The Exploratorium: A Playful Museum Combines Perception and Art in Science Education

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The role which museums can play in science education is discussed in general and with particular reference to the Exploratorium in San Francisco. We describe how art, an atmosphere of playfulness, and exhibits about the mechanisms of human sensory perception, have figured in the development of our museum. It is suggested that some of the objectives of interdisciplinary survey science courses can best be achieved in museum like settings where students and general public alike can gain firsthand experience with the fabric of natural phenomena.

Frank playing with one of his favorite exhibits, the Shadow Kaleidoscope.

THE EXPLORATORIUM

The Exploratorium is an institution that was conceived to provide opportunities for education that are difficult to achieve in school classrooms or through books, films, and television programs. It has been growing gradually since it opened to the public in September 1969. Its initial funding came through a grant of $50,000.00 from the San Francisco Foundation in May of that year. The Exploratorium leases 90,000 square feet in the recently reconstructed Palace of Fine Arts from the City of San Francisco for a nominal rent. It is supported through grants and donations to the Palace of Arts and Science Foundation, whose chairman is Donald McLaughlin, of the Homestake Mining Company, and a former Regent of the University of California.

The initial and rather meager funding has been used to develop exhibits and to operate the museum as a resource for the Bay area. Many exhibits have been presented in the Exploratorium machine and electronic shops by the staff and by students. Others have been contributed by industries, artists, federal agencies, and scientists throughout the country. There are about 200 exhibit pieces. Eventually we should be able to develop about five times this number.

The current monthly attendance includes about 6000 school students in scheduled class visits and an additional 15,000-20,000 general public visitors. The general public visitor stays an average of one hour, but many stay two to three hours and return repeatedly.

SIGHTSEEING

The Exploratorium is a science museum. Certainly not all aspects of science can be communicated in a museum. One cannot do much with those parts of our understanding of nature that depend on mathematical analysis to make them transparent and universal, nor can one teach people how to calculate the right answer or even convincingly assure them that scientists are able to do so. However, in a museum, one can provide an appropriate environment for many of the phenomena of nature.

The Exploratorium's museum floor on a casual afternoon in the early 1970's

In the process of mapping nature and substantiating this mapping, scientists have unearthed an ever increasing number of natural phenomena and processes. In fact, the previously unsuspected things that are happening around us, near and far away, inside and outside of us, minute and unimaginably large, now constitute the wonders of the world. A part of the pleasure of teaching lies in making it possible for people to appreciate these wonders.

We learned, in elementary school, of Marco Polo as one of the heroes of European culture. Marco Polo went sightseeing. Darwin, during the voyages of the Beagle, was sightseeing, and after his return these sights led to the formulation of ideas that have fundamentally changed the way people view themselves and their relationship with nature. The roots of science frequently lie in sightseeing. In recent years much of high energy physics, especially bubble chamber analysis, has constituted little more than a very elaborate form of sightseeing. The individual sights combine to form patterns, which constitute a simple form of understanding. The process continues beyond this stage as groups of seemingly disparate patterns then coalesce to form the patterns that provide the deepest insights about nature. We are exploring various forms of museum teaching and learning in the Exploratorium, but our effort would be worthwhile even if it did no more than provide some good sightseeing.

Sightseeing always requires some amenities to make the sights accessible. If one is concerned with the interest and understanding of the general public then sightseeing must not require, as it did with Marco Polo, an undue amount of heroism or expense. Conventional sightseeing has been made easier by comfortable accommodations and transportation and by providing roads and trails as well as maps and guides - but what can be

done about the sights that lie below the surface of nature - the host of normally inaccessible natural phenomena that have been and are being discovered that require special instrumentation or environments in order to be observed?

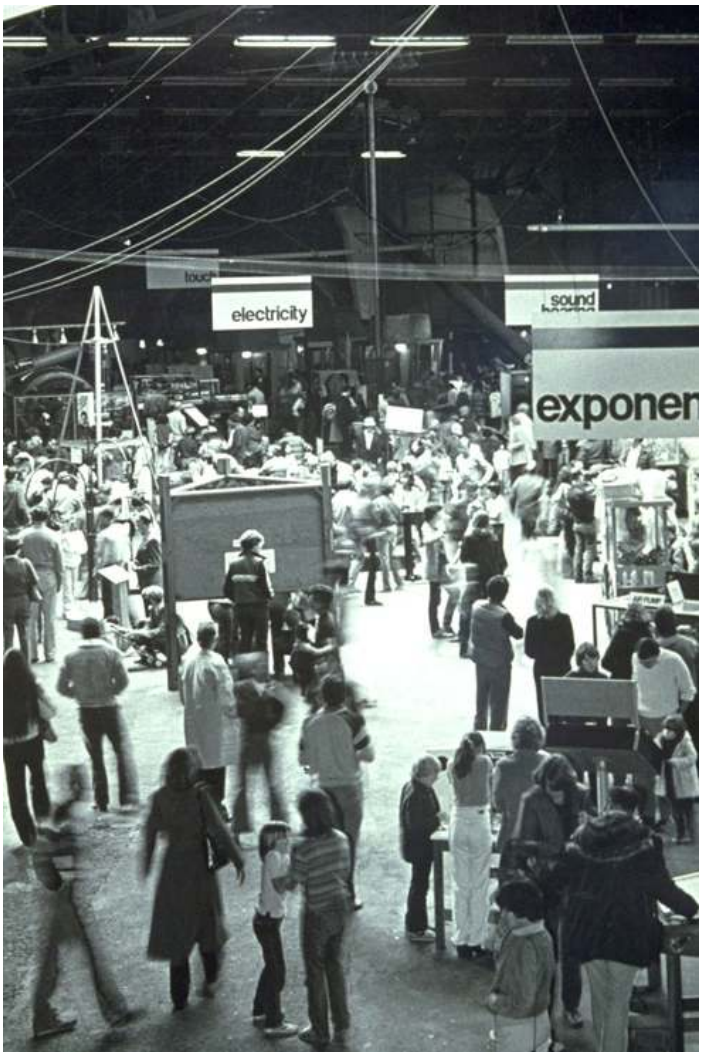
Classrooms and even television films afford severely limited possibilities for showing these sights. Sightseeing through these media resembles sightings from the windows of trains that are unstoppable, irreversible, and dominated more by the smells, sounds, and motions of the train than by the landscape. Sightseeing is invariably unsatisfactory where the main concern is a rush toward a destination or a need to catch the next train. The best kind of sightseeing involves some exploration and the freedom to decide what not to investigate and where to linger. The more one can become involved with the sights through touching, feeling, smelling, and activity, the more rewarding it can be. It is nice to be able to linger and backtrack. It helps to be able to exchange remarks with one's friend and even with strangers. Quite generally, museums should be able to display many of the less accessible sights, and they can do so on an appropriate scale. The Exploratorium certainly does provide this kind of participative sightseeing. In fact, it is impossible to lead a group through it on a guided tour. If one starts off with a group, one soon finds oneself alone, other people having stayed behind to play with or investigate one or another of the displays of the intended tour.

Museums can, in addition, present a broad view. The need for interdisciplinary survey material has been felt at all levels of instruction and there have been repeated attempts to devise curricula for this purpose. It seems to me quite possible that museums can assume the responsibility for organizing the material that fulfills this need and that they can do so more effectively than an academic course. Updated museums would then be able to relieve the schools of an obligation that has been thrust upon them but that they are not in the best position to fulfill.

There is something of a contradiction in the notion of an interdisciplinary course. Students in a course usually feel dissatisfied unless they have acquired some special skill or some new way of handling or understanding an idea. But the disciplines involved in doing and understanding physics, for example, are quite different from those involved in chemistry or biology. An interdisciplinary course therefore is likely to be a mere juxtaposition of these different disciplines and not a fusion of them. It is true that one can give an interdisciplinary survey, but a survey implies that one takes in many components of the scene at once and is a far cry from a course that meets for one hour on Monday, Wednesday, and Friday for 36 weeks. Survey courses usually depend too crucially on the inspiration and personality of a particular instructor to make them effective in the general situation.

In a museum, on the other hand, both interdisciplinary scenery and interconnecting pathways can be laid out. Individuals visit museums in different fashions, but frequently they first survey what is there and later return to selected sections to become more deeply involved. Their second look is more deliberate and enables the visitor to appreciate the details of the exhibits as well as their relationship to one another and to the general landscape. By presenting a multiplicity of examples, in a variety of contacts, of an abstraction such as wave motion or energy or randomness, the museum can build up the visitor's intuitive familiarity with such concepts.

The teaching and learning that takes place in museums is obviously not restricted to display techniques. Exhibits can serve as props to be used in conjunction with more analytical courses, and lectures and available material can be used by school classes and individual students for special study projects. Groups of exhibits can be filmed and demonstrated on local television to a large audience in a way that not only explains ideas in detail, but that invites this audience to come to the museum and interact with the very same demonstrations that they see on film. Furthermore, because of a looser scheduling in



The museum floor on a crowded day in the 1980's

a museum than in a classroom, a much wider group of people can find a way to contribute to a museum than to a school. A larger element of the population can thereby become involved in the over-all educational process.

In the Exploratorium, high school and college students are employed to explain the material to the general public and to school classes. Other students are employed to build and to maintain the exhibits. People from all walks of life bring ideas and exhibits to the museum. These people range from the wandering and searching youth of today to engineers at research and industrial laboratories who are also looking for ways to broaden their contribution. The conception of exhibits, as well as their development, fabrication, exposition, and maintenance, require a wide variety of skills and knowledge which draws many volunteers and provides opportunities for specific commissions. In this indirect way, therefore, museums can help reduce the shortage of well qualified teachers and the public cost of education.

ART AND SCIENCE

Most museums retain artists to help design didactic exhibits; we are no exception in this respect. In the Exploratorium we also display works that artists have created quite independently of our purposes. Around some of these works of art we then build related didactic exhibits. For example, we have a lovely work on loan from the artist Ben Hazzard that is entitled Pin Ball Machine. In it he makes use of the phenomenon of polarization by reflection, and we have devised a number of collateral demonstrations that bear on this phenomenon. Our many pieces by artists also include a Tactile Gallery within a 30 ft diam dome that is both a work of art and an experience in exploration. We have not yet been able to attract as many works of art as we would like. Artists must sell their works, and some of them, I fear, do not feel that our exhibit hall lives up to the stereotype of art any more than some apparatus exhibitors feel that it lives up to the stereotype of science. But nevertheless, we welcome both with open arms.

All people are uncannily good at pattern recognition, at least compared with contemporary computers. However, artists and scientists, in very different ways, are especially concerned with seeking out patterns and in sensitizing others to what they perceive. Unfortunately, both their self-image and the public image are unnecessarily divisive. These images suggest that scientists are interested only in the "right answer" and that artists are not interested in any "answer" at all. In reality, both have their criteria of validity and both make intellectual and aesthetic choices that are governed by a sense of concordance with nature. Both kinds of sensitivity and both kinds of answers are complementary and are required for a full description of natural phenomena. Their separation misrepresents

both science and art and suggests that neither is connected with nature. In fact, most large book stores have separate sections labeled Science, Art, and Nature.

The works of artists and the didactic demonstrations of scientists and engineers combine to do more than show the sights. They alter, each in a characteristic mode, the way in which individuals perceive both their past and future experiences, and they make people aware of aspects of their surroundings that they have either learned to ignore or never been shown how to see.

PLAY

The Exploratorium is not designed to glorify anything. We have not built exhibits whose primary message is, “Wasn’t somebody else clever,” or “hasn’t someone done a great service to mankind and the American way of life.” Nor do we tell people what they are supposed to get out of a particular exhibit or make them feel silly or stupid because they enjoyed it in a way that was perhaps not intended. In this sense the Exploratorium is a playful place, and people are aware that they are not being pushed around. Our one firm rule prohibits riding a bicycle among the exhibits.

A large part of the play of children involves using common physical and cultural components of society in a context that is divorced from its primary purpose. It is through such inventive and repetitive play that they learn to feel at home with the world. In this fashion, our exhibits are also playful. A large screen, designed to show the effect of retinal disparity using red and green shadows, becomes an area for shadow dancing and pantomime. A harp, which illustrates a photo-feedback process and sings in the light, as an aeolean harp sings in the wind, becomes a device for producing rhythmic modulations by hand waving. A rotating turntable, which illustrates the conservation of angular momentum, becomes a way of learning about dizziness. Through such play, the visitors make genuine discoveries, and we avoid the too frequent shortcoming of the so called “discovery method” of teaching where students are allowed to “discover” only what the instructor had in mind. In exhibits that are obviously intended for play, exhibits that themselves use props divorced from their original context, all manner of lovely things are discoverable, even by the people who invent them.

The flexibility that allows exhibits to be used for play carries with it an additional pedagogical advantage. Science museum demonstrations that do only what they are supposed to do when one pushes the button are, although common, nevertheless quite unsatisfactory. Only a limited amount of understanding comes from watching something behave; one must also watch what happens as one varies the parameters that alter the behavior. For example, one learns less optics by focusing a projector than by forming images with a hand-held lens, and one learns more from a gyroscope that has two wheels which can be spun in opposite directions than from a motor driven version. The response of a resonant system to a fixed driving frequency teaches less than the response to a variable frequency. Flexible features, built in to permit and encourage playfulness, are vital for education. In fact, in our rapidly changing culture, adults probably require play as much as children do in order to cope with and adapt to these incessant qualitative changes.

PERCEPTION

The theme of human sensory perception has provided a guiding over-all rationale for our planning of the Exploratorium. This choice of theme has proved fortunate for many reasons. The study of perception is extraordinarily fascinating both to the public and to our staff. It is currently a very lively field as well as one that is young enough that the forefront of the science remains accessible to a wide audience.

Perceptual phenomena intrigue children as well as adults and are impressive to both lay and professional people. They lend themselves to demonstrations that are clean and logical as

well as striking. They illustrate,that there are both large areas of similarity among all people and important individual differences between them. The detailed understanding of these sense organs and the nervous system involves many disciplines and therefore requires explanatory exhibits on physics, neurophysiology, chemistry, and biology. Furthermore, much of technology has served to amplify and extend the domain of the senses and is therefore encompassed within a rationale that is based on perception.

Perception also provides an extremely natural way of linking art and science since both of these influence the way in which people perceive their environment. Our planning includes not only the display of works by artists but also a history of perspective in painting, the cultural differences in the way European and Chinese perspective has developed, and the interesting studies on the different ways in which people who have lived only in round thatched houses react to our familiar line drawings such as the arrow length illusions.

The Exploratorium has some material based on the sense of touch, on hearing, on rhythm, on balance, and on smell, but our initial development has provided more material connected with vision, optics, and the visual arts than with the other senses and arts.

Our treatment of perceptual phenomena makes for a basically humanistic atmosphere in the Exploratorium, and it has, at the same time, tied together an extremely wide range of natural and technical phenomena. We feel no compulsion to “cover the ground,” nor are there narrow limits as to what is appropriate within this integrative rationale. The Exploratorium is only two years old, and much remains to be done. We are, however, encouraged by what this rationale has enabled us to accomplish thus far.

The study of the mechanisms of perception is uniquely appropriate for a science museum in a way that we did not initially appreciate. There is no unique description of the way we perceive reality through our senses and there is no easy categorization of the methodology of science. However, a statement in R. L. Gregory’s book The Intelligent Eye does suggest a parallel between the two. He states that perception “makes remarkably efficient use of strictly inadequate and so ambiguous information for selecting internally stored hypotheses of the current state of the external world.” Gregory is undoubtedly correct in his general conclusion that visual perception is not a simple stimulus-response mechanism. In his view, there are a number of possibilities for the state of the external world, one of which appears most plausibly consistent with the visual evidence. So called “illusions” reflect the normal, logical, and experiential function of the sensory mechanisms, and indeed, they would not be called illusions if we were actually deluded. They are intriguing only after one has sought out enough additional cues to determine the true nature of reality. Illusion can result from over reliance on a single cue or from an unwillingness to insist that all the evidence be consistent with the same hypothesis. The difficulty of determining the truth can result from a remarkable property of the mechanisms of perception: even in very simple situations, perceptual evidence is arranged in a strict and automatic hierarchy of importance and reliability. One tends to pay attention only to the single type of evidence that dominates this hierarchy. People require training, perhaps education, to become aware of hierarchical bias and to seek out additional kinds of evidence.

Hierarchical phenomena can be illustrated in extremely simple visual situations such as a determination of the relative distance of two objects. Apparent size, color, brightness, stereoscopic evidence, and obscuration can affect this determination. If all the cues are present, even though some are arranged to be contradictory, one automatically pays attention only to the evidence at the top of the hierarchy; for example, the fact that a nearer object partially obscures the one behind it. If one eliminates the top cue, the next one takes over even though it may indicate that a different object is nearer. It is not clear how these hierarchies are established, and their order

The Exploratorium, not long after opening, in the early 1970's

differs from person to person. But once established, they seem very absolute, for the contradictory evidence produces no sense of confusion or doubt about the conclusion. It would be interesting to discover whether art enables people to rearrange their own perceptual hierarchies. Hierarchies must enter into all kinds of judgments and may account for the stubbornness of those that involve skin color or some particular foreign accent. Scientists pride themselves on being immune, at least in a narrow domain, to the illusion producing compulsion of such hierarchies. In fact, a frequently avowed objective of science teaching stems from this pride, and it would indeed be fine if demonstrations on the mechanisms of perception suggested to our visitors that conclusions about "the state of the external world" must be consistent with all available bits of evidence.

Although the Exploratorium does not consciously glorify the achievements of people, it is impossible to come away without some sense of awe at the subtleties, complexities, and the almost unbelievable reliability of sensory information and processing. One also frequently comes away with a new awareness that causes one to stare, squint, close one's eye, or cock one's head, in a word, to experience everyday phenomena.

In the context of the title of this panel, I should mention the word "relevance," because so many students have complained about the lack of it in their education. I must confess that I am confused about the meaning of the word in this connection. There is very little that one can learn that is not relevant to something, but I do not think that the students mean "relevant to something." My guess as to their meaning is that something can appear relevant only when the experience of the present moment in some way forms a link between experience of the past and those of a conceivable future. In this sense, and also because it is manifestly noncoercive, the Exploratorium. has responded to the criticisms and the tenor of the times.