AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
150 YEARS • 1848-1998

PUTTING SCIENCE IN THE HANDS OF THE PUBLIC

ILLUSTRATION: ALLAN M. BURCH

GOÉRY DELACÔTE, *scientist and educator, holds a Ph.D. in solid state physics from the École Normale Supérieure in Paris. He is currently professor of physics at the University of Paris and executive director of the Exploratorium in San Francisco. His most recent book,* Savoir Apprendre, *addresses his long-standing concern for educational reform of science both in France and the United States.*

*"It is not the answer that enlightens but the question."**

–Eugène Ionesco

The informal science education movement offers people of every age and status opportunities for life-long learning, entertainment, and debate based on exploration of the physical and technological world. It aims to make the world of science a little more inviting, democratic, and friendly and a little less obscure and distant. In doing so it draws minds, particularly young minds, to science. It can be enjoyed by watching television shows, reading magazines, reading and doing activities found in "how-to" science books or proposed by community-based organizations, joining science clubs, going to zoos and natural history museums, or visiting science centers of which there are over 300 in the United States alone. America's public television stations and the Association of Science and Technology Centers are examples of public organizations that support the informal science education movement nationally. Here, using the example of my own center, the Exploratorium in San Francisco, I shall attempt to describe how and why the informal science education movement has become such a notable success.

A learner-centric approach. The Exploratorium is a museum of science, art, and human perception, with over 500 interactive "hands-on" exhibits. Each year it attracts more than 600,000 visitors. It is located in San Francisco's historic Palace of Fine Arts, which has an open design that for the past 30 years has provided the museum's exhibits with the flexibility that they require. Its proximity to Presidio Park at the entrance to the Golden Gate Bridge facilitates easy access for field trips into this wonderful urban park.

One of the Exploratorium's key working principles is that scientists, exhibit designers, and teachers (called "Explainers") develop a "learner-centric" perspective as they try to communicate and teach about the world. Many young people have participated in the Exploratorium's Explainer program, which was created in 1969 by the Exploratorium's founder, Frank Oppenheimer, a physicist like his brother Robert who headed the first atomic bomb construction project for the United States. The Explainer program was inspired by the preexisting, still very successful, program of the Palais de la Découverte in Paris, where graduate students and senior researchers, so-called chargés d'exposé, give demonstrations and lectures to the public. These presentations echo the early, ebullient days of the Palais in 1936, during which some of the best French physicists demonstrated to the public the ongoing experimental work that they were pursuing in their own laboratories.

At the Exploratorium, Oppenheimer put his own, unorthodox spin on the Palais's program by inviting younger, and therefore less educated, students (high school and early college years rather than graduates) to be the key players. For 12 weeks, Explainers work part-time, for minimum wage, helping visitors to the museum. Oppenheimer had a provocative approach to learning, which can be summarized by saying that the best way to learn is to teach, the best way to teach is to keep learning, and that what counts in the end is having had a shared, reflected experience. In addition, he insisted that individual exhibits be centered on the learner and therefore designed to facilitate individual exploration, in part to prevent any clear line of demarcation between those who know (or believe they know) and those who do not know. Such a schism would occur if, for example, the exhibits used a more explanatory and didactic approach. Our exhibits are complex enough to intrigue scientists and simple enough to entice young children (have you ever played with the inner structure of a three-meter-high gentle tornado?). They are designed as prototypes, similar to those one might find in any active research laboratory, and while it is normal for exhibits to be finished products, ours are works in progress.

How do we know that the approach used by the Explainers is beneficial to themselves and to visitors alike? Evidence for this has been provided by comments made by Explainers, three of which follow.

First, on the proposal that active experience with real objects or phenomena stimulates further exploration:

> There is an exhibit here about the expansion of metal as it heats up. You can actually feel a metal rod growing as it heats up. I mean, that is exciting. Even though everyone knows that it expands, they were never able to observe it. I think the fact of observing it makes it a lot more interesting. (David)

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*Eugène Ionesco, quoted by Neal Lane (former director of NSF, presently the presidential science adviser) in *Assoc. Sci. Technol. Cent. Newslett.* **5** (no. 6), 2 (Nov./Dec. 1997). †Available at www.exploratorium.edu, our award-winning Web site that exemplifies exploratory learning, designed under the supervision of R. Semper. ‡G. Delacôte, *Savoir Apprendre, les nouvelles méthodes* (Odile Jacob, Paris, 1996). Also available as G. Delacôte, *Enseñar y aprender con nuevos métodos* (Gedisa Editorial, Barcelona, 1997). §Sponsored by UNYSIS and NSF. ‖"La main à la pâte," Les Sciences à l'école primaire, présenté par Georges Charpak, Flammarion, France, 1996.

Second, on the proposition that it is not the answer that enlightens but the question:

> It was the weird exhibit called Benham's Disk. Half the disk is black—the other half is a series of broken black lines on a white background. When the disk spins, it tricks the photoreceptors in the eye, and the brain processes an illusion of color. This got me wondering about the brain's entire system of storing sensory information. Now look at the trouble I am in! (Xander)

Third, on the realization that in working on the floor, the Explainers learn as much from interacting with people as from interacting with the exhibits themselves:

> I learned to tolerate a lot of my own mistakes. On the floor, you fall on your face a lot in front of those who know better. Once at an eye dissection, I got into a conversation with an ophthalmology student. I'd be explaining things, but all of a sudden I was learning new stuff by talking to this guy. (Gabe)

Generalizing the message. My experiences at the Exploratorium allow me to draw conclusions that can be extended beyond museums to other mediums: print, for example.

First, the focus must be on the learner, who should be offered an active experience rather than a passive one; the aim should be to foster a sense of wonder and an ability to generate questions.

Second, although it may sound paradoxical, this learner-centered approach is universally applicable, whether the target audience is young children or educated adults.

Third, to create a more valuable experience for the learner, there should be a seamless connection and a cross-fertilization between informal learning opportunities, such as those that are available in a museum, and more formal opportunities, such as those that are available in a school.

Fourth, it is important to adopt an interdisciplinary and multifunctional approach, to create enticing environments that appeal to the senses. Artists and scientists must collaborate and be directly involved in the process.

Fifth, there is a growing need to mix different media. Technology can be used to make resources globally accessible and to enhance interaction between people. For example, live images of an eclipse visible in the Caribbean (available at www.exploratorium.edu/eclipse/index.html) were transmitted to the newly designed Exploratorium Webcast Studio, and from there the images were made available worldwide, together with real-time images and Q&A from museum visitors in the studio.[†] This demonstrates how electronic technology can extend the natural and the social experience—science centers do not have to choose between the traditional presentation of the real world and the new "virtual" approach, but can integrate both to maximize visitors' learning and imagination.

Sixth, a subtle rule: Any institution seeking to foster an inquiring approach in visitors to its premises or users of its Web site must be suffused with a particular culture—the culture of learning.[‡] The culture of an institution is idiosyncratic and can be hard to define, but if it is pervasive, it will influence outsiders. If the institution has it right, visitors will find it easy to frame their questions. This is true not only of the visitors who show up or log on in search of learning and discovery, but also of the more casual guests motivated purely by curiosity. A truly effective learning institution will engage its guests in a dialogue, an exchange of ideas in which the exhibits and explanations engender questions, and the visitors in turn generate questions from the institute.

Conclusions. The noblesse of being a scientist brings obligations to stay open and alert to dialogue in the public domain, among educators and in the media, and to develop communication channels between the world of science and the larger world. Scientists, designers, artists, and educators need to come together in an interactive, iterative, experience-based fashion; they must hold an inspired conversation from which everyone gains a deeper understanding. In doing so, they will foster good public relations and help create a more intelligible, inviting, democratic, and unfragmented world.

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Internationally, many are recommending a closer interaction between science and education. It has become a goal in science education in America, where the curriculum is mostly task oriented, and in France and Japan, where teachers focus more on conceptual learning. Everywhere, educators are discovering the merit of using an inquiry-based approach in which student initiative, experimentation, practice, and conceptual learning are intertwined. Science centers can become strategic allies in the science education reform movement, as they help teachers integrate formal and nonformal ways of learning about science into their curricula. Already museums in Boston, Miami, New York, Philadelphia, St. Paul, Amsterdam, London, Mexico City, Tokyo, and Paris are implementing programs designed to aid and educate teachers, and some are interconnected under the umbrella of the Science Learning Network.[§] Georges Charpak, a French Nobel laureate in physics, has launched a new initiative entitled "la main à la pâte"[‖] (a smart translation of hands-on or inquiry-based science) with the support of the French Minister for Education, Research, and Technology, and with the noted geophysicist Claude Allègre. This collaboration has begun to consolidate the introduction of experimental science in French elementary schools.

My message to readers of *Science* is to "get involved." Scientists' contributions to public understanding has been shown to be intellectually exciting, rewarding, and valuable—not only for the public but for the scientists as well. Some scientists have learned how to shift from being mere information providers to focusing on the needs and questions of the learner, and to accepting the challenge of interacting with young people. Yet even more effort is needed. This challenge is critical, but the rewards are great. As Mitzy, a former Explainer, wrote:

> I really learned that learning is an ongoing process. I go back to the Exploratorium often and find new insight into old exhibits. It increased my belief in the perfection of the way the universe works. For a nonscientist, physics is essentially magic, and understanding a bit more caused me to love and appreciate the physical world around me.

ILLUSTRATION: TERESE WINSLOW