Chapter 9
The More, the Earlier, the Better: Science Communication Supports Science Education

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Abstract Since the 1980s, science communication and science education have experienced noteworthy changes and progress. Evolving and expanding on their way to accomplishing their historical missions, the two areas have at least one goal in common—to improve the scientific literacy of the people to enable them to live well in a modern society that is being transformed by science and technology more rapidly and completely than ever before. Considerable achievements have been made in both areas, but there are still many opportunities to do better. The authors review and analyse work in science education and science communication over the past three decades, focusing on common goals. They argue that problems in science education, such as shortages of trained science teachers, can be reduced in the short term by applying practices from science communication, by linking scientists and science communicators more closely with educators, and by doing so at an earlier stage in students' school education.

Keywords Education, science, science communication, science community, science education, scientific literacy

9.1 Introduction

The decade of the 1980s was a period of impressive social reform, during which the world witnessed great changes in the political and economic spheres. These social shockwaves and the ripples that followed are attributed by many, to a certain extent,

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to the 'stirring hand' of science and technology (S&T)—creations nurtured by society that paid society back with their impacts. History reveals the interactive relationship between science and society. As science communicators, we are concerned with that relationship and with the active elements in it.

Campaigns for the public understanding of science (PUS) and for science education reform have been important elements in the science–society relationship. Both types had occurred before the 1980s, but two crucial documents that appeared in the middle of 1980s illuminated science communication and science education and the links between them. In 1985, the Royal Society published *The public understanding of science*, initiating an enduring global PUS campaign; and in 1986 the American Association for the Advancement of Science (AAAS) published *Science for all Americans*, signalling the direction of a new round of science education reform and initiating the long-term Project 2061 scheme.

The following years saw more, broader and much more sophisticated activities in the two domains. UNESCO initiated a campaign for science education in 1990 (UNESCO 1990) and strengthened it in the *Declaration on science and the use of scientific knowledge* in 1999 (UNESCO 1999) and a series of other declarations. In the face of urgent social problems accompanying the progress of S&T and society generally, the science community took the lead in a re-examination of the remit of science communication, paying close attention to the scientific literacy of the public. Many national governments began to take steps to prepare their citizens for a knowledge-based society, and expressed concerns about the social implications of S&T communication and education.

In all these areas, science communication and science education were closely connected. Although two different social activity domains, they share the goals of raising public scientific literacy and fostering the harmonious development of science and society. For a long time, however, each evolved in its own disciplinary 'space' and followed its own track. In dealing with social problems, the two disciplines were not well prepared to take better and more effective joint actions.

From the science communication perspective, there is plenty of room for the science communication community to provide assistance or services for science education. This is especially true in the areas of institutional construction, effective initiatives and resource allocation. There is a need for such assistance.

This chapter looks into science communication and science education separately, focusing on similar or common challenges in the two domains, and then presents our ideas about possible solutions. We argue that the science communication community should take active steps to integrate with the science education community and provide practical, facilitative support for its counterpart, especially in primary and secondary school education. The more support, and the sooner it is delivered, the better. If the two communities are to achieve their mutual objectives, we should make full use of science education as a main channel for the improvement of public scientific literacy and the continued construction of scientific culture.

9.2 Science Communication: From Popularization to Social Participation

In its early days and for a long time afterwards, science was considered the business of a small group of people—mainly the literate upper classes. As scientists moved towards specialization and professionalization just before the middle of the 19th century and scientific associations like British Association for the Advancement of Science and the AAAS began to grow (Bruce 1987, Kett 1994), science entered a long 'golden age' of popularization. The birth of the Science Service in 1921 allowed an even greater audience to be reached through new media (Rhees 1979, Lewenstein 1994). After World War II, especially from the late 1950s when science popularization began to take in the entire society, the traditional public 'gee whiz' at the wonder of science gradually gave way to concerns about the social impacts of scientific advancement and about public science literacy.

The most significant changes took place in the 1980s. One event with long-lasting effects was the release of *The public understanding of science* (the Bodmer Report) in 1985. Perhaps its most valuable contribution was that it put forward the idea of engaging the public in science (Briggs 2003). The report can be regarded as the starting point for PUS campaigns on a global scale (Broks 2006); ever since then, the public has been encouraged to participate in science.

The underlying rationale for PUS campaigns was sophisticated. On the one hand, while enjoying the benefits brought by S&T, the public was alert to the threats of nuclear weapons and environmental pollution from the inappropriate application of technology. Antagonistic voices were becoming louder (Gregory and Miller 1998). On the other hand, public scientific literacy surveys in the US and some other countries showed that public command of scientific expertise was at a low level—an apparent inconsistency in modern social systems, which rely ever more heavily on the progress of S&T.

In such a context, better public understanding of science was erected as a milestone to be reached. It matters, said the Bodmer Report, because it contributes to the enrichment of the individual's life, the improvement of public life and the national prosperity (Royal Society 1985). Better understanding comes from improved public scientific literacy. Discussion of scientific literacy was widespread, its connotations multiplied and the concept became enriched.

The tide swirled to a climax in the 1990s, as the campaign swept across the world. More international organizations and more countries joined in, especially the developing countries. In this rapidly changing social context, public science communication became a grand view in at least the following aspects:

- The scope of the movement expanded. While the science content of communication activities grew and methods multiplied, activities in many countries spread from cities into rural areas and from upper classes to other groups (especially to underrepresented social groups, such as women and ethnic minorities, whose particular requirements had usually been neglected).

- Infrastructural and institutional construction mushroomed in many countries. S&T museums and science centres were built. Universities inaugurated discipline subjects and created professorial positions related to science communication.
- Science reporting in the mass media soared, and the internet became a major tool for communicating S&T.
- National governments drew up strategic plans for science communication and backed them up with managed programmes and increasing financial investments.
- Public engagement became the leading trend, in both theory and practice. The didactic 'top-down' concept was edged out by 'bottom-up' methods that emphasized listening to and engaging in dialogue with the public.

In this expanded ensemble of science communication, one of the key tunes was still the one calling for us to raise the scientific literacy of the public at large.

From 2000, science communication was further recognized for its value in national, social, scientific and technological progress. From the national perspective, public understanding of and participation in science was highlighted in social governance. It was widely taken into national policy frameworks for S&T, and seen to be closely related to a nation's general competitive capacity, creative ability and sustainable economic development. Guiding policies were tailored more closely to the real world, and large-scale national action plans emerged here and there, such as the Science and Society Action Plan of the European Commission's Research Framework Programme and China's Outline of National Action Plan of Scientific Literacy for All Chinese Citizens.

From the societal perspective, the dynamic function of science communication in raising the public's awareness and ability to take part in social activities was broadly accepted by consensus. Although the meaning of 'public engagement in science' is understood and explained differently in different countries or communities (due to their different stages of development), this does not stop them producing well-planned and well-received activities corresponding to their local needs. As a result, science communication around the world has an animated, multifaceted collection of patterns and objectives. With the encouragement and support of national governments, more and more scientists and scientific institutions are now approaching the public through the education system, the mass media and many other channels. One of their missions is to join the public and get it involved in knowing, discussing and assessing the unavoidable questions about ethics, uncertainties and risks in S&T, and get it involved in decision making. The public needs to be scientifically literate to live well in modern societies, and scientific literacy remains the basic target of all the efforts of the science communication community.

After three decades of strategies, plans, campaigns and initiatives, however, some problems remain unsolved in the domain of PUS. The public at large continues to hold a comparatively high interest in science, but public scientific literacy has lingered at a marginal level over the years (OECD 1997, European Commission 2002, Cheng et al. 2006, Broks 2006).

To tackle this problem, science communicators need to come up with new ideas and make harder efforts. In our view, we need to take a progressive and pragmatic approach, and actively cultivate citizens' scientific literacy through science education. In the vernacular of our country, the science communication community should uphold the banner of public scientific literacy, march forward and abreast with science educators, take a positive stand to combine with them, and assist and support their efforts.

In the following discussion, we examine how science education has developed in the recent past, discuss the possibility of science communication and science education coupling to produce better results, and to describe a few commendable cases where this has already happened.

9.3 Science Education: from Passing on Knowledge and Skills to Nurturing Scientific Literacy

In parallel with mainstream PUS campaigns advocating 'science for all' in the 1980s, science education was brought into focus amid waves of education reform.

Science has been taught in schools as a legitimate part of the curriculum for no more than 200 years. But science education, a group of young subjects compared with grammar, Latin and mathematics, put its roots deeply into education systems and grew up quickly and vigorously. It soon became an object of concern and study by many educators, education researchers and sociologists, and was also a key area of concern of governments and international organizations. For example, science education always features prominently at United Nations conferences and in UN documents on S&T policies or education policies. Specific statements about science education are also made in papers and resolutions about other topics, such as development, poverty alleviation, health and the environment.

The reason for this focus on science education is the proliferation of S&T into all areas of social life and the dynamic response of education systems. The background message is that, in an era of globalization, economic growth based solely on capital investment gives way to growth that relies heavily on science-based technology and higher worker productivity. S&T not only decides the products and the markets, but also transforms the content of labour at the same time. In particular, the advent of computer as a tool in production and management is none other than a revolution in traditional notions of labour.

In these circumstances, human resources become an indispensable and non-negligible component of the competitive capacity of any country. If a nation does not possess an abundant labour resource with a fundamental S&T education, if qualified engineers cannot be easily hired, if there is no cutting-edge creative corps, or if there is not substantial research and development to support S&T innovation, the nation will be beaten in an international contest for products and markets that is growing harsher day by day. In the production chain from design and innovation through manufacturing to selling and servicing, countries without this nucleus of competitive S&T capacity have no choice but to cling to the manufacturing link, making low value-added products through high resource consumption.

Scientific literacy is also likely to become a personal, internal requirement for citizens who aspire to meet their social obligations, pursue their aspirations and live dignified lives. Educating youngsters in school to develop scientific literacy enables them to take up their responsibilities for the future of their society, their families and themselves, and has become a natural obligation of school education systems, placed on them by society at large.

For these economic and social reasons, many countries have made it their priority to improve the quality of science education, starting from the elementary stage.

In the current round of science education reform, the goal has shifted from producing sci-tech elites (capable candidates for upper level S&T education) to developing every student's scientific literacy. This strategic change has given rise to a chain reaction in many other areas of education, such as curriculum development, pedagogy and evaluation. The teaching of science as a package of knowledge has been converted into the nurturing of scientific literacy, so the content of courses has changed as well. This down-to-earth policy and practice reflects the aim of 'scientific and technological literacy for all' (UNESCO and ICASE 1993), which followed the advocacy of 'education for all' put forward in 1990. Overall reform in the education domain as a whole has also showed the impacts of PUS campaigns, particularly the notions of 'science for society' and 'going to the public'.

Today, the science education aim of improving the scientific literacy of all students is the dominant trend. However, it has not yet been achieved. Three big, embarrassing obstacles block the way:

- A lack of excellent science education resources
- A deficiency of qualified science teachers
- Declining interest in science among young students

A common challenge facing science educators around the world is the need to develop new curriculums for general scientific literacy and to find suitable, up-to-date teaching materials. The Project 2061 office of the AAAS assessed the science textbooks in use in secondary schools in 1999, and commented that 'not one of the widely used science textbooks for middle school was rated satisfactory' (Koppal 1999).

The shortage of suitable teachers for new courses is also a global problem, and has resulted in a drive to transform teacher education and provide in-service training for science teachers. The consensus of educators and policymakers is that teachers are the crux of science education reform; the question is where to find (or rather, to develop) teachers who are capable and well prepared to teach for scientific literacy.

Today, when societies and economies rely more and more on S&T, a paradoxical emerging trend has alarmed the leading industrialized countries of the West: young people are losing their interest in S&T and are moving away from choosing S&T as a career. Many research reports have detected the trend. Although various corrective measures have been taken in recent years, the current situation is no cause for optimism. Politicians understand the seriousness of the problem clearly: 'Stimulating interest among Europe's young for science and technology is crucial if Europe is to have a future based on the best use of knowledge' (Potočnik 2007).

As we see it, there is no quick way to remove the three key barriers to achieving the new science education objectives. It is therefore worth considering the adoption of some strategies and initiatives from the PUS domain to reduce the barriers and reinforce science education reform.

9.4 Backing Up Science Education

In our review of science communication and science education, it is easy to notice the conspicuous interrelation between the two domains. Two aspects stand out: one is the compatibility of the aims of the two domains; the other is the interdependency of solutions in both areas. Starting in the 1980s and from different angles (such as 'science in society' and 'education for future citizenship'), both called for scientific and technological literacy for all. The common goal is to produce citizens, now and in the future, who can participate in the life of modern society and are fortified with the values of democracy, and to ensure a sustainable future for a planet that has been transformed by the application of high technologies. Science communication and science education belong to different social domains, but because they share a goal and their target groups overlap, they can surely support and benefit each other by sharing initiatives, human resources and information.

To enhance public scientific literacy is one of the primary goals of science communication activities, while school science education is normally regarded as the basis or main channel for reaching that goal. Science education must respond to modern society's calls for the scientific literacy of every citizen, and at the same time produce a large enough cohort of high-quality scientists and engineers each year to meet economic and technical demand. To achieve these twin goals, science education (especially in primary and secondary schools) must urgently renew its teaching materials and facilities. Unfortunately, current levels of human resources and facilities make it hard to carry out this significant transformation. Therefore, there is an urgent need for large numbers of S&T professionals with an empirical approach to scientific inquiry to help schoolteachers in transforming their pedagogy. This may mean huge investments in school systems, and will certainly take some time.

Nevertheless, if we take a wider look at the problem, we might find a way around the problem, at least for the short term. 'To win the battle with borrowed troops', as an ancient Chinese war strategist described, could be the right strategy. If it is possible to overcome deficiencies in school science education by drawing on the resources available in the science communication domain, why not do it?

For example, we could use the facilities in scientific institutions as resources for science education, mobilize S&T workers and science-based organizations to support science teachers in their teaching practices, and follow the example of out-of-school hobby group practices to employ inquiry-based learning methods in science classes. The following section discusses these and other options.

Generally speaking, science communicators pay close attention to the interaction between S&T developments and the demands of society, and they are used to answering queries and dealing with doubts. Seen from the point of view of science communicators, science education is a kind of large social project, in which the goal of scientific literacy for all school students closely matches the ‘science for all’ goal of science communication in the 1980s.

Starting from this position and taking into consideration the interactions of the two domains, this section expands on the involvement of science communicators in science education.

We could bring science education under examination from various angles, such as by following the primary–secondary–tertiary education hierarchy, by dividing it into school education and out-of-school education, and so on. However, in the light of our knowledge of lifelong learning, we divide it here into formal education, non-formal education and informal education.

9.4.1 Formal Education

Science communicators have been doing a lot in formal science education, including:

- Taking an active part in science education policymaking
- Giving advice and making recommendations to governments on science education reform and getting involved in drafting reform documents
- Working on curriculum development and creating curricular standards
- Training science teachers
- Opening laboratory facilities to schools for them to practise inquiry-based education

One eye-catching achievement has been the Pollen Project, which is being carried out in 12 European countries. The project is a joint action, but is implemented under the guidance of local education authorities. Scientists come to work side by side with primary schoolteachers, and cooperate with teachers and curriculum specialists in curriculum development, teacher training, online consultation and the like. The joint activity stimulated and strengthened female schoolteachers’ interest and confidence in teaching science, and aroused students’ curiosity about science (especially girls and children from disadvantaged family backgrounds).

The Pollen Project sheds light on two important factors. One is that the science community should be intervening in formal science education at an earlier stage. It is too late to intervene at the higher degree level, as people used to believe to be appropriate. As we understand it, the Pollen Project had its roots in an initiative of physics Nobel laureate Georges Charpak. He once led a group of scientists from the

French Academy of Sciences into primary schools and kindergartens and set up a programme named '*La main à la pate*' in cooperation with teachers there. Through the programme, they brought an inquiry-based approach into early-stage science education.

The second important lesson is that the transformation of pedagogy is just as important as content reform in science education. Reformed teaching methods are an effective and important way to maintain the appeal of science to young people—a key requirement for any nation that wants to retain its competitive S&T edge in the future. To make these changes happen, it is extremely important that the science community's intervention into science education should directly assist schoolteachers to transform their teaching methods from traditional 'didactic' practices to inquiry-based approaches.

9.4.2 Non-Formal Education

Non-formal education is an important supplement to formal education, and has been attracting more and more attention in many countries. Science communication practices in this arena have included:

- Organizing many types of science activities for primary and secondary students in conjuction with science institutions and organizations, such as summer camps, science fairs and so on
- Running workshops or training courses for special target groups, such as pragmatic technique training for farmers
- Opening research institutes, science museums and science centres for students to practise hands-on experiments

The organizers of non-formal science education programmes lay stress on cultivating participants' interest and keeping them engaged through an inquiry-based approach. Success arises from the correct combination of science education with social practice, and these activites work best when they pull S&T and the public closer together and foster the scientific literacy of the target group.

Notable successes include the British Association for the Advancement of Science's youth programmes and the S&T activities for teenagers organised by the China Association for Science and Technology (CAST):

- The British Association's Young People's Programme[1] aims to engage and inspire young people with S&T and its implications. It sponsored a series of well-designed award schemes for young people of all ages, such as CREST Investigators for primary students, BA Science Communicators for ages 11+, and BA CREST awards for years 11–19. As well as these awards programmes

[1] http://www.the-ba.net/the-ba/YPP/index.html

for children, the British Association also provides training and resources for teachers and organizes events for young people to experience S&T directly.
- CAST organizes series of science contests, such as the National Adolescents Science and Technology Innovation Contest[2] to foster adolescents' innovation and practical abilities. Its Big Hands Hold Small Hands outreach programme encourages hundreds of scientists to go to schools every year to present popular science lectures and mentor students' scientific activities.

9.4.3 Informal Education

Informal education is either an industry that needs billions of dollars in investment (Friedman 1995), or an extensive space where society is the classroom, living is learning and the learner is every member of the society. This is a field in which lifelong learning is driven by the interests, needs and curiosity of individuals, and the invisible educational channel through which public scientific literacy is improved bit by bit and day by day by way of seeing, listening, touching and experiencing.

Science communicators are active in informal education in many ways, including:

- Organizing science weeks or science days, such as the EU annual Science Week, which creates an atmosphere of scientific culture that 'bathes' the public
- Presenting participatory exhibitions by science museums and science centres to advance lifelong learning
- Cooperating with journalists to deliver science information through the mass media
- Running popular science websites for more interactive science communication.

For informal science education to be effective, it is pivotally important that the science community collaborates with the media world. The media do not produce knowledge (they are merely the vehicle for its passage), but their speed, coverage and influence magify its efficacy. PUS surveys in several countries demonstrate that the media, especially television, have become the main channel by which the general public obtains S&T information. In recent years, with the support of the science community around the world, there has been much more media coverage of science-related topics (such as climate change, genetic modification, tsunamis, avian influenza and so on). This has raised the public's awareness of the science and increased its ability to deal with unexpected events.

The many cases of successful informal science education have relied heavily on effective science communicators. However, in our view, there is still enormous space for the closer integration of the two domains to achieve greater depth, breadth

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[2] http://www.xiaoxiaotong.org

and universality. This is still an underdeveloped enterprise, in which there are many valuable things waiting to be accomplished and investigated.

9.5 Conclusion

The discipline of public S&T communication grew from a need to deal with contemporary social problems. It grew by developing its practitioners' consciousness of responsibility, and then by examining its own social accountability. In a parallel process, science researchers and organizations, partly through their involvement in science communication, should take up their social responsibility to engage in science education.

The involvement of the science community in non-formal and informal science education is already undergoing a kind of regularization and professionalization with the addition of a 'third assignment': science communication. Sweden and France passed laws in 1979 and 1981, respectively, asking science research institutions to take up that third assignment (Felt 2003). In 1993, Research Councils UK was also asked to include science communication as one of its missions (British Council 2001). In 2006, the same requirement was promulgated by the Chinese Academy of Sciences in its *Outline of medium and long term development of science communication,* which is in effect from 2006 to 2020.

We believe that the science communication community should deepen its involvement in science education at the earliest possible level to achieve the common goals of the two domains. Science communicators should make a much wider and much better contribution by:

- Bridging the gap between scientists and science educators by taking responsibility for coordinating scientific expertise, facilities and information to support science education in and out of schools
- Promoting systematic reform in both domains to put support for science education into the science communication agenda and, at the same time, introducing the best practices of science communication into science education
- Helping to organize social activities for science education in schools and providing assistance in those activities
- Engaging in science education research
- Training science teachers

The science of the 21st century will play a major role in human society: our fate, and the fate of our society, are bound up with it. For this reason, science communicators should intensify their efforts, and go to the public, to the society and into science education. It is expected of us and is also our social responsibility. It will also benefit the development of our discipline.

Science communication and science education have never been seen so vigorous as today, but they are really just beginning to develop. They need to be adjusted, rationalized and improved for greater effectiveness. The two domains' traditional separation and isolation from one another is no longer appropriate.

To equip the 21st century public with basic modern scientific literacy, we need to create favourable environments and conditions. We need to build a multi-element resource system for science education that includes teachers, schools, governments, scientists, science communicators and science institutions and creates an extensive, spacious arena for cooperation and collaboration.

Science communicators are uniquely placed to catalyse this transformation.

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