two decades, as will be shown in the next section.

Today PCS in Mexico is considered a professional multidisciplinary field. Due to its complexity, these professionals must specialize, for instance, in a certain area of science, the audiences they address or the media they use. Usually this specialization involves a combination of these elements. Therefore, within the group of full-time science communicators, we find people with many different backgrounds: writers, reporters, scientists, journalists, museographers, photographers, designers, computer scientists, engineers, artists and educators. There are also others who support this activity through public relations, promotion, marketing, administration and management (Herrera et al., 2009). As can be inferred from what was mentioned previously, this rich panorama has not always been the case in Mexico. In the next section, we present a brief description of how it has evolved.

3. Brief history of modern science communication in Mexico

The institutionalization of science in Mexico in the mid-20th century provided an appropriate setting for the development of PCS as a professional field. The first attempts started in the Universidad Nacional Autónoma de México (UNAM, National Autonomous University of Mexico)[5] by the physicist Luis Estrada. In 1968, with the support of a small group of colleagues, mostly from a

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scientific background, and students, he launched a journal called *Física* (Physics) for physics teachers and university students. Two years later, this journal was renamed *Naturaleza* (Nature) with the purpose of offering a larger scope of scientific topics. The elaboration of this journal became a practical school for science communicators, as well as an arena for theoretical discussions related to the field (Estrada et al., 1981). In 1974, Estrada received the UNESCO Kalinga award for this work (Zamarrón, 1994).

Between 1975 and 1980, other journals appeared. CONACyT (National Council for Science and Technology)[6] produced two journals: *Ciencia y Desarrollo* (Science and Development), considered more appropriate for the educated reader, and *Información Científica y Tecnológica* (ICyT, Scientific and Technological Information) with more of a scientific journalism approach containing interviews, reports and news. The Facultad de Ciencias (School of Science) of the UNAM started *Ciencias* (Sciences), which covers a broader cultural scope. In the 1980s, other publications appeared such as *Chispa* (Spark) for children, *Avances y Perspectiva* (Advances and Perspectives) for the academic community, *Cuadernos de Nutrición* (Notebooks on Nutrition) with an educational perspective and many others produced by various institutions throughout the country. Nearly 20 years later, in 1999, the UNAM started a very popular science journal for teenagers called *Cómo ves* (What do you think?). The most recent one is *El Faro* of the Coordinación de la Investigación Científica of the UNAM (CIC, Coordination for Scientific Research).[7]

In 1970, Estrada and six other colleagues founded a science department within the Dirección General de Difusión Cultural of the UNAM (General Direction for Cultural Dissemination of the UNAM) with the purpose of communicating science to the non-experts. In 1980, this department became the Programa Experimental de Comunicación de la Ciencia (PECC, Experimental Programme for Science Communication), which was the seed for an institution called Centro Universitario de Comunicación de la Ciencia (CUCC, University Centre for Science Communication) opened a year later. The CUCC was the first university institution devoted completely to science communication, a very important step towards the professionalization in the field (Zamarrón, 1994). In 1997, the CUCC became the Dirección General de Divulgación de la Ciencia (DGDC, General Direction for the Popularization of Science) (Acuerdo CUCC-DGDC, Gaceta UNAM, 1997).[8] At present (2014), 704 persons work in the DGDC, of which 96 are full-time science communicators, 244 are students, and the remaining 364 perform administrative tasks, technical activities and maintenance chores.

The DGDC has two science museums; communicates science using a full range of media (radio, television, web, conferences, demos and science theatre); edits a magazine for teenagers and the general public on science-related issues; offers courses and workshops on scientific topics for teachers, children and the general public as well as postgraduates courses for training professional science communicators; organizes and participates in events such as a Summer course for children, science fairs and outreach programmes; collaborates with research institutes and other museums within Mexico and abroad; and carries out studies and research in the field of PCS (www.dgdc.unam.mx).

One of the preferred forms for communicating science in Mexico is by means of activities such as informal lectures, demos and workshops. The pioneer in this endeavour is the Academia Mexicana de Ciencias (AMC, Mexican Academy for Science).[9] In 1982, the AMC initiated a series of informal talks on a wide range of topics called 'Domingos en la ciencia' (Science on Sundays) given by scientists and science communicators to the general public which continue to take place in various cities and towns throughout the country to this day. Other similar experiences are the 'Encuentros de divulgación científica' (Encounters in Science Communication) organized every year since 1985 by the Sociedad Mexicana de Física (Mexican Society for Physics)[10] in the city where the annual physics conference is held, and the 'Science and Technology Week' organized by

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the CONACyT which takes place every year all over the country since 1994. Besides the CONACyT, each state in the country has its own science and technology council, each one responsible for the dissemination of local science activities. In 2012, a special fund was created within the CONACyT to support and promote programmes for the PCS developed by each of the 32 state councils in Mexico. This initiative called 'Estrategia Nacional de Difusión y Divulgación de la Ciencia, Tecnología e Innovación 2012: Ciencia para todos y en todos los rincones' (National Strategy for the Dissemination and Popularization of Science, Technology and Innovation 2012: Science for all and in every Corner of the Country) emphasizes particularly in reaching marginal communities in rural areas of difficult access (Patiño et al., 2013).

One of the most ambitious editorial projects in PCS was launched in 1986 by the publishing house *Fondo de Cultura Económica*: a collection of books on different topics written by Mexican scientists called 'La ciencia desde México' (Science from Mexico). In 1997, having reached 157 titles, the collection became international and its name was changed to 'La ciencia para todos' (Science for Everyone), with the purpose of including authors from other Spanish speaking countries (Farías, 2002). To date, the collection is composed of 333 titles.[11]

Traditional sciences museums have existed in Mexico since the 19th century. Within the UNAM, two outstanding examples are the Geology Museum[12] opened in 1906 and the Botanical Gardens of the Institute of Biology[13] in 1959. The first two hands-on science museums in Mexico were the Museo Tecnológico[14] (Museum of Technology) founded in 1970 and the Centro Cultural Alfa[15] in Monterrey, in 1978. In the 1980s, there was an international boom of interactive science museums and centres. In Latin America, three pioneer museums belonging to public universities are the Estação da Ciência in São Paolo, Brazil, opened in 1987; UNIVERSUM[16] on the university campus of the UNAM in 1992; and the Museo de la Luz[17] (Museum of Light) in 1996. The first offers a remarkable programme called 'Clicar' designed specifically for the children and youngsters that live in extreme poverty; the second one is known because most of its exhibits were planned and designed for the Mexican public by a multidisciplinary team of professionals within the UNAM; and the third one blends science, history and art around the topic of light. Within the next few years, science museums and centres sprouted in many other parts of Mexico as well as other Latin American countries. Some outstanding examples which offer special programmes designed to serve underprivileged sectors of society are Centro de Ciencias EXPLORA[18] in León, Guanajuato in Mexico, opened in 1994, and Maloka[19] in Bogota, Colombia, opened in 1998, and the Museo de la Ciencia y el Juego, opened in 1984, also in Colombia.[20]

Most children's museums in Latin America have an important component of science-related exhibits and activities. The first children's museum in Latin America was the Museo de los Niños[21] in Caracas, Venezuela, inaugurated in 1979. Another outstanding example is the Papalote Museo del Niño[22] in Mexico City opened in 1993, which has been the seed for several other children′s museums throughout Mexico.

UNIVERSUM is one of the main contributors to the analysis of the role these environments play for science communication as can be seen in numerous publications such as *La museología de la ciencia: 15 años de experiencia* published by the DGDC (2007), and *Aportes a la museología Mexicana* (2009), as well as various articles circulated internationally and nationally.

As in the rest of the world, the presence of science issues has increased considerably in the last few years. The website called Cienciorama[23] coordinated by Luis Estrada is the result of a multidisciplinary effort geared to offering a forum for the analysis and discussion of a wide range of scientific topics, particularly research that is done in Mexico.

The UNAM provides reliable information to news media with publications produced by different research institutes. It also produces radio and television programmes on scientific topics which

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are broadcasted on commercial or cultural channels and stations as well as the UNAM's TV channel[24] and radio station.[25]

As for professional networks in this field in Mexico, the first one was SOMEDICyT founded in 1986, with only 19 members located in the urban area of Mexico City. Today, this society, composed mostly of full-time science communicators, scientists, teachers and journalists, has 240 active members from 17 of the 32 states in the country (Patiño, 2014). Some of the products and activities of SOMEDICyT are series of books on science topics for children and youngsters, peer publications in the field, the development of exhibitions and science museums, and products on the Internet. It has organized numerous national and international conferences and has contributed to the professional development in the field by means of seminars, courses and workshops. It offers an annual award to outstanding communicators and encourages young science communicators by organizing contests for essays on different scientific topics.

The Asociación Mexicana de Museos y Centros de Ciencia y Tecnología[26] (AMMCCyT, The Mexican Association of Science and Technology Museums and Centers) was created in 1996, and it includes most of the science museums and centres in Mexico. AMMCCyT's mission is to contribute to the effective promotion of scientific and technological culture of the Mexican society. Through this network, its members collaborate, share exhibitions and stimulate professional growth.

The most important team effort in the Latin American region is the creation of the Red de Popularización de la Ciencia y la Tecnología para América Latina y el Caribe[27] (Red POP Network for the Popularization of Science and Technology in Latin America and the Caribbean) founded in Rio de Janeiro in 1990. This interactive network is composed of centres and programmes for the popularization of science and technology with members from 12 countries in the region, including Mexico, associate members from Europe and the United States. As a reference, we recommend the publication by Julian Betancourt (2001) on the 10th anniversary of the network. In 2013, SOMEDICyT won the Latin American Prize for the Popularization of Science given by the Red POP for its contributions to the development of popularization of science in Mexico and Latin America (www.somedicyt.org.mx).

Different programmes strengthen Latin American regional cooperation, such as the Convenio Andrés Bello (CAB: Andrés Bello Agreement), the Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo (CYTED: Ibero-American Programme for the Development of Science and Technology) and the Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura (OEI: Organization of Ibero-American States for Education, Science and Culture). These resources are undoubtedly fundamental to the development of scientific and technical culture in our region. Mexico is a member of all of the above-mentioned programmes.

4. The training and professionalization of science communicators

During the late 1960s and the decade of the 1970s, a first generation of science communicators in Mexico started taking shape. At that time, formal courses in science communication did not exist in Mexico or abroad. The only school for this pioneer group in science communication was practical experience. Most of them came from a scientific background and the rest from the field of communication. Those whose initial background was science had to acquire experience and skills in some communication media, and those who started out in the field of communication had to learn to collaborate with scientists.

Gradually, a second generation of science communicators began to emerge. Its members also had an initial professional training in one of the fields mentioned above, but decided to take a step further and enrolled in formal postgraduate studies or specialized courses in a complementary field they considered would be useful for their work.

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The need to plan and design specialized courses to train science communicators soon became evident. Both generations combined their expertise to develop and teach these courses. In 1995, the UNAM launched the Diplomado en Divulgación de la Ciencia (Science Communication Diploma), a 240-hour course designed with the purpose of providing the required theoretical and practical tools in order to enable graduates to communicate science to the general public (Reynoso-Haynes, 2009). Since that date, this course is offered every year. At present (2014), the 19th edition is underway. Over 340 students have graduated from this Diplomado. The demand for this course increases every year, as well as the number of requests the DGDC has received to offer similar courses in other institutions within Mexico and abroad.

Continuous evaluation has been a fundamental instrument for the planning and updating of these courses. In 2007, the Diplomado en Divulgación de la Ciencia was subject to a thorough diagnosis (Medina et al., 2007).

In recent years, there has been an increase in the number of courses in Mexico that offer professional training in the field. Graduates, master degrees and subjects in undergraduate programmes are part of the offer. Some examples are the courses in scientific journalism in the School of Political Sciences of the UNAM, postgraduate courses offered in institutions such as the Universidad Autónoma Metropolitana[28] (UAM: Autonomous Metropolitan University) in Mexico City, and the Master's Degree in Science Communication and Culture at the Instituto Tecnológico y de Estudios Superiores de Occidente[29] (ITESO: The Western Institute for Superior Studies) in the city of Guadalajara, Jalisco. Each one has its entrance requirements, curricula and graduate profile depending on different needs and approaches.

Since 2003, the Postgraduate Programme in Philosophy of Science of the UNAM offers a master and a doctorate degree with several terminal options, one of these is science communication, strongly focused on theory and research skills. This programme is shared and supported by several university departments: the School of Philosophy and Literature,[30] the School of Science, the Institute for Philosophical Research and the DGDC at the UNAM.

The 21st century presents new creative, intellectual and ethical challenges to the field of science communication that increase day by day in complexity, richness and diversity including new theoretical and methodological contributions, a growing presence in the web, new proposals and approaches for communicating science, new media, as well as new options and professional needs. Based on the two UNAM experiences, the Diplomado en Divulgación de la Ciencia and the Science Communication branch of the Philosophy of Science Postgraduate Programme, as well as present-day needs for professional development in the field in all its complexity, the academic department within the DGDC is currently working on a project for a postgraduate specialization in science communication that will offer students a solid theoretical and methodological background as well as the opportunity for extensive practice in some area of personal interest.

5. Research in science communication

In Mexico, experience on research in SC goes back to 1983 with an article by Carlos López Beltrán (1983), 'La creatividad en la divulgación de la ciencia' (Creativity in science communication), published in the last issue of *Naturaleza*; in this paper, SC is considered a multidisciplinary activity, strongly dependent on scientific content but at the same time with creative independence in the style and resources used to communicate scientific contents. A few years later, a text by Daniel Jacobi and Bernard Schiele (1988) 'La vulgarisation scientifique. Thèmes de recherche' in *Vulgariser la science, Le proces de l' ignorance* appeared in France. In this paper, the concern about SC as an object in itself for interdisciplinary research was presented for the first time.

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At the same time and along the same line of thought, the CUCC (Centro Universitario de Comunication de la Ciencia, 1988) prepared a collective document with the title 'Aspectos de investigación en la comunicación de la ciencia' (Aspects of Research in Science Communication), where it is suggested that communication of science should be performed with a more professional methodological approach and that research should have a multidisciplinary perspective. It points out the need for combining effective ways of establishing a communicative bridge between the audience and scientific concepts, by recreating the initial scientific discourse, with a critical and analytical spirit that facilitates the evaluation of the effectiveness and originality of what is produced.

According to this document, research activities carried out in this field can be classified into two major categories: (a) the study and analysis of scientific disciplines themselves in relation to their content and discourse, and (b) the forms and resources used to communicate science. In this second category, research projects could focus on inquiring about the characteristics and interest of the target audience, the study and responses and mechanisms that allow a continuous feedback about how the process is evolving. It is interesting to note these issues still apply today, and based on these ideas, the suggested strands for future research are as follows:

1. The analysis of different facets of scientific knowledge: how it is constructed, fundamental paradigms and the relationship between science and its context.
2. The relationship between science and other disciplines with the purpose of understanding science in a broader perspective, as well as the multidisciplinary nature that characterizes the solution of complex problems in which scientific knowledge intervenes.
3. The construction of a cultural atmosphere which includes science and its relationship to other disciplines, daily life and activities such as industrial ones. In Mexico, the relationship between science and industry is still quite rare.
4. An analysis of how to move from the discourse of academic science to a discourse of science for the public.
5. An analysis of the impact of science communication.
6. The discussion of basic fundamental concepts needed to understand scientific ideas and how to present such ideas in comprehensible terms.
7. The development of criteria for evaluating products and activities in the field with the purpose of establishing guidelines for improvement.

In 1989, with Jorge Flores as director of the CUCC, the first institutional initiative to produce written analytical work on science communication was launched in collaboration with the AMC. A section dedicated to studies in science communication was proposed in *Ciencia* (AMC's journal). The section initiated in 1991 with an article by Ana María Sánchez (1991) with the title 'Sobre la elaboración de artículos de divulgación científica' (About the elaboration of science communication articles) which was the first of a series of five. This project proved the need for a peer publication on the subject. Another big and successful project in this direction is a collection of books proposed by Juan Tonda, from the DGDC, called 'Divulgación para Divulgadores' (Science communication for science communicators). Until now, this collection has ten books of which one has been translated into Portuguese (Sánchez, 2003).

In the proceedings of conferences of the SOMEDICyT and Red POP, various studies in diverse fields of SC have been published, such as methodological proposals (Sánchez, 1991) and impact evaluations of journals (Tonda and Burgos, 2007). Nevertheless, research carried out in science museums and centres are the most numerous and have contributed considerably to our understanding of the role such environments and their activities play in science literacy. Over the past decade,

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considerable progress has been made in trying to understand the meaning of learning in museums. From such studies, we have learned that the three characteristics of informal learning apply to science museums; these are that learning is a personal experience, that it is contextualized and that it takes time. However, there is still a need to learn more about how the complexities of this learning process interact holistically, and then, how this kind of research will significantly contribute to the development of improved frameworks for practice and evaluation in our museums, as well provide a basis for future research. There are many examples of this kind of research in Reynoso-Haynes (2000, 2001, 2003), Lozano (2005), Rico (2009) and Sánchez-Mora (2002, 2006, 2009, 2009, 2012).

Despite the previously mentioned efforts, as Miller (2008) pointed out, there is almost no connection between these theoretical proposals and practice. Ana María Sánchez (2010) considers that 30 years after the first attempts at analysing the "science communication phenomenon" as well as numerous outstanding published papers, the results of some of these investigations are inconsistent and sometimes contradictory, and this is of course the case with Mexican research. The main criticism of such studies in some cases is their lack of potential for application because they are too specific and correspond to a particular context with no possibility of becoming more generalized, and in others because they are vague and therefore not applicable to concrete cases.

Research in science communication usually comes from the social sciences, and there has been a tendency to insist on the need for methodology, and the use of formal instruments such as quantification, statistics and models. Although statistical studies with demographic variables are useful, some criteria used and results of these studies are questionable (see Bauer et al., 2006). Sánchez (2010) points out that research in this field refers to the analysis of products of an intellectual-artisanal activity in situations that cannot be repeated, and therefore with no possibility for prediction or generalization.

Finally, the evaluation of products and research in PCS are closely related. The issue of evaluating science communication products, activities as well as the producers themselves is an old but at the same time contemporary debate. A Latin American contribution to this discussion can be found in the proceedings of a workshop held in Cartagena, Colombia, in 2006, in which several experiences and proposals related to the evaluation of products and activities in this field were presented (Lozano et al., 2008).

Another current discussion has to do with the evaluation of the science communicators themselves. Several efforts in this direction have been underway now for several years. A group within the DGDC has been working on a proposal which includes peer evaluation, criteria and parameters for an adequate and just evaluation for a wide spectrum of profiles of science communication professionals. The first results of these discussions can be found in the proceedings of conferences and formal communications such as Delgado et al. (2003), Reynoso-Haynes (2008), and more recently in the XIII Red POP and XIX Somedicyt conferences (Bravo et al., 2013).

Among the conclusions of such discussions is that the evaluation of products and their producers is inseparable. Any scheme proposed for this purpose is based on a specific conception of science communication, which includes the objectives that are pursued on carrying out this task, the image of science that one wishes to portray and the relationship we seek with the recipient of our products. This issue is particularly important to those who work in universities and research institutions (Reynoso-Haynes and Tonda, 2013).

7. The future and challenges of science communication in Mexico

The analysis presented in this article shows that the field of PCS in Mexico is in a state of growth and consolidation, with groups carrying out this activity in almost every state in the country (Reynoso-Haynes et al., 2004; Crúz et al., 2006). The aims and objectives for communicating

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science to different sectors of the population have increased and diversified, covering a wide and varied scope of topics and issues, using all the different media available. As the discipline matures, research in science communication has at least permitted, if not the solution, the raising of problems that previously went unnoticed (Sánchez, 2010).

Theoretical and methodological contributions from other areas of knowledge, the exchange of experiences, reflections, analyses, studies and experimentation have helped build a body of knowledge all of its own. Some indicators are the generation and strengthening of professional networks and associations in the field, both nationally and internationally, the quantity and quality of publications, conferences, academic forums and professional theses on subjects related to science communication.

In order to be competitive in this field, there is an increasing need for theoretical frameworks, tools and skills. Although the field of PCS has reached worldwide recognition, it is still a young and therefore vulnerable profession with many challenges to be faced. Broadly speaking, we can classify these challenges into three big categories:

a. The challenges related to the national context in which this profession is carried out.

Although the need to incorporate science into the general culture of the population is recognized as urgent, the activities and programmes aimed at achieving this goal have not received an adequate level of acceptance and support from decision makers and the society as a whole. A greater presence in the media is necessary as well as more opportunities for encounters between experts and citizens, so that the latter can learn and participate in debates on matters related to scientific knowledge that have an impact on their personal and collective lives. In order to reach the desired goal, collaboration between several sectors of society is required: researchers, teachers, the media, decision makers and the community of science communicators as intermediaries between all the abovementioned sectors and the public.

The starting point for this collaboration is an analysis of the meaning of scientific culture and its link to society. Some of the issues that will have to be tackled are the goals and objectives of a scientific culture for the population, the necessary basic knowledge and skills needed to fulfil these goals and objectives and the attitudes and values that should be promoted when applying this knowledge (Reynoso-Haynes, 2007).

In this era of global knowledge, the balance between global and local knowledge is fundamental, as well as the application of this knowledge to the solution of local problems. We propose the use of a glocal model for science communication, which is based on the idea of combining global knowledge and its application to the local context considering local interests, problems, solutions and expertise. This model encourages in the public a sense of belonging and commitment to their natural, social and cultural surroundings (Reynoso-Haynes, 2003, 2005; Reynoso-Haynes et al., 2005). This approach is highly advisable in cases in which citizen engagement is critical, such as in issues related to public health, environmental problems and climate change.

b. The challenges corresponding to the institutional context in which science communication is carried out.

Most science communicators in Mexico work in universities, higher education or state institutions. Unfortunately, due to the relative professional youth of this activity, programmes, projects and groups in these institutions are vulnerable to political and institutional changes. A clear mission is required as well as strategies to guarantee their stability. Programmes should not be attached to one specific administration or to political interests but instead to long-term plans framed within an

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institutional project that is based on a collective analysis of the need to integrate science to the general culture of the population as well as the role of the community of science communicators in this task.

Institutions need to have clear guidelines and plans for their development, which includes criteria for hiring, promotions, permanence and professional growth of its personnel. Different types of profiles for science communicators should be established with the purpose of facilitating these decisions. At the same time, the personnel hired deserve to be evaluated with fair criteria based on the nature of the work they perform.

c. The challenges inherent to the activity.

Finally, the challenges mentioned above are based on the problems that are inherent to the activity in its quest for obtaining a respectable 'professional status'. Issues such as the definition of the required scientific culture for the population and our social responsibility and relationship with our audience must be dealt with. Contributions to the field of knowledge are in order, with proposals of new theoretical and methodological foundations, studies, experimentation and evaluation.

Parameters must be established for evaluating products and activities with the purpose of learning and improving, not grading or legitimizing. These tasks should not be viewed as 'intellectual luxuries' but as necessary instruments for communicating science effectively, with quality and responsibility. Such activities should be seen as fundamental to the adequate and successful development of projects and therefore require full institutional support.

Last but not least, professionalization requires the support of postgraduate studies, postgraduate courses, courses to learn new topics or skills, workshops, exchange programmes, and participation in forums and conferences for professional development.

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Notes

1. The term science communicators will be used in this article to refer to those who communicate science to non-experts.
2. Divulgadores en primera persona (2014).
3. www.inegi.org.mx/Sistemas/temasV2/Default.aspx?s=est&;c=17484
4. Sociedad Mexicana para la Divulgación de la Ciencia y la Técnica (2013). La divulgación de la ciencia en México desde distintos campos de acción: Visiones, retos y oportunidades, México.
5. http://www.unam.mx/
6. http://www.conacyt.gob.mx/Paginas/InicioNueva.aspx
7. http://elfaro.cic.unam.mx
8. http://Gaceta UNAM. 132.248.247.1/cgi-bin/pwisis.exe
9. http://www.amc.unam.mx/
10. http://www.smf.mx/
11. http://www.fce.com.ar/ar/libros/listado.aspx?cat=c&idCol=22
12. http://www.geologia.unam.mx/igl/index.php/difusion-y-divulgacion/museos/museo-de-geologia

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13. http://www.ibiologia.unam.mx/jardin/historia.swf
14. http://www.cfe.gob.mx/mutec/es/Pages/Home.aspx
15. http://www.planetarioalfa.org.mx/
16. http://www.universum.unam.mx/
17. http://www.museodelaluz.unam.mx/
18. http://www.leon-gto.com.mx/la-ciudad-leon/explora-museo-ciencias/
19. http://www.maloka.org/
20. http://www.cienciayjuego.com/jhome/
21. http://www.maravillosarealidad.com/
22. https://papalote.org.mx
23. http://www.cienciorama.ccadet.unam.mx/
24. http://www.tvunam.unam.mx
25. http://www.radiounam.unam.mx/
26. http://museosinteractivos.org/ammccyt.pl
27. http://www.redpop.org
28. http://www.uam.mx
29. http://portal.iteso.mx/portal/page/portal/ITESO
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