# Communicating Science to the Public

*John S. Rigden*

From the itinerant lecturers of the 18th century to popularizing physics in the 21st century – exploring the relationship between learning and entertainment
Proceedings of a conference held in Pognana sul Lario / Italy, June 1-6, 2003.
Eds.: Jürgen Teichmann, Arthur Stinner, Falk Rieß,
Munich, Winnipeg, Oldenburg 2004
www.deutsches-museum.de, www.hsse.uwinnipeg.ca, www.uni-oldenburg.de/histodid

CARL VON OSSIETZKY universität OLDENBURG Didaktik und Geschichte der Physik

The UNIVERSITY of WINNIPEG

Deutsches Museum

I. I. Rabi, one of the great physicists of the 20th century, said, "Science exists at the pleasure of the larger public." Like most scientists, Rabi recognized that support for scientific research is dependent on the generosity of the public. In a democracy, corporations respond to the desires of the general public and governments respond to the wishes of the general public. Therefore, if support for science is to be sustained, it is the general public that is the audience of influence. Consequently, scientists need to communicate with the public and do so effectively. Indeed, Rabi was right: science does exist at the pleasure of the larger public.

But Rabi meant something more than just maintaining a society that provides grant money to scientists. In the most basic sense, Rabi meant that citizens must believe in the values of science and share those values if science is to be a living presence in a society. Specifically, citizens should cherish the rational abilities of the mind, citizens should trust rational pursuits and allow no superstitions or beliefs to impede that pursuit, and citizens should place no limits on what can and what cannot be critically examined. These are the values of science itself, the values that science introduced into the world.

Communicating science to the public is an educational activity. Many excellent television programs are devoted to science; over the course of any month many fine books and articles are published which have science as their subject; many individual scientists design useful ways to reach out to the public and they do so on a regular basis. Yet, in spite of these wonderful efforts, the general public remains largely lacking in their understanding of science and, perhaps more importantly, the public is only partially aware of the potentials of today's science. How should scientists respond to this scientific illiteracy that characterizes much of modern society?

My purpose in this talk is to develop background that will allow me to ask two questions. The first question is at the core of why we are gathered here in Italy. If we assume that public support is based on the broad acceptance of the values of science, what should scientists be communicating to the public? Or, the same question asked differently, what does the public need to know and understand? The second question is much more disturbing and it could be vastly more significant. The question is this: Should the public be informed about the potentials of contemporary scientific research?

The first question, What should scientists be communicating to the public?, sounds quite straight forward. Is it as straight forward as it sounds? Perhaps not.

As a way of thinking about this question, consider a contemporary research physicist and a modern dairy farmer. A contemporary research physicist works at the frontier of the discipline. As the Physics and Astronomy Classification Scheme demonstrates, the frontier of physics is long. You can download this classification system from the American Institute of Physics web site and if you print it out it will cover 132 pages. Yes, a long list of specific research specialities in physics and astronomy that covers 132 pages. So let us assume the frontier of physics is about 3,700 centimeters (28 cm/page x 132 pages) long. On this basis, any particular physicist typically works along 5-to-10 centimeters of the frontier. For our present purposes, it does not matter where on the physics frontier the research physicist works; what does matter is that a research physicist works along a 10-centimeter section of a frontier that is 3,700 centimeters in length. To express this another way, contemporary research physicists are highly specialized and narrowly focused. As a result, a physicist can be in total command of his or her 10 centimeters which represents his/her research speciality, but be quite uninformed about what is going on along the other 3,690 centimeters of the physics frontier. And the same research physicist can be quite ignorant about things going on in chemistry, biology, geology, and the rest of science. The contemporary physicist is a focused specialist.

By contrast, consider the modern dairy farmer. A successful contemporary dairy farmer commands a wide range of scientific knowledge; for example, animal behavior, animal physiology, bacteriology, animal genetics, insect physiology, insect behavior, hybrid botanical species, soil chemistry, meteorology. In addition, the modern farmer possesses engineering and mechanical skills. Add to all of this, the modern farmer typically organizes large amounts of information in an extensive computer system in which he tracks animal breeding, monitors crop yields, maintains crop-rotation histories, records periodic changes in pasture grass types and correlates grass types with milk-yield per cow, tracks weight changes in cattle, tracks bushels of wheat per acre, and all the other variables that go into agricultural success. All of this is required in today's agribusiness. I believe it is accurate to say that the farmer commands a wide range of knowledge that we would identify as scientific knowledge.

Here then we have the physicist and the farmer. The physicist is narrowly specialized; the farmer possesses a wide range of scientific knowledge. Yet, in spite of a modern farmer's detailed scientific knowledge, the farmer most likely lacks the intellectual framework that gives detailed scientific knowledge a significance beyond the particular. More than this, the modern farmer may have no appreciation or understanding of how science works.

Consider, for example, the farmer's response to the claims and counterclaims about a very important subject: global warming. The farmer may well recognize short-term changes in weather patterns, and may even recognize little hints that suggest a longer term trend of gradual warming. But the same farmer may reject the concept of global warming and may absolutely reject any suggestion that human activities are contributing to this warming. Why is this? The farmer, who commands a lot of scientific content knowledge, may have little knowledge about the practice of science; that is, how scientific knowledge is obtained, how imperfect data is often the best that a scientist can gather, how assumptions and approximations are often made as a legitimate part of the scientific process. As a result, scientists often disagree in their conclusions about complex natural phenomena such as global warming. Since scientists disagree about the causes of global warming, the farmer's attitude may be, "Wait until the scientists know what they are talking about." And with that, the farmer may dismiss global warming as unworthy of attention.

By contrast, the specialized physicist understands that complex phenomena can be interpreted in different ways and that definitive answers are often elusive. Moreover, the specialized physicist understands the data that shows the steady increase of greenhouse gases in the Earth's atmosphere and fully appreciates the physical significance of those accumulating gases. Certainly the physicist is unable to manage a 300-head herd of cattle, but the physicist is able to connect the fact of a warming planet with other known phenomena such as the run-away green house effect where at some threshold a positive feedback loop gets activated and the warming becomes irreversible. The lack of clarity or the lack of consensus among scientists does not prompt the physicist to dismiss the importance of global warming.

Science and technology are the dominant influences that shape the society and the culture that the scientist and farmer share. It is a rapidly changing social milieu in which citizens are bombarded with new information and expanding knowledge. New ideas often challenge those basic principles that bring meaning to the lives of individuals and guide their day-to-day lives. The result of this intellectual buffeting can be a sense of loss, a sense of alienation, even a sense of despair. The scientist, in spite of the narrow focus of his or her specialization, is typically able to assimilate novel ideas and new knowledge into a larger context and maintain emotional and intellectual stability even in the face of rapid, and sometimes disruptive, changes. By contrast, the farmer, in spite of his broad scientific knowledge, may lack the ability to put new knowledge into a framework that brings a rational perspective and a sense of equanimity.

I have been comparing a research scientist and a farmer. My purpose has been to suggest part of an answer to the first question; namely, that scientific content knowledge, even rather extensive content knowledge, does not provide the farmer with the intellectual tools he needs to understand science and to be at home in an age of science. The farmer is one member of the general public and I suggest that what is true for the farmer is true for the public more generally. In short, the public needs more than scientific knowledge.

Unfortunately, scientists in general, but physicists in particular, are preoccupied with content knowledge and emphasize content to the exclusion of all else. For proof of this claim, examine any introductory textbook of physics. In spite of the fact that introductory textbooks are 100 years out of date, they are dense with content information. Deeply important concepts, concepts that took the best minds decades to grasp are treated in a few paragraphs at a rate of almost one concept per page. Further, the concepts of physics are presented in their fully modern and fully complete form. Newton's laws just appear and follow from nothing; Faraday's law of induction appears, probably in the form of Maxwell's 3rd equation, and follows from nothing. Textbook authors pass over the thinking of great physicists of the past; they omit the instructive evolution of cardinal ideas; they ignore the way connections were developed between basic concepts of physics. Textbook knowledge leaves students in a situation similar to the farmer: detailed knowledge with no framework to give significance to the particulars.

Students need more than content knowledge; the general public needs more than content knowledge.

We arrive back at my first question: What should scientists be communicating to the public? I shall not answer this question because I can't. However, I shall suggest elements that I believe should be a part of any answer. Content knowledge is necessary; however, the public needs a framework that gives significance to their content knowledge. For example, the public should understand the gravitational force law because it embraces a rich range of phenomena and connects much of that phenomena together. But knowledge of the gravitational force law, in and of itself, is not sufficient. If, however, the public knew something about Aristotle, Ptolomy, Copernicus, Galileo, and Kepler, if they knew how Newton drew from the work of these predecessors, if they knew how Newton came to the force law, if they knew how the force law qualitatively (and quantitatively) assimilates numerous observed phenomena, if they knew how the force law led to the discovery of Neptune, then citizens would understand and appreciate what it means when Newton's gravitational force law is called universal. And, if the public knew how Newton's force law qualitatively ties into Einstein's general relativity, the public would have an intellectual framework that would bring meaning and significance to the gravitational force law and more importantly, they would have an intellectual framework that could be expanded. So one element in an answer to the first question is that scientists should provide an intellectual framework for the content knowledge they communicate.

Here is a second element to the answer: scientists should communicate to the public the way science is done and how it advances. Textbooks represent science as a sanitized activity. It is not. The public should know the role of assumptions and approximations, the public should know that scientists must often work with imperfect data and that often tentative conclusions are the best that can be accomplished. The public should understand that differences among scientists concerning the cause of a particular phenomenon is no reason to dismiss the phenomenon.

Finally, in communicating science to the public we should recognize that the basic aim of science is to understand the universe, to understand homo sapiens, and to understand the place of men and women in the universe. Science can be threatening, but it can also be reassuring. To have reasoned answers to some of life's big questions are what many citizens yearn for. If we can provide an intellectual framework from which such reasoned answers emerge, scientists will have communicated with the public effectively.

The second question posed earlier was this: Should the public be informed about the potentials of contemporary scientific research? This question is very different from the previous question. The first question is a matter of strategy; the second question is a matter of honesty. The first question is morally neutral; the second question is not.

Throughout history, scientists have studied natural processes, manipulated them, and sought to understand natural processes and to control them in predictable ways. We have studied gases, liquids, solids, and plasmas; we have studied the basic interactions of Nature; we have studied radiations across the electromagnetic spectrum; we have studied the inorganic and organic worlds in great detail. Throughout the past we have studied Nature, in Nature, and on Nature's terms. Over the past 25 years this has changed. With the assistance of technology, scientists are now able to create extreme experimental conditions that are not a part of Nature and that are alien to the natural world. In so doing, physicists are studying Nature, beyond Nature, and on their own terms.

At some point during the past 25 years, science crossed a threshold and scientists today are often creating experimental conditions that extend beyond the boundaries of what happens naturally in Nature. There is one exception - an earlier instance where the threshold between Nature's way and scientist's way was crossed. This exception occurred in 1945.

As the test for the first nuclear device approached, physicists began to recognize that the energy that would be released in a nuclear explosion was without precedent here on Earth. Of course, nuclear reactions are a part of Nature as they occur in stars throughout the universe. But they do not occur in planetary atmospheres. So physicists began to wonder whether the nuclear device might ignite Earth's atmosphere and extinguish the Earth. Calculations were done and, based on these calculations, physicists concluded that no catastrophe would occur. Nonetheless, they were creating an extreme experimental condition and there were attending uncertainties. The decision was made to proceed with the nuclear test. Should the public have been informed about this potential catastrophe?

Here is a more recent example which may appear innocuous. In the absence of heat sources, the universe is in equilibrium with the 3K background microwave radiation. Nothing is colder than that. In low-temperature physics laboratories, however, small volumes are routinely brought to temperatures very close to absolute zero. In such experiments, extreme conditions are created which cross the threshold separating what Nature does and what Man does. More recently, however, Peter Michelson, a Stanford physicist, was building apparatus to detect gravity waves. In this process, he cooled a large bar weighing over one ton down to almost absolute zero. Peter Michelson identified it as "the coldest large object in the universe..." In that experiment, a large piece of matter was transported across a threshold, into a domain that was foreign to Nature. Was there any risk involved in this process? Probably not, but the fact remains that physicists crossed the threshold and entered an extreme experimental domain with no precedents to draw from because Nature's response to a large object near 0K was unknown. Should the public been informed about this uncertainty?

There are other examples in physics. When physicists at Brookhaven National Laboratory prepared to accelerate massive nuclei, like gold nuclei, and bring them together in a head on collision, they were creating an extreme experimental condition that is alien to Nature. Highly energetic particles from space strike Earth's upper atmosphere and many collisions occur. But the arriving particles are small compared to a gold nucleus and the target atoms are light atoms. Gold on gold collisions raised troubling questions for the experimental and theoretical physicists. Could a black hole be formed that would attract everything around it, grow, and destroy the Earth? Or, could the quarks from the resulting quark-gluon plasma arrange themselves into a stranglet (I do not know what a strangelet is) which could convert all the surrounding material objects into a new form of matter? Or, finally, could the energy created in such a collision rip space itself apart and create a new kind of vacuum that would propagate through the universe? These were questions addressed by the physicists at Brookhaven. Should the public be informed?

Nanotechnology is also providing the means to cross the threshold between the known physical environment and an alien physical environment. Self replicating nanomachines raise the specter of replication going out of control with catastrophic results. It sounds like science fiction and, when we have learned more, we may have sound reasons to disclaim any threat. But we do not have such reasons now. Examples like these are discussed in a fascinating new book, Our Final Hour, by Sir Martin Rees, the Astronomer Royal in England. It is worth reading.

It is in the life sciences, however, where it has become routine to cross the threshold between Nature's way and Man's way. And of course, this raises new and deeply important concerns. Our friendly farmer is an example. Remember, the farmer commands considerable scientific knowledge, mostly practical knowledge to be sure, but the same kind of knowledge taught in schools of agriculture. But the farmer's scientific knowledge may not prepare him for new developments that depart from Nature's ways of doing things. For example, the farmer may have no framework that enables him to connect his detailed scientific knowledge with the cloning of a cow or the planting of genetically modified corn. In fact, such a prospect might frighten the farmer and prompt him to react in hostile and irrational ways towards the new science. By contrast, the specialized physicist is able, most likely, to evaluate the new science, to make connections between old and new information, and to import the new knowledge into a coherent system of thinking. This does not mean, of course, that the specialized physicist is at ease with the new potentials being realized in the life sciences.

Back to the second question: Should the public be informed about the potentials of contemporary scientific research?

As we have seen, experimental physicists are now able to carry out experiments that have no counterpart in the natural world. In such experiments there are unknowns and perhaps risks. Even in those cases where the experiments can be modeled and careful calculations carried out, there remain uncertainties. Should the public be informed of the uncertainties and any risks? Suppose the experiment in question, if successful, promises great benefits to world citizens, but it also carries the potential of an unspeakable catastrophe? Should the public be informed and should the public be part of the decision-making process?

The same kind of uncertainties exist in the experiments now possible in the life sciences. We shall soon know how to alter the genes of an individual in precisely prescribed ways. The short term effects may appear attractive, but we cannot say what the long term effects will be for the human race. Some of these issues are being debated, but once again we must ask: should the public be informed about the full extent of the potentialities and invited into the debate?

In addition to the uncertainties inherent in some of contemporary science, there is the fact that the directions of scientific advances are not exclusively a consequence of scientists' intellectual curiosity. Corporations and governments support scientific research, but they have their own objectives and they tell scientists what to do. In this way, they establish the directions to be taken in scientific research. Since both corporations and governments are, to some extent, responsive to the public, the need to keep the citizenry informed, fully informed, can be argued for even more cogently.

Throughout the entire history of science, communicating science to the public has largely been a form of public relations designed to maintain the good will of the public and to keep the public's support. However, over the past 25 years, the advance of science has brought scientists face to face with apocalyptic questions, questions with potentially catastrophic answers, questions with a deep moral dimension. What this means is that we are entering a new era with regard to our responsibility to the general public and to what and how we communicate to them.

The challenge for us, as we enter this new era, is to acknowledge our responsibility to the general public and to establish effective strategies to help them understand this enticing, yet sometimes frightening, new world. The way we meet this challenge could determine the future of science, but more importantly, it could determine the future of the human race.

John S. Rigden