feature article

The evolution of the science museum

Alan J. Friedman

Once resources for the scholar and serious student, science museums are now dedicated to public education. But just how institutions define and meet their educational goals is a continuing story.

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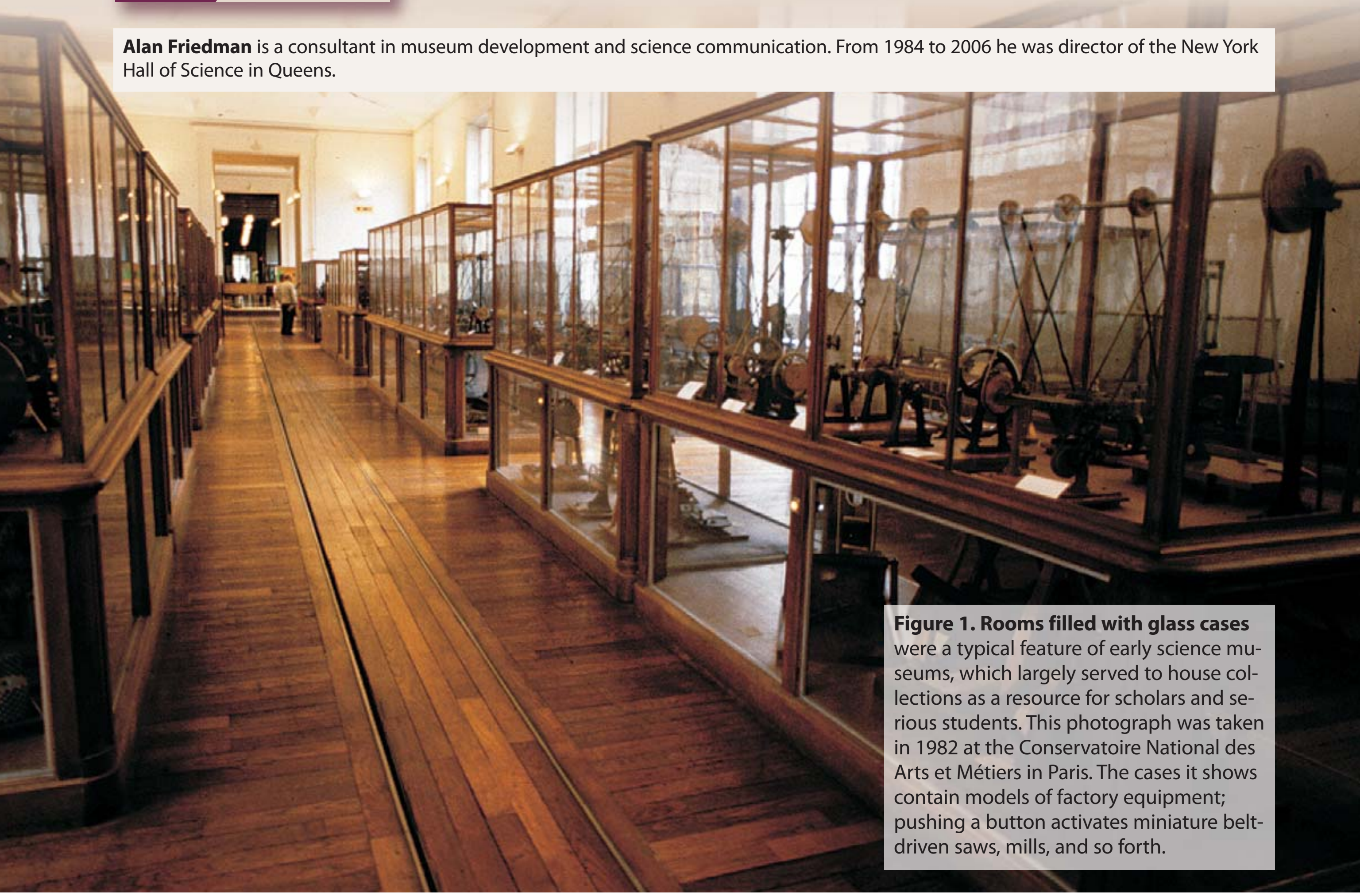

Figure 1. Rooms filled with glass cases were a typical feature of early science museums, which largely served to house collections as a resource for scholars and serious students. This photograph was taken in 1982 at the Conservatoire National des Arts et Métiers in Paris. The cases it shows contain models of factory equipment; pushing a button activates miniature belt-driven saws, mills, and so forth.

When did scientists first become interested in science? A 1998 survey of 1400 scientists, conducted by the Roper Starch organization for the Bayer Foundation and NSF, reported that a respected adult, such as a parent, was the biggest factor in stimulating childhood interest in science. But the survey also identified other important factors:

> Teachers were as influential as parents. And, apart from formal science classes (82 percent), a variety of informal activities had an effect. More than 80 percent said science toys and equipment like chemistry sets and telescopes; 78 percent reported newspapers, magazines and other media that covered science; 76 percent said science museum visits; and, 69 percent felt that doing science experiments at home was influential.[1]

Those channels, which have inspired people to retain a lifelong interest in science or even to become scientists, probably interact to a substantial extent. Parents encourage their children's interest in science by taking them to science museums and buying them science toys; teachers take their students on field trips to museums and assign them readings, television programs, and websites for reports in science classes.

Of all those factors, science museums were the fastest growing during most of the past quarter century. In 1973 the 24 hands-on science museums in the US and Canada formed the Association of Science–Technology Centers. Today ASTC

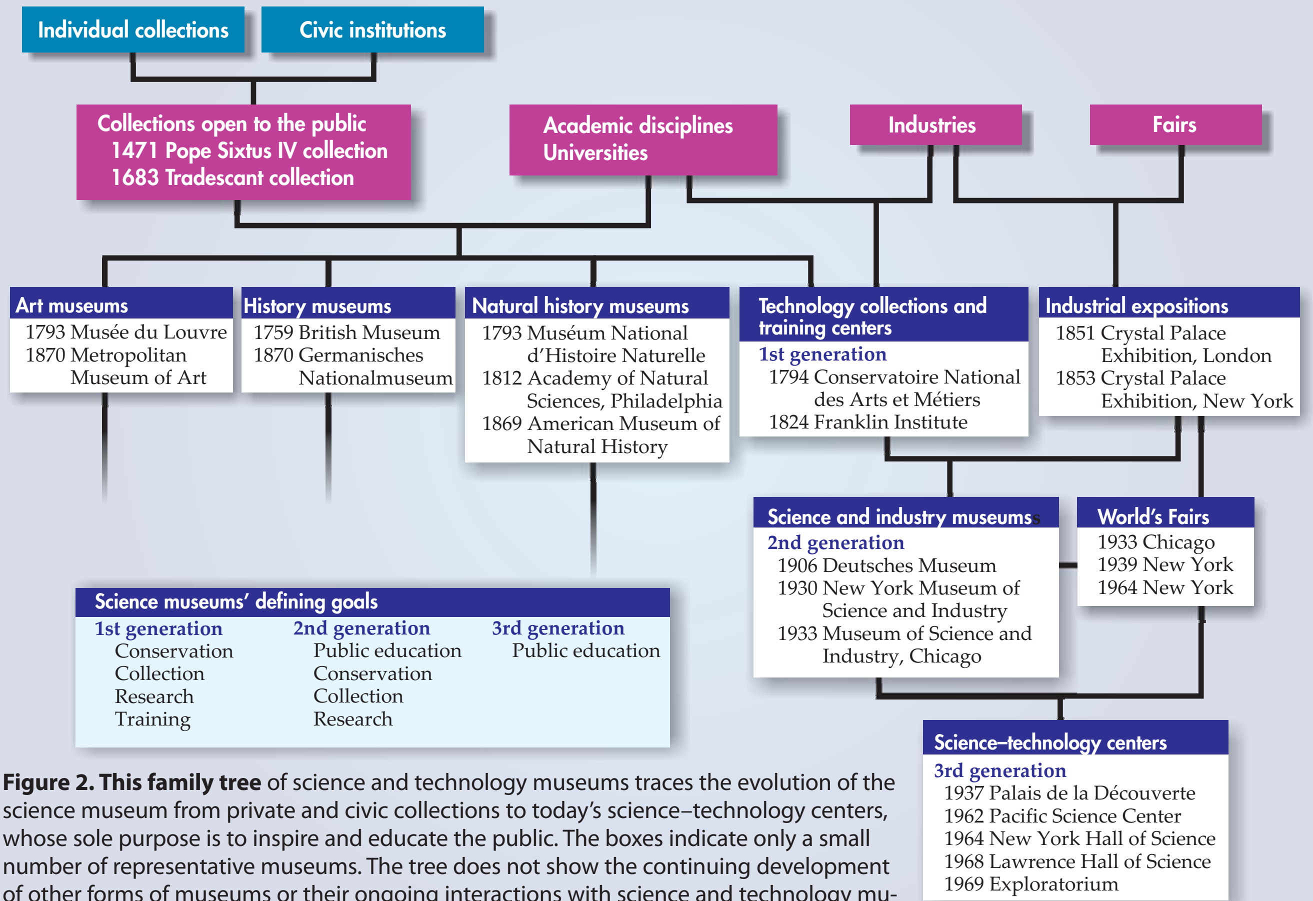

Figure 2. This family tree of science and technology museums traces the evolution of the science museum from private and civic collections to today's science–technology centers, whose sole purpose is to inspire and educate the public. The boxes indicate only a small number of representative museums. The tree does not show the continuing development of other forms of museums or their ongoing interactions with science and technology museums, topics under study by others.[14]

includes 349 member science centers and museums in the US and 95 members in other countries. Based on a 2009 survey, ASTC estimates that 82 million people visited its member museums that year.[2] Hundreds of additional institutions worldwide belong to regional organizations. The number of science and technology museums in Europe, Asia, and Latin America has also grown dramatically, with corresponding increases in the number of visitors.

A working telescope amid the artifacts

I never visited a science museum in my hometown of Atlanta, Georgia, when I was growing up in the 1950s. Atlanta didn't have a science museum until well after I graduated from college. A childhood devoid of science museums is much less likely for children today, though, since science museums now exist in every major city throughout the world.

I did visit the American Museum of Natural History on trips to New York to see my grandparents. All I remember of those early encounters are the rows of glass cases and, of course, the dinosaurs. There was that startlingly wondrous room where the stars came out—the Hayden Planetarium—but that seemed like another experience altogether. It wasn't until the early 1970s that I visited science museums in London; San Francisco; and Berkeley, California. But I had a hard time figuring out from those experiences just what a science museum was supposed to be, because the museums in the three cities were so different from each other.

In 1970 the Science Museum in London was much like the natural history museum in New York: row after row, room after room of glass cases such as those shown in figure 1. The only difference was that instead of butterflies, clay pots, and stuffed animals, the London museum's glass cases were filled with ship models, telescopes, and assorted industrial artifacts. In place of the giant dinosaurs were giant steam engines. Those exhibits were fascinating, but one display at the museum especially intrigued me. It was a unit, near a glass case with the antique telescopes, that I could manipulate. It consisted of a working model telescope, with rotating disks that allowed me to select different lenses, thus changing the magnification. And I could actually look through the telescope and see the result of the choices I made.[3] That was my first experience with a hands-on exhibit. I looked through the museum in vain for other examples.

It wasn't until two years later that I visited the Lawrence Hall of Science in Berkeley and discovered dozens of hands-on exhibits. The Lawrence Hall of Science still had some glass cases with a superb collection of crystals and Ernest Lawrence memorabilia. But it also featured many interactive exhibits. Most of those were in the push-the-button or turn-the-crank mode; others, however, allowed more intensive manipulation. Shortly after visiting that museum I went to the Exploratorium, across the San Francisco Bay. The glass cases were entirely absent; in their place were hundreds of highly interactive devices. The devices and displays were not as pretty as those in London or Berkeley. Indeed, they were downright rough in appearance. The message seemed to be that the phenomena were beautiful, and the devices served merely to reveal the phenomena.

It took me a decade to realize that the three museums I saw in the early 1970s were not just three individual, independent creations. Rather, they represented various stages in the ongoing evolution of the science branch of the museum world. Science museums and centers have been undergoing that evolution for more than 200 years.

The first two generations

Museums began as private collections—of paintings, furniture, memorabilia of famous people, seashells, and the like—turned over to some public agency for care and display after the owner's death. The Tradescant collection, which became the Ashmolean Museum in Oxford, UK, is perhaps the best-known example. The collections, whose principal beneficiaries were research scholars and serious students, were often displayed with little order or plan. After the French Revolution in the late 18th century, a rational, encyclopedic approach was applied to the collections, and they were treated as instruments for bringing culture to the public at large. The private collections of paintings became art museums; the furniture and memorabilia became history museums; and the seashells became natural history museums.

Technology collections started around the beginning of the 19th century. The products of the Industrial Revolution, however, were scarcely ever gathered in private collections. Early technology museums were created to meet practical needs of universities and industries, rather than to preserve existing collections. The first of those, the Conservatoire National des Arts et Métiers, in Paris, opened in 1794. (The museum family tree in figure 2 places that museum in the context of others of the time and traces the future development of technology museums.) Much of its collection was fresh from the factory and the craftsman's workbench. A major function of the conservatoire was to train new craftsmen and designers, using the collections as teaching aids. The Franklin Institute in Philadelphia began along the same lines.

At the beginning of the 20th century, a second generation of science and technology museums gradually began to merge the form of first-generation museums with that of popular industrial expositions, such as the famous Crystal Palace Exhibition in the UK in 1851, that embraced the idea of the trade show as advertising and public education.[4] The Deutsches Museum in Munich and the Museum of Science and Industry in Chicago are the most notable early members of this second group. Public education is one of their goals, and they include exhibits that can be touched or operated by button and crank. Preservation and collection are also defining goals, as manifested by hands-off historic exhibits of things such as airplanes (see figure 3) and medical apparatus.[5]

Governments, private individuals, and industry provide funding—and often the exhibitions themselves. The audience mix is different from that of first-generation museums, since the general public and younger children are primary; serious students and scholars become secondary targets. From the beginning, industry often looked at second-generation museums as an advertising medium. The Museum of Science and Industry in particular became famous (or notorious) for a period in the 1960s and 1970s when it allowed industries to design, build, install, and maintain some exhibitions—complete with brand-name product promotion.[6]

Public education becomes the only mission

Albert Einstein's visit to Paris in 1922 stimulated an interest in public science education that, after many years of gestation, gave birth to the Palais de la Découverte in 1937. The Palais, the first of the third-generation science museums, deliberately omitted permanent collections of artifacts and their research, collection, and conservation. Instead, it was devoted purely to public education. Even the word "museum" was omitted from its name.

The Palais de la Découverte model needed time to catch on, but by the late 1950s, several forces were in place to make it influential. The success of the Russian arms and space programs, illustrated by the launching of the *Sputnik 1* satellite, elevated science education—particularly in the US—to a matter of national urgency. And the influence of Jean Piaget's theories of learning, which stressed the role of concrete experience, inspired a new hands-on science curriculum for the schools. The industrial exhibitions were now huge fairs that dramatically displayed new technology and the wonders of scientific phenomena—and the audience could participate. World's Fairs in Chicago and New York before World War II, and again in New York in 1964–65, demonstrated that millions of people would line up to see such displays.

The demand for improved public understanding, the model of the Palais de la Découverte, and the popularity of science in the World's Fairs resulted in the explosive growth of the third generation of museums, now known as science–technology centers. In those centers, public education is usually the only goal, and World's Fair–inspired intensive animation and interactivity are the primary techniques.

The Exploratorium in San Francisco, founded in 1969, is the purest example of the new generation. Like many of the new museums, it is housed in an abandoned fair building. But the Exploratorium's current home—it plans to move to a renovated pier on the San Francisco Bay—has characteristics particularly unlike a museum: a severely utilitarian entrance, bare concrete floor, and the cold environment of a giant metal Quonset hut. The exhibits are pure phenomena. Visitors will find no product promotion whatsoever and few if any simulations; indeed, computers were not introduced until many years after the founding. Visitors will discover that they need intensive interaction to activate nearly every exhibit unit.

The Exploratorium exhibits might be rough wood and metal, but the phenomena and interactions they produce are dazzling. Dozens of the Exploratorium's color, light, vision, and mechanics exhibits are among the most commonly replicated in the world. Few of the hundreds of science–technology centers have deliberately copied the Exploratorium's rough ambiance, however. Most of the third generation has aimed more at the World's Fair glamour of the second generation. Along with interactive exhibits, spectacular presentation technology—particularly in the form of giant-screen movies—has become a financial and programmatic mainstay of the third generation.

A few first- and many second-generation museums remain today, although they often include some elements clearly recognizable as third generation. Second-generation museums, such as the National Air and Space Museum in Washington, DC, continue to be highly popular. From time to time, new ones debut; a recent example is the Flying Heritage Collection, now in Everett, Washington, which opened to the public in 2004. Second-generation museums are now incorporating aspects of third-generation institutions, such as intensive visitor interaction and large-format theaters, but they still retain their collection and research functions.

A focus on the visitor

The strengths, challenges, and prospects for third-generation science–technology centers are in large part reflections of their differences from traditional museums. Centers have no permanent collection of artifacts to be preserved for future generations, no research in subject areas covered by the exhibitions, and in general no substantial endowment.

The lack of a collection, in particular, has meant that a new science–technology center can be created more easily than a traditional museum. Founders can buy their initial exhibitions off the shelf as copies of exhibitions in other museums or as original units commissioned from commercial exhibit-building firms. On the other hand, a collection is both a permanent legacy and a resource that can be exploited for endowment fundraising. Its absence has forced science–technology centers to be opportunistic in their project choices: Institutions often plan their exhibit topics around the availability of a restricted grant, even if it means swerving from an established strategic plan.

From their earliest days, science–technology centers have looked to visitor numbers, satisfaction, and learning as the primary measures of their success. In the 1970s, NSF, the major source of federal support for science–technology center exhibitions and programs in the US, began to require increasingly sophisticated evaluation of visitor learning in NSF-funded exhibitions and programs.

Sophisticated forms of evaluation to improve the quality of their offerings have become integral to the culture of most science–technology centers.[7] One reason that evaluation is a higher priority for science–technology centers than for traditional museums is that an interactive science exhibit that fails to communicate is more obvious—people cannot physically make it work—and the penalties are higher. If visitors are frustrated by their inability to operate an interactive component, they tend to respond by kicking it, complaining, and declaring, "Everything is broken." In contrast, an art exhibit that visitors don't understand is more likely to be ignored than to be attacked.

We who are involved with science–technology centers understand that formal education involves hundreds of hours to achieve its desired cognitive gains and that relatively little can be accomplished with our few hours of visitor exposure per year. But we also know that the centers have reliable impact on inspiration, interest, and appreciation. Those positive goals fit well with a broader societal intention to increase the labor force in the economically powerful fields of research, development, and technology.

Economic and political factors have broadened the focus of science–technology centers to encompass more than the traditional socioeconomic classes and adult audiences that have characterized most art and history museums. Many centers have made major efforts to attract and retain audiences of children and visitors from populations underrepresented in science and technology. Although visitor demographics are not widely available, some data indicate those programs are achieving success. One example is the New York Hall of Science, located in the most diverse county in the US, according to the 2000 US census. In the 1980s, to make the institution more welcoming and engaging to the community and to encourage students to pursue careers in science, the museum established a program to employ local high-school and college students in various positions. As shown in figure 4, regular surveys of weekend visitors indicate an audience diversity that reasonably reflects the population as a whole. Males and females visit in approximately equal numbers.

Replication and collaboration

Traditional museums take pride in the uniqueness of their collections. Although many science–technology centers have some unique exhibits, the majority of their exhibitions exist in more or less the same form in dozens or even hundreds of other centers. Figure 5 shows a center with a mix of exhibit types. Interactive exhibits and components originating at the Exploratorium, the Franklin Institute, the Ontario Science Centre, the New York Hall of Science, the Science Museum in London, and many other centers can be seen on each other's floors as well as in other institutions around the world.

Relationships that began during project replications

Figure 3. The Museum of Flight is a second-generation science museum in Seattle, Washington. In addition to the airplanes seen here, the museum has a learning center with hands-on activities and an in-house drama troupe.

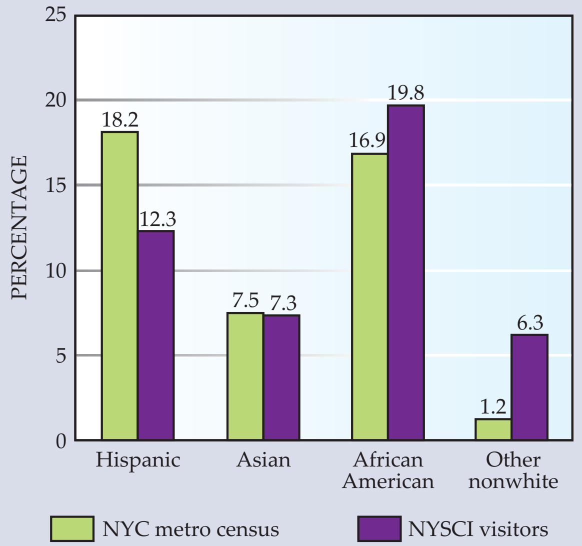

Figure 4. Visitors to the New York Hall of Science (NYSCI; purple) reflect the diversity of the museum's locale in Queens, New York (green). The visitor data are averages of surveys taken in 2003–05 by Morey and Associates for the NYSCI. The comparison demographics come from the New York City metro census of 2000.

have often led to ongoing collaborative efforts in other areas of center operations. Museums have established collaborative agreements to produce new exhibitions in multiple copies and so achieve economies of scale, and to undertake complex, ambitious exhibitions that no individual institution could tackle on its own. For example, in 1993 a nine-institution consortium of second- and third-generation museums, the National Health Sciences Consortium, created three identical versions of a major traveling exhibition on AIDS—a difficult, socially and culturally sensitive topic. Inspired by the success of that effort, the same group then prepared a large traveling exhibition on women's health issues. Other collaborative efforts include the Science Museum Exhibit Collaborative and the TryScience Web project. Both of those involve a half dozen or more partners, have created multiple products, and have been sustained for a decade or longer.

"Learning is broader than schooling"

With no mission to collect, conserve, or research, science–technology centers have had the luxury of establishing education as their undisputed first priority. In a sense, everyone in each center is an educator. Exhibitions, demonstrations, theaters, discovery rooms, and websites are all just alternative media to serve the goal of education. Internal staff relationships at such centers, from the 1960s on, have been different from those at traditional museums because of the centers' unitary mission. The conventional hierarchy of curatorial staff, exhibitions staff, and education staff could not apply, especially since few science–technology centers have curators.

Evidence for the impact of the centers on science education has largely been through evaluations of individual exhibitions and education projects, but field-wide impact evaluations have been increasingly prevalent. For example, ongoing studies of the impacts of informal science learning in general, and science museums in particular, are being encouraged by the NSF-supported Center for Advancement of Informal Science Education and collected on the InformalScience website, http://informalscience.org. The most comprehensive study to date was published in 2009 by the National Research Council.[8] A National Academies press release announcing the report gave some of the NRC's key conclusions:

> "Learning is broader than schooling, and informal science environments and experiences play a crucial role," said Philip Bell, co-chair of the committee that wrote the report, and associate professor of learning sciences at the University of Washington, Seattle. "These experiences can kick-start and sustain long-term interests that involve sophisticated learning. Think of the child who sees dinosaur skeletons for the first time on a family trip to a natural history museum, and then goes on to buy dinosaur models and books, do Web searches about dinosaurs, write school reports on the subject, and on and on."
>
> The report notes that experiences in informal settings can significantly improve science learning outcomes for individuals from groups which are historically underrepresented in science, such as women and minorities. Evaluations of museum-based and after-school programs suggest that these programs may also support academic gains for children and youth in these groups.[9]

Challenges

For all their positive features, science–technology centers face formidable challenges. When center directors get together, they frequently talk about the question of sustainability.[10] The problems center on small or nonexistent endowments, shrinking government support, and private support typically targeted at restricted grants for new projects. Coming up with each year's general operating revenue is increasingly difficult.

Science–technology centers can and do attempt to appeal to wealthier segments of the population, who can afford higher admission fees and will spend more in the shop. On the other hand, the centers want to broaden their attendance to include more diverse socioeconomic groups. How the conflict will be resolved is unclear. Centers are experimenting with raising admission fees and charging extra for certain exhibits or shows while at the same time offering more free hours, discount opportunities, and sponsored free events or memberships for targeted groups who may not be able to afford the higher fees.

A second area of tension is between serving the general public and functioning as an adjunct to the formal education system. Many science–technology centers have traditionally based their appeals for private and public support on what they could do for the schools. Indeed, the centers are heavily enlisted in providing professional teacher development, curriculum units, and science experiences outside the schools. Colleges and universities have the exclusive franchise to train preservice teachers in the US, but they are less involved with providing ongoing professional development and science resources for teachers throughout their careers. Hundreds of science centers and museums have stepped in to fill that gap; indeed, they do more in-service professional

Figure 5. The Explora in Albuquerque, New Mexico, like many third-generation science–technology centers, has both original and fairly common hands-on science exhibits. What is unusual is that Explora provides semiprivate spaces around each unit. As a result, families spend more time engaging with and discussing the exhibits than they do in the usual big, open exhibition floors.

development than universities.[11]

Yet relying on their relationship to formal education has subjected the centers to political forces beyond what they can influence and perhaps even understand. When the No Child Left Behind Act of 2001 imposed new classroom priorities, focused on math and language arts, many science centers suddenly found their professional development courses underenrolled, school visits falling precipitously, and contracts for supporting the schools cancelled or not renewed. Some science–technology centers have responded by putting even more effort into securing partnerships and long-term service contracts with schools; others have scaled back their school-based initiatives in favor of more community programs, digital theaters, and blockbuster exhibitions.

Most centers will probably continue to work both sides of the divide that separates formal and informal education. They argue that they can be long-term partners in formal education and that they also provide a separate channel for the public to connect to science and technology. In my opinion, it is essential to preserve those aspects of the centers that are least like school. First, the centers afford alternative ways of learning for students who may find science in their classrooms unappealing. Second, the centers provide a route for those who are out of school to acculturate to a lifetime in a society that is daily changed by science and technology.

The accelerating pace of change in science and technology will also be evidenced in the changing nature of science–technology centers. In recent years, many centers have been learning how to present contemporary developments rather than the 19th-century physics, astronomy, chemistry, and biology that still make up most exhibitions. The new information and communications technologies will be part of those presentations. Web-based exhibits, live coverage of events, podcasts, and cell-phone audio tours can all help science–technology centers to communicate and carry out their missions. The catch is that there seem to be no proven revenue streams to pay for them.

New horizons

What delighted me on those first visits to science museums in the 1970s is what still delights me today. I visit science museums in different parts of the world every year and always come back with treasured pictures and new ideas. Seeing unique objects, hearing new sounds, operating novel devices, perceiving connections I didn't know existed, and enjoying the ambiance of a unique and friendly environment are benefits available in every science museum. Interactions with staff and other visitors, no matter how brief, have been critical elements of my experiences.[3] I know science museums and centers must continue to evolve, but I expect the essential functioning of their exhibits, facilities, and staff will likely remain basically as they have been for the past half century.

What will be different, I believe, is the range of activities that science–technology centers will undertake. It is clear that the internet is fast becoming the universal tool for information presentation and retrieval. The large and popular websites operated by science museums demonstrate that those institutions are well qualified to make the Web significantly more effective as a medium for improving the public understanding of science and technology.[12] Millions of people who use those websites regularly have not visited and probably never will visit the sites' home institutions. Another example concerns an exciting new technique for engaging the public: Citizen Science, through which nonscientists collect data for real science and sometimes see their data used and published in important studies. The idea began with the pioneering Project PigeonWatch at the Cornell Lab of Ornithology and has now grown to hundreds of projects around the world, many of them based at science centers.

I also expect that the business model for science museums will change. The commercial successes of the traveling exhibitions Body Worlds, which explores human anatomy, and Titanic: The Artifact Exhibition are too tempting. Science-museum collaborations will likely launch their own mega-attractions, including presentations at venues that are not always science museums or even associated with not-for-profit organizations. Traveling exhibitions may stray far from the core content interests of the science–technology centers and serve primarily as revenue generators, teasers to attract new audiences, or experiments to see how well the museums can find relevance to science and technology in popular interests. Following the pattern of the Guggenheim Museum and the Exploratorium, science centers will explore the possibility of satellite installations, some of which will help the institutions' bottom lines. All the while, science museums will have to address the tension between maximizing earned revenue and improving audience diversity.

Science–technology centers will undertake far more interdisciplinary and extramural collaborative projects. Nowadays, placing science in the traditional boxes of physics, chemistry, and biology is almost impossible. All the excitement in science is emerging from the intersections of conventional disciplines, in such fields as nanoscience, environmental biology, and neuroscience. And a similar kind of excitement is coming from areas in which science and technology intersect with the arts and humanities. The next generation of science museums may not be science museums at all but far broader institutions in which the sciences, the arts, and the humanities are inextricably bound together in exploring vital questions about the universe and its inhabitants.

Portions of this article are based on earlier articles I published in the Informal Science Review *and* Curator *and are used with permission of the publishers.*[13]

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