Experiential Exhibits, Models and Teaching Props in Science Centers

by Joe Ansel

James D. Bradburne and Drew Ann Wake, in their article ***Invention, Revelation, and Learning in the Science Center*** honestly question the educational efficacy of exhibits pioneered by the Exploratorium science center in San Francisco and furthermore suggest that such exhibits might actually impede discovery.

> "Here we are, after nearly thirty years of exhibit building, with science exhibits that communicate bits of scientific information, but prevent the visitor from engaging in a process of questioning and discovery." [i]

For exhibit designers, educators and administrators working in science centers the question bears great weight. Have our efforts been wasted and should we be doing otherwise?

With welcome clarity, Ted Ansbacher's article, ***Exhibits and Learning at the Science Center: Another View,*** [ii] rebuts Bradburne and Wake, in part, by establishing a primary goal for science museums: that of encouraging rich, engaging personal experiences. Such "experienced-based learning" provides what schools rarely offer—a kind of physical knowledge[iii]. By laying before the public myriad phenomena, including the particularly beautiful and ugly or the common and rare, science museums aptly supplement and greatly enhance the work of schools. Exhibits, often interactive exhibits, have become a principal means for providing such experiences. Exploring good exhibits makes meaningful a more rigorous study of the phenomena they present. As Frank Oppenheimer, the founding director of the Exploratorium, said, studying science without experience is like "Learning to swim without getting wet." Of course exhibits do not stand on their own, rather interpretive science center programs, explainers, teaching props, models and experiential exhibits all work together to make for learning and teaching in a social setting. Hopefully my comments and examples herein will support Ansbacher's position and provide a level of detail with respect to exhibit design and use sufficient to explain and establish the value of what we have done and might yet do.

Exhibits of Revelation vs. Experiential Exhibits

While exhibit builders at the Exploratorium during the 1970's and early 1980's were often unaware of distinctions such as those established in Bradburne and Wake's article, by no means did we set out to create "Interactive exhibits of revelation…designed to illustrate a single, specific, scientific principle to visitors; each…engineered to demonstrate the same fact every time without fail." [iv]

In fact, a major criticism Oppenheimer leveled at one of my inventions was that it only did one thing. The exhibit in question, ***Cool Hot Rod***, expanded and shrank in length as it was heated and cooled. While interesting to technical folks, the experience provided by the exhibit was modest—the rod only moved about 1.5 mm (.060 inch) over a temperature range of about 4° to 44°C (40° to 110° F). This small change was detected by comparing the "step" that developed between a reference surface and the end of the rod, but Oppenheimer felt the experience was unimpressive and we added a dial indicator to amplify the movement. We also made it possible to move the indicator itself by hand so the visitor could gain some sense for the dial indicator's range. While not an experiential hit, ***Cool Hot Rod*** did show a real phenomena, was usable as a teaching prop and also interested a few visitors on its own. These elements gave it a minor place at the Exploratorium, although we all knew it would not stimulate the level of interest that we generally sought.

In general, such single activity exhibits were not favored by Oppenheimer, nor his exhibit builders, as indicated below:

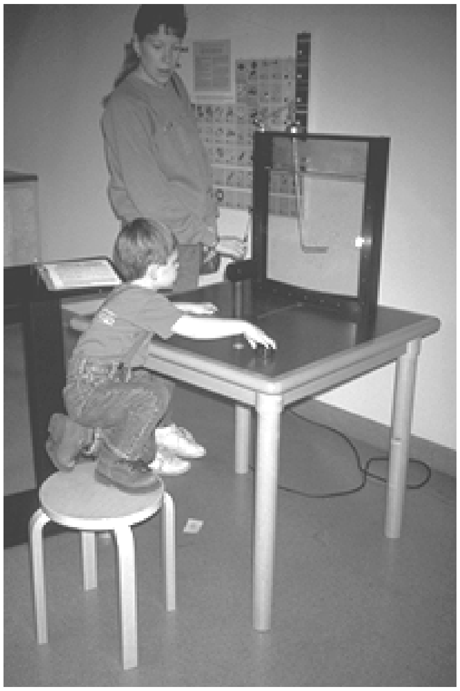
> "Although the single activity of the Gray Step exhibit is satisfactory, many of the single-activity exhibits in our electricity section are extremely disappointing." [v]

Related and delightfully more heretical is the important notion that exhibits should be useable, perhaps fun to use, in irrelevant or even irreverent ways, not just one way. For if an exhibit forces the user to a predictable conclusion, often no genuine personal discovery occurs. Good experiential exhibits usually allow choices which produce no or unexpected results, although more didactic outcomes remain possible too. For people quickly perceive when they have real choices and when they do not. Bradburne and Wake correctly note this problem without noticing that in most cases, Exploratorium exhibits avoid it.

> "Each of these exhibits (exhibits of revelation) represents a single experiment, which inevitably ends with the same result and often the visitor has no intellectual engagement with the subject matter." [vi]

As Ansbacher points out, Bradburne and Wake assign little value to the experiences embodied in exhibits and simply fail to recognize the richness of many well designed Exploratorium exhibits. Using some "single activity" exhibits such as ***Gray Step One***[vii], as referred to above, (other wise known as ***Horse's Tail***) is so compelling that intellectual engagement is almost guaranteed: the experience is had, curiosity is piqued and questions arise which can often be answered by careful consideration, by graphics or by using other exhibits. What more should science exhibits do?

As opposed to single scientific principles, richly related phenomena, which are striking or engaging, provide multiple starting points, connections and experiences for exhibits. ***Convection Currents,*** an exhibit I created in 1979, was more successful in Oppenheimer's way of thinking because it embodied and revealed multiple phenomena as the exhibit was explored. Moreover, in its final form, ***Convection Currents***, presented these phenomena well enough so that their inherent intriguing aesthetic stimulated curiosity and interest. The exhibit consists of a 150 watt heating rod immersed in a thin water tank which is illuminated by a brilliant, movable point source lamp. As the heater is turned on warm water rises from the heater to produce interesting and evocative, changing shadow images on the wall. These images are a bit like rising cigarette smoke—another convection phenomena. When I first saw the shadow images, I knew the exhibit would capture other's interest as it did mine. While the exhibit shows that warm water rises, it also shows that warm water is less dense, and bends light a little less, and that such subtle changes in density can act as a constantly changing lens to move light from one area to another thus producing the images themselves. If you turn the heater up slowly, the image of the heater itself appears to swell as the warm water seems momentarily bound to the heater, only then to begin a gentle swelling rise upward. At full tilt the heater produces tiny, but visible, steam bubbles within the tank and you can even place your ear on the glass to hear the water boil. The design of the lamp assembly allows you to move the projection point to gain a close-up of the heater or to see the entire tank. And a view of the entire tank shows one marvelous convection cell, with water rising in the center, cooling and then dropping down the sides. (The sides are air cooled so that the differential between the freshly heated water and the surrounding tank remains high.) The heater rod itself can be



Convection Currents at Liberty Science Center

moved, so as to stir the tank, whereupon one can discover that subtle differences in temperature are detectable and appear marbled, moving throughout the tank for the longest time after the heater itself has been turned off. After some fiddling, we discovered light from the lamp produces a sparkling reflected image from the water / air boundary and that this is projected on the screen. Finally the point source lamp is great for producing shadow characters on the wall—something unrelated to the exhibit's general topics that visitors nevertheless often do.

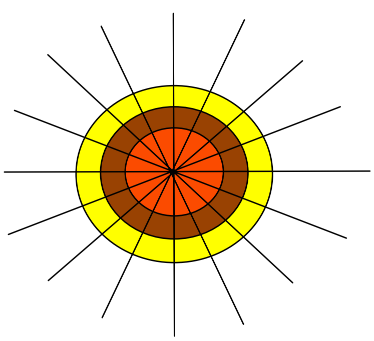
Of course, some people turn the heater up and down much too fast to see the variety of the effects the exhibit might produce or they move the light rapidly without stopping to look at the details, instead observing the "wow-wow" effect produced by the expanding and shrinking image. Few listen to the heater in the tank. Many do not even encounter the exhibit at all. But for those who do, they can experience in one exhibit so many related beautiful phenomena: convection, conduction, refraction and reflection. The exhibit is also a good example of a Schliren system, contains a bit of basic engineering and also might incline one to consider why and how the image changes as the light source is moved.

Intriguing, multifaceted, open ended, non-coercive exhibits which provided real experiences, such as ***Convection Currents***, were the aim for exhibit builders at the young Exploratorium. In describing their solution, in my view to a non-existent problem, Bradburne and Wake seem to advocate more rigor in overall exhibition design in order to incline the visitor to connect individual exhibits and in doing so to model scientific thinking. Their example leaves it unclear how this actually works, or even if it does "work." But exploration choreographed by others is none at all, nor do most wish to be tested or judged in the science center setting. What a turn-off! While good exhibit design is essential and proper evaluation valuable, this is exactly the problem with many "overly designed" and "tightly-evaluated" exhibits; they try to re-create the schools and force the point. Often visitors aren't interested or if they are, would prefer to read about the concept at home, rather than printed on a museum wall. Visitors own interests and choices should create a personal thread of inquiry within science centers.

To foster such personal inquiry at the early Exploratorium we all knew we were building multiple examples of the same, and related, phenomena; thus if one exhibit didn't provide what a particular visitor wanted, another would. Each exhibit built on others, so if you experienced and understood one exhibit, you were often prepared to explore others nearby. At one point we even set about "gap-filling" our exhibit collection by adding exhibits where there were insufficient examples of a particular phenomena. And at such exhibits, combined with the interpretive programs offered at good science centers, people learned a great deal of science more deeply and in a fundamentally different way than they would have by attending school alone—they still do today. Plus, as Bradburne and Wake have correctly observed, such learning experiences in the museum setting can be social and highly enjoyable, unlike much formal schooling.

Models and Teaching Props in the Science Center

Not all science center exhibits provide a natural phenomena experience directly. Valuable, perhaps essential, are exhibits which model phenomena. A computerized exhibit which allows visitors to vary the mass and velocity of planets to see the effect on their orbits is an example of a "modeling" exhibit. In such case, there is no way to show the real phenomena, so a model will have to do. Given their subject matter, many scientific disciplines such as archeology and physics require the use of exhibit models within science centers.



In addition, teaching props, which may be either experiential or models, serve as excellent "connectors" between the exhibit collection and various formal and informal interpretive programs which science centers offer. An example of a teaching prop I am most familiar with is the ***Inverse Square Law*** exhibit at the Exploratorium. ***Inverse Square Law*** teaches an important, but simple, understandable equation: $\frac{1}{r^2}$. If you think of a tiny point expanding into a sphere of ever increasing size, you have the image which goes with the inverse square law. While the surface area of the sphere increases by the square of the diameter ($A=4\pi r^2$), the "density" of whatever constitutes the surface, falls off by $\frac{1}{r^2}$. Thus the inverse square law applies to phenomena which involve spherical radiation from a point: examples include, explosions, super novas, gravitational fields, sound waves, light and even spray painting. So this “boring” math means that being 10 feet from an explosion (assuming no shrapnel) is four times as bad as being twenty feet from one!

Inverse Square Law at the Exploratorium

To illustrate the inverse square law I placed a point source lamp in the center of an opaque stainless steel sphere. Centered on a radius I cut a small square “window” over which was soldered a perforated screen with 256 holes in an array 16 by 16. At 1 unit from the lamp this assembly cast an image on a movable screen of about 1 square inch, at two units the image was 4 square inches, at three units nine and so forth. A ruler on the a table top to the left of the sphere made it simple to place the movable screen exactly at whatever distance interested the user. On the screen itself I inscribed the square that the lamp produced at 1 unit from the point source lamp. Within this square would fall 256 points of light at one unit, 64 points at two units, about 28 points at 3 units and so forth. The user could count the sides of the light array and a table mounted calculator served as an aid in doing the arithmetic involved. There were a few other ways to use the exhibit, for example the screen could be set at a grazing angle of incidence to the points of light and in such case the available light spilled across a very large projected area and off the screen itself.

After its completion, I didn’t play with ***Inverse Square Law*** as often as other exhibits—after all the experience it offered as a model was modest. At some point I realized the exhibit was not being used by many and determined to modify or discard it. Before discarding the exhibit, I polled a few of my peers. When I reached the head of the Exploratorium's teacher training program he was aghast upon hearing that I might want to change or remove the exhibit. The exhibit helped him to teach an important lesson in $1/4^{th}$ the time it would normally take and he felt that while the exhibit was a bit boring on its own, it was extremely valuable to his classes. The exhibit remains at the Exploratorium today and has been duplicated by others.

Museums and Schools

In an effort to justify their work, appear professional or even to better secure funding from educational sources, science center staff may tend to judge themselves by standards similar to the schools. This is entirely wrong. No one to one correspondence between using a particular exhibit and understanding particular facts need occur in science centers, although this may often come about. Encountering the myriad real objects and engaging in the experiences science centers have to offer, both from experiential exhibits and science center programs, is entirely sufficient to justify our work. For these valuable experiences generally cannot be had elsewhere. Very rarely does a genuine social setting for learning and teaching occur in the schools: especially one that includes family and friends. Science centers are properly places for people to make free choices and explore topics and engage in activities they care about or may come to care about in the course of their visit.

Predictably Bradburne and Wake introduce multiple concerns and lines of inquiry related to "school-like" standards by which they judge the value of science center exhibits:

> "Is it possible for a museum visitor, a non-scientist with a moderate education, to grasp scientific information that is normally the domain of the professional scientist? Further can the visitor then explore and manipulate this information to become a creative scientific thinker?" [viii]

First, what about the very young or those with little education? Are they excluded from effectively using information-conveying, idealized exhibits as seen by Bradburne and Wake? Clearly they do not intend so as shown by an example they describe: their radiology exhibit. Fortunately experience based learning generally appeals to, and educates, all depending on their background and capacity to learn. When kids spin on the Exploratorium's ***Momentum Machine*** they have no concern for the concept of the conservation of angular momentum, but they surely gain the experience to understand the concept quite well in the future. And they enjoy the exhibit immensely, play with it on their own and often express interest in spinning things. When I play with the same exhibit, I like spinning too and have devised the most terrifying way of storing energy to enter a roaring spin. And a roaring spin nicely completes, in an absolutely essential way, my more theoretical (though limited) understanding for an axis of rotation, torque, momentum and acceleration. No lecture, textbook, picture or graphic panel substitutes for direct experience. More to the point, such experience inclines people to want to know why and to ask questions most relevant to their interests. Ernest, honest inquiry is a necessary precondition for learning and the pursuit of knowledge itself.

Second what is "scientific information." Although I cannot remember the topic, I can clearly recall Oppenheimer arguing with a stodgy educator among us, that a teenager's erroneous speculation about some bit of physics was science. Frank shouted: "It was his science and we had better well respect both his attempt and his theories, even if his was a very bad science." After all, the most advanced theories will change and are not complete nor in a fundamental sense correct. Only phenomena are given. So at what level of "science" should we stop at in our attempt to convey information, how fine should the resolution be? If we set the scale too high we exclude the very young and un-educated, if we set the scale to low we bore the bright. But if we create exhibits which simply reveal the phenomena, each person sets their own resolution. And most important, whatever is conveyed, place no emotional barriers to learning in our museums, as sometimes happens in exhibits which test their user, by denigrating earnest, but ill informed theories formed by the public.

Third, Bradburne and Wake expect too much, and too little, of science centers. They expect too much in assuming that science exhibits should convey scientific information to the general public as a professional scientist might understand it. Science centers are adjuncts to schools, universities, libraries and other educational resources, not replacements for them. Schools have their proper place. Rare indeed is the person who becomes a scientist by attending a science museum. While one might become interested enough in science at a science center to undertake the additional school work and home study required to pursue science as a career, the real power of science museums is the hope that they can raise the general level of public education, encourage people to become both teachers and learners and thereby make science itself more a part of our culture and our lives. Oppenheimer understood this better than I when he wrote:

> "Nobody either gets a degree or a black mark as a result of a museum visit, and nobody really keeps track of each individual in the sense that he or she is kept track of in school. But museums do provide most splendid and rewarding opportunities for teaching and learning….If the learning is done by the learner for learning itself and the teaching by the

> teacher is done for the satisfaction of communicating what they know and love, then it will be possible to develop a really expanded view of public education that includes not only the classroom, but also the conglomerate of adjunctive learning and teaching resources that we are in the process of creating." [ix]

Finally, notwithstanding honorable motives, Bradburne and Wake expect too little of science centers when they overlook the importance of experiencing and observing natural phenomena through well designed experiential exhibits. Discovery adds immensely to our lives, regardless of how far pursued. Plus they fail to credit the substantial teaching that occurs in science center programs such as docent programs, demonstrations, films. lectures, workshops not to mention the sometimes educational chatting of groups as they explore together. Moreover Bradburne and Wake expect too little of visitors, whom they feel must be so carefully guided to learn, when in fact close control may make personal discovery unlikely and cool visitor interest. And little other than genuine interest, encouragement and time is required to become a creative scientific thinker (albeit perhaps a bad one initially) by Oppenheimer's definition as set forth above. All the rest is just a matter of maintaining that interest so as to expand and correct one's knowledge.

[i] Bradburne and Wake, ***Invention, Revelation, and Learning in the Science Center*** THE INFORMAL SCIENCE REVIEW, Sept. - Oct. 1995, Informal Science Inc., Washington, DC, page 12

[ii] Ansbacher, Ted, ***Exhibits and Learning at the Science Center: Another View*****,** THE INFORMAL SCIENCE REVIEW, May-June, 1996, Informal Science Inc., Washington, DC, pages 6, 7

[iii] As Ansbacher acknowledges in the footnotes to his article, The term “physical knowledge” comes from Constance Kamii and Rheta DeVries, 1978, ***Physical Knowledge in Preschool Education: Implications of Piaget’s Theory*** (Prentice-Hall, Englewood Cliffs, NJ)

[iv] Bradburne and Wake, ***Invention, Revelation, and Learning in the Science Center*****,** THE INFORMAL SCIENCE REVIEW, Sept. - Oct. 1995, Informal Science Inc., Washington, DC, pages 11

[v] Oppenheimer, Frank, ***Exhibit Conception & Design,*** *Working Prototypes*, The Exploratorium, San Francisco, CA, 1986, pg. 10

[vi] Bradburne and Wake, ***Invention, Revelation, and Learning in the Science Center*****,** THE INFORMAL SCIENCE REVIEW, Sept. - Oct. 1995, Informal Science Inc.,. Washington, DC, page 11

[vii] For a description of **Gray Step 1**, see Exploratorium Cookbook One, Recipe No. 43, but really only using the exhibit will make the point.

[viii] Bradburne and Wake,***Invention, Revelation, and Learning in the Science Center*****,** THE INFORMAL SCIENCE REVIEW, Sept. - Oct. 1995, Informal Science Inc.,. Washington, DC, page 12

[ix] Oppenheimer, Frank ***UNTITLED*** Paper prepared for the AAAS Meeting, Toronto, 1981, page 8