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Planetariums as 21st Century Digital Dioramas

By Ryan Wyatt

For more than a century, natural history museums have used dioramas to allow visitors to experience a sense of travel in the confines of an exhibit gallery. With fulldome video projection technology, modern planetariums can recreate virtual environments that extend the concept of travel to celestial realms—and connect the human scale to global and even cosmological scales.

This paper explores how planetariums and natural history museums share objectives around creating a sense of travel (in both space and time), around maintaining visual and scientific authenticity, and around providing larger context for individual objects, specimens, and discoveries.

The Experience of Space and Time

Since their origins as "cabinets of curiosity" in the 16th Century, museums have collected objects from widely-dispersed locales and, in the very act of bringing items together for display, have constructed physical travelogues. And as they evolved into curators of life's evolutionary heritage, natural history museums also began to communicate a temporal context to their collections. Thus, visitors to natural history museums are invited to experience travel in both space (the locations from which specimens have been collected) and time (the periods from which fossils date or the evolutionary relationships which exhibits depict).

Planetariums have long attempted something similar; indeed, the most thorough history of planetariums bears the title *Theaters of Time and Space* (Marché, 2005). As planetariums have evolved from the opto-mechanical reproductions of the night sky (nonetheless addressing many contemporary astronomy topics in their programming) into fulldome immersive environments, the deepening of astrophysical data representation and the broadening of science topics have collectively tightened the focus on spatio-temporal voyages.

As fulldome planetariums begin to encroach on disciplines more traditionally addressed in natural history museums, I believe that we are extending the work of the last century's museum professionals. In particular, we have an opportunity to wed traditional representations of the natural world seamlessly with 21st-century data visualizations: by integrating these tools across spatio-temporal scales, we can establish meaningful context for modern discoveries and allow audiences to make profound connections to critical global trends.

Natural History Habitat Dioramas

When Charles Willson Peale opened his museum of natural sciences in Philadelphia in 1786, he brought together the relatively new art of taxidermy with his training as a painter. Painting skies and landscapes behind his specimens, he pioneered what we today think of as a museum diorama (Quinn, 2006). Recognizing this seminal contribution, it nonetheless makes more sense to situate our modern conception of habitat dioramas within the larger context of immersive art in the 19th Century.

Panoramas (also called cycloramas) made their debut in London just a year after Peale's museum opened across the Atlantic, and they skyrocketed in popularity over the next century. Typically site-specific, these cylindrical paintings in rotundas a few stories tall and tens of meters in diameter cropped up all over Europe and the United States, depicting ancient cities, exotic locales, and bloody battles. Accessed in a manner (via corridors and staircases) intended to disorient visitors, panoramas created the illusion of travelling to a distant place and/or time. And in many such works, three-dimensional figures, mannequins, and foreground objects integrated seamlessly with the background. In short, "panoramas had to be so true to life that they could be confused with reality" (Comment, 1999).

In 1822, Louis Daguerre coined the term "diorama," from the Greek words *dia* (meaning "through") and *horao* ("that which is seen") in reference to his invention that differed considerably from most current implementations. Daguerre's dioramas used painted scrims in front of a changing light source to create the illusion of depth in a confined space. Conceived as commercial ventures, these dioramas initially competed with panoramas for public attention and admission fees, but in the face of waning enthusiasm and a destructive fire in 1839, Daguerre prepared only one final diorama and then focussed his attention on perfecting his photographic technique, the daguerreotype.

And in the latter part of the 19th Century, the wax museums Madame Tussauds in London and Musée Grévin in Paris began staging historical reconstructions in their galleries. At Musée Grévin, one could encounter the latest grisly murder or international intrigue displayed in meticulous detail, in a constantly-changing series of tableaus designed to grab the public's attention—and admission fees (Levingston, 2014).

These various immersive experiences certainly influenced the development of the habitat diorama in natural history museums. (Indeed, these influences reverberated well into the 20th Century: the panorama, for example, spawned the moving-image Cinéorama, a film-based immersive experience that appeared briefly at the 1900 World's Fair, and eventually culminated in Disney's Circle-Vision 360° experience much later in the century. More on that later.)

Credit for creating the earliest habitat diorama usually goes to Carl Akeley, a taxidermist, sculptor, and painter who combined his varied skills in his work. In 1889, at the Milwaukee Public Museum, Akeley assembled "a diorama that featured mounted specimens in a re-created foreground habitat that merged with a realistic background habitat painting. This example of a new genre measured three feet tall, four feet wide, and two feet deep, and depicted muskrats in a re-created marsh against a mural of a wetland. It is still on display today" (Quinn, 2006). Thus, taxidermied specimens appeared in context with the environments in which they lived, engaged in activities characteristic of the species—in the case of the muskrats, feeding, burrowing, and even swimming.

Akeley's subsequent work at the Field Museum, along with the efforts of Frank M. Chapman at the American Museum of Natural History (AMNH), refined the concept of the habitat diorama, and the design spread to other institutions. In 1916, the California Academy of Sciences (the Academy) opened its North American Hall of Birds and Mammals, which featured numerous innovative dioramas. "Illuminated by natural light, they treated the viewer to a dynamic that varied with the seasons and the time of day, a concept new to the museum genre" (Wellck et al, 2003).

Simson African Hall opened in 1934 in the original California Academy of Sciences building complex. Image courtesy of the California Academy of Sciences Archives.

It's worth noting that "most dioramas in the museum depict an actual location somewhere in the natural world." And very early on, AMNH designed the work with significant conservation messages. "The museum's habitat dioramas were intended not just to be popular. They evolved in response to the public's growing awareness of wildlife and wilderness as finite and fragile ecosystems as well as a resource for human exploitation. They were created to promote the love of and concern for nature and its wise stewardship. Their goal was its protection and preservation, both within the diorama and in the real world" (Quinn, 2006).

California Academy of Sciences exhibit preparators Cecil Tose and Toshio Asaeda working on Water Buffalo exhibit in 1958. Image courtesy of the California Academy of Sciences Archives.

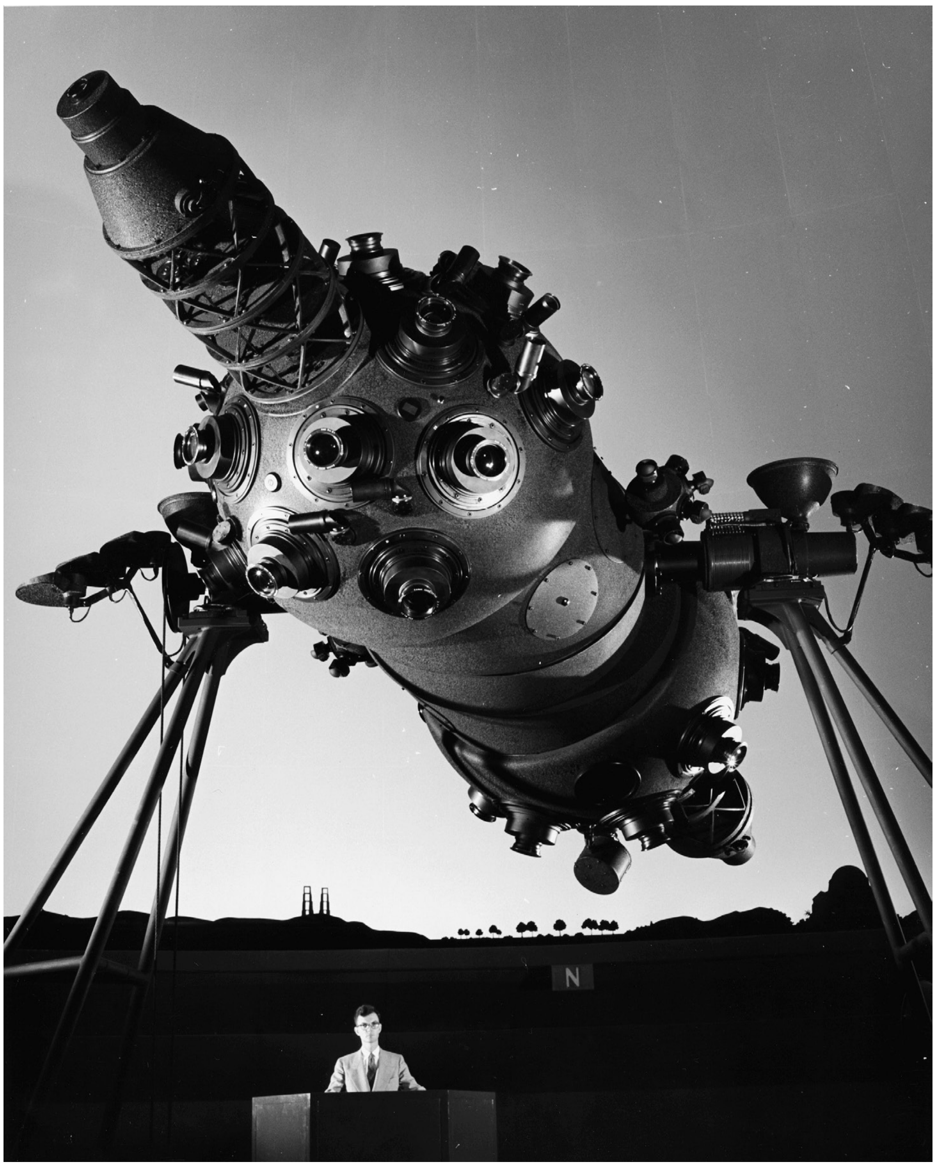
The habitat diorama arguably reached its apotheosis in AMNH's Akeley Hall of African Mammals, which opened in 1936. "In the center of the hall, Akeley's massive elephant group stands out on an elevated platform. The elephants are depicted in a state of alarm: the old bull faces the entrance, ears extended, trunk testing the air; a younger bull has wheeled around to guard the rear of the herd. All around the elephants, embedded in walls of black polished marble, are Akeley's habitat groups. They stand out in the darkened hall in a blaze of internal sunlight, as if one were looking through bright windows into another world at another time—the Africa that Carl Akeley wanted so to save" (Preston, 1986).

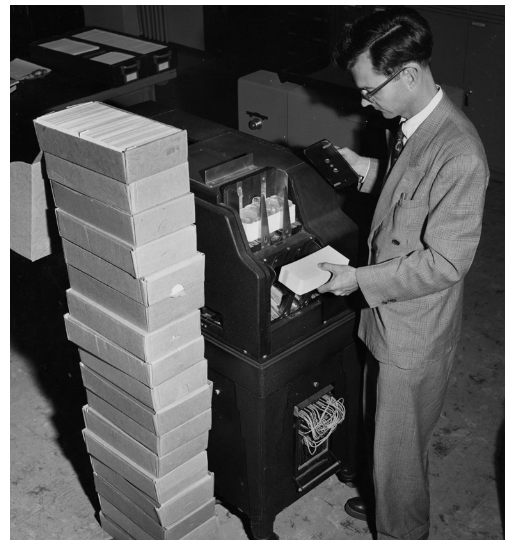
Opto-Mechanical Planetariums and the Night Sky

Much like dioramas, early planetarium experiences were valued for their verisimilitude and accuracy: "one of the amazing triumphs of science and engineering" (Luyten, 1927), "optical effects that correspond precisely with those of nature" (Kaempffert, 1928), and a "realistic experience… beyond belief" (Fisher, 1934), to quote selected contemporary sources.

Each successive generation of planetarium projectors refined the accuracy with which they addressed the mechanical challenges of simulating diurnal (daily) motion, the movement of the planets, and the precession of the equinoxes. Luckily, the "mechanical universe" proved amenable to analog solutions involving mostly gears and motors. But in addition, there were thousands of stars to position accurately in the simulated sky. From a modern perspective, we can see this as a data visualization challenge—albeit one focused purely on a single dataset, namely the stars as observed from Earth.

Leon Salanave painstakingly described one solution in an article written for the Academy's *Pacific Discovery* magazine at the time, detailing how the team used digital techniques to address the challenges of accurately positioning 3,800 stars on the physical projection mechanism. "One of the big jobs in the building of our star projector involved sorting out the stars to be assigned to each of the 32 fields, and then computing the stars' positions thereon. The vast amount of labor involved in this work was carried out on International Business Machines sorting and calculating devices in the Computing Laboratory, University of California, Berkeley" (Salanave, 1952). Modern planetariums have become increasingly dependent on computers (see below), so this article makes for intriguing historical reading.





Left: *Star projector with Leon Salanave at console of the original Morrison Planetarium. Image courtesy of the California Academy of Sciences Archives;* ***Top right:*** *Leon Salanave putting IBM cards in sorting machine to help calculate star positions for the original Morrison Planetarium. Image courtesy of the California Academy of Sciences Archives;* ***Bottom Right:*** *Leon Salanave stands at one end of a 58-foot-long printout of complete data on over 6,000 star locations. Image courtesy of the California Academy of Sciences Archives.*

What motivated the drive for accuracy? Marché draws parallels between planetariums and museum dioramas in terms of preservation, arguing that conservation-minded museums may have driven "museum directors, curators, and educators to unite astronomy with other exhibits and programs" in order to protect the vanishing night sky. "When viewed from the confines of an urbanized, industrial landscape, the innate starry sky had become another of those elements that had vanished from the natural world." (Marché, 2005) Indeed, a *New York Times* article about the opening of Adler Planetarium in Chicago (the first planetarium in the Western Hemisphere) addressed this concern in the second paragraph: "The crowding of hundreds of thousands into large industrial centers is chiefly responsible for the decline of popular interest in the noblest of sciences" (Kaempffert, 1928). The planetarium community took this charge very much to heart, viewing preservation of the night sky as a core function—indeed, a definitional aspect, for some—of the planetarium.

Perhaps this is also reflected in the grandiloquent, quasi-mystical language that planetarium professionals could often employ in describing the medium…

"There is something about a planetarium environment that is unique, save for the real out-of-doors under nature's sky. It is this uniqueness that makes the planetarium experience potentially superior to the documentary Film. What is this mysterious quality? From the physical point of view, it is the dimension of space. Under the realistic stars, one soon forgets that he is looking at a projection on a curved surface, for the planetarium sky adds the impression of the third dimension. On a more inspirational level, the planetarium setting, with stars gliding slowly overhead, affords the viewer an opportunity to contemplate the mysteries of creation, to consider the vastness of space, and at the same time to gain some insight into his own relation to time, space, and eternity" (Hagar, 1980).

"The lights are turned down gradually, just as in a theatre before the curtain rises on a play. Gradually, your eyes accustom themselves to the darkness. You lose all sense of confinement. In some incomprehensible optical way you have been transported out into the open on a marvelously pellucid night. What was once a naked white vault is now the deep blue nocturnal sky, but strangely orbless. A miracle happens. A switch has been thrown, and that cerulean vault suddenly becomes a firmament of twinkling stars. Even trained astronomers who know exactly what to expect cannot suppress a long-drawn 'Ah-h-h!' of astonishment and pleasure when they behold this dramatically presented counterfeit of the heavens for the first time" (Kaempffert, 1928).

Or, as Clyde Fisher, director of AMNH's astronomical department, expressed the role of astronomy in his 1927 plea for establishing a planetarium in New York City: "What field of science offers so great an opportunity to enjoy majestic beauty? What subject helps us more in our natural struggle to comprehend the infinite? What science does most to lift one out of the petty things of everyday life, thus allowing the soul to expand?" (Fisher, 1927).

Fulldome Planetariums and the Digital Universe

The most recent advance in planetarium technology, fulldome video, allows the planetarium dome to showcase a wider range of content than simply the night sky. Fisheye lenses or seamlessly blended video projectors fill an entire hemisphere with visuals, allowing for the recreation of diverse environments, whether through computer-generated imagery or real-world videography. The primary emphasis has remained astronomical, but the toolkit has widened to include visualization of three-dimensional data and accurate depiction of astrophysical phenomena well beyond an earthbound perspective (Wyatt, 2004, 2005).

Although fulldome video entered the planetarium field in the late 1990s, the re-opening of AMNH's Hayden Planetarium in February 2000 registered as a signal change within the profession. Aside from igniting debate among long-time planetarians (often related to the moral imperative to focus on naked-eye astronomy), it helped redefine expectations for planetariums in general.

As *New York Times* reviewer Malcolm W. Browne described the new Rose Center for Earth and Space at the time of its opening: "The domed Space Theater, which is the centerpiece of the Rose Center, the latest branch of the American Museum of Natural History, offers synthetic views of the cosmos far more detailed than the most elaborate Hollywood productions. With the help of a supercomputer, a state-of-the-art Zeiss star projector, an advanced laser system, a gigantic data base (in which the motions and distances of thousands of stars are catalogued) and, of course, the hemispheric Space Theater itself, the builders have created a marvelous celestial playhouse" (Browne, 2000).

In my six years as science visualizer at AMNH, I worked with dozens of scientists (mostly astrophysicists and the occasional geologist) to interpret their data for the highly-produced "space shows" that engage the majority of visitors to Hayden Planetarium. However, the backbone of the shows also had a real-time instantiation: the Digital Universe data that Browne mentions parenthetically and incompletely could be loaded onto the aforementioned supercomputer and piloted through in a live presentation.

Director of Astrovisualization Carter Emmart hosted informal after-hours gatherings, "tours of the Universe" that eventually evolved into public programs sponsored by the institution.

In a 2004 article cowritten with my AMNH colleagues, we described the advances in technology as follows: "When the Hayden Planetarium reopened in 2000, after its extensive renovation, a virtual trip through the universe required a supercomputer. Navigating databases of thousands of celestial objects and displaying them in a series of still images at the standard video rate of thirty times a second posed a tremendous computational challenge. Fortunately, the phenomenal growth and popularity of flight simulators and electronic video games spurred the field of data visualization to grow up almost overnight. Thanks in part to the video-game industry, personal computers today incorporate graphics processors that surpass the capabilities of the supercomputer the planetarium purchased only five years ago. The new technology arrived practically ready-made for transfer into industry and academia" (Abbott et al, 2004).

AMNH's leadership in these efforts, bridging the divide between planetariums and astrophysics researchers, helped elevate the medium and establish visualization as a core function of modern digital theaters. In particular, the real-time tools and data have since spread to literally thousands of planetariums around the globe, and their application extends to terrestrial and even microscopic topics as well as the more typical cosmic purview of planetariums.

Connecting to the Human Scale

Whatever the focus of the programming, fulldome video has developed clear parallels with immersive filmmaking such as the aforementioned Circle-Vision 360° or IMAX formats. As we look to tap into the true power of the medium, we cannot design our content like typical television or film productions. Instead, we need to explore immersive-appropriate techniques for science storytelling.

I think of a successful immersive experience as an embodied experience, ideally connecting with the whole person—intellectually, emotionally, and viscerally. (If you like, you can think of these as imprecisely mirroring Bloom's taxonomy of cognitive, affective, and psychomotor domains, respectively.) My intended meaning of an intellectually and emotionally engaging program probably makes sense to an uninitiated reader, but I want to emphasize the visceral aspect of an immersive experience: a planetarium provides an ideal environment for inducing the sensations of flying, of changing scale, of moving through space, of *travelling* in a way that affects the individual in a physical, visceral manner—preferably without causing discomfort or motion sickness.

Filmmaker Ben Shedd describes this as "frameless film," in contrast to the long history of framed cinema, with its well-developed vocabulary of camera moves, shots, and cuts. "In accounting for the sensation of movement, the filmic experience has moved from passive, from being held in a frame, to active, to becoming the engulfing reality with the audience present within the filmic events. In frameless film the audience becomes the main character in the film" (Shedd, 1989).

I refer to this as a "narrative journey," an audience-centered approach to filmmaking that integrates storytelling and virtual travel (Wyatt, 2005). Insofar as we can incorporate this mindset into our productions, I believe that we are poised to create content that can connect powerfully with our audiences—and effect the kind of change that Akeley and others attempted with their work more than a century ago.

These stylistic considerations have critical didactic implications as well. I maintain that transitions in scale are particularly amenable to the immersive environment, allowing viewers to experience continuous changes in size relationships that helps in constructing mental models of the phenomena. Thus, when we depict human-scaled phenomena in a fulldome planetarium—and then continuously transition to larger or smaller scales—we have an opportunity to connect spatial relationships that include our own human, embodied experience.

California Academy of Sciences Fulldome Productions

Although the planetarium community has embraced non-astronomical content rather slowly, an increasing number of shows and programs address terrestrial topics. Aside from the Academy shows I will describe below, the programs *Natural Selection* (2011), *Dynamic Earth* (2012), and *Dream to Fly* (2013) have made significant inroads into distribution and/or garnered awards at various fulldome festivals.

Since its reopening, the Academy has committed to producing planetarium programming that addresses a variety of science content, especially that which reinforces the institutional mission to "explore, explain, and sustain life."

The Academy's opening show, *Fragile Planet* (2008), begins in a virtual model of the planetarium itself, before fading away the screen and the dome, then lifting up to reveal the exterior of the building. The 23-minute film includes no cuts ("frameless film" taken to an extreme), so the audience experiences a seamless journey from their seats to the Virgo Cluster (some 60 million light years distant) and back home to Earth. About two-thirds of the show addresses astronomy topics (in particular, the possibility of life elsewhere), but a significant portion of the remaining time addresses biodiversity loss, remote sensing, and climate.

In the Academy's subsequent productions, digital artists have worked in close collaboration with researchers to recreate specific locations for display in Morrison Planetarium. In this sense, we have continued the work of diorama artists into the digital realm.

Life: A Cosmic Story (2010) opens in a redwood forest, recreating Bohemian Grove in Muir Woods, about 25 kilometers north of San Francisco. Within the computer-generated reconstruction of the forest based on photography of the site, butterflies (western tiger swallowtail, Papilio rutulus) and birds (Junco), animated in Maya, flutter overhead. From the familiar perspective of standing in the grove, we follow a twisting path toward the underside of a redwood leaf, photo-textured from microscopic images from the Academy's botany department. En route, we pass by computer-generated ants (of an appropriate species, Stenamma diecki) based on observations of living specimens supplied by Academy entomologist Brian Fisher. Reference diagrams and micrographs drove the design of the leaf's interior as well as the cell structures—from the major organelles to the interior of the chloroplast—based on a combination of reference diagrams and micrographs. Finally, having traversed twelve orders of magnitude in scale, we arrive at the surface of a thylakoid, showing four molecules involved with photosynthesis (ATP Synthase, Photosystem I, Photosystem II, and Cytochrome) based on models from the Protein Data Bank (PDB) archive, with the animation of ATP Synthase's ratcheting motion based on research by John M. Walker at Cambridge University (Wyatt et al, 2012).

The California Academy of Sciences Visualization Studio production team previews the opening shot of Life: A Cosmic Story *(2010). Image courtesy of the California Academy of Sciences Visualization Studio.*

This example takes the core concept of the habitat diorama and extends it meaningfully into the digital realm, not simply re-creating an environment but also allowing audiences to explore it in a different way. Because the scene connects the human scale, the cellular scale, and the molecular scale, it enables viewers to link the objects and the concepts in a coherent, unified fashion. It establishes context for the viewer in a highly visual, intuitive, and visceral manner.

Similarly, in a single scene from *Earthquake: Evidence of a Restless Planet* (2012), we transition seamlessly from a street-level recreation of the 1906 San Francisco Earthquake to a global-scale supercomputer simulation of the event. This unbroken transition allows viewers to place local events in a global context.

Along the same lines, a scene in our upcoming production will take viewers from a human-scaled view of water transport in a Douglas fir forest through the root system and down to the size of mycorrhizal fibers wrapped around the root tips, then follow the movement of water up the height of the tree before being transpired through the needles and into an aerial perspective of the forest… At which point, the show reveals regional, continental, and global phenomena that connect the forest ecosystem to worldwide climate and environmental networks.

In addition to pre-produced shows, we also create live programming that showcases the work of the Academy's researchers, integrating georeferenced data with images and 3D scans of specimens. As collaborators on the NOAA-funded Worldviews Network, we designed immersive virtual environments to help audiences evaluate complex global change issues across multiple scales of space and time. Through live presentations, interactive scientific visualizations, and community resilience dialogues, we are bringing the cosmic and global down to the local and back again.

These very literal, embodied (albeit digital) experiences allow us to give visitors a new perspective on these disparate topics—and to ground that perspective in their own sense of time and space. Creating digital environments and integrating them with data visualization, we can leverage the impact of traditional museum dioramas and planetariums—19th- and 20th-century innovations—in a truly 21st-century medium.

A historically-accurate recreation of 1906 San Francisco moments after a simulated earthquake. Image courtesy of the California Academy of Sciences Visualization Studio.

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Science for Every Child: Integrated Approaches to Engaging Diverse Learners

By Rabiah Mayas

Approximately six miles south of downtown Chicago on the shore of Lake Michigan sits the Museum of Science and Industry, Chicago (MSI). The museum's vision, to inspire and motivate children to achieve their full potential in the fields of science, technology, medicine and engineering, is advanced through world-class exhibitions and innovative educational programming that make science come alive for children and adults of all ages. In support of this vision, the Museum is committed to engaging diverse science learners, through a comprehensive network of programming that reduces barriers to access and leverages the learning potential of every guest.

Center for the Advancement of Science Education (CASE)
The Center for the Advancement of Science Education (CASE) is a hallmark of MSI's extraordinary commitment to science education. CASE is home to a rigorous set of programming designed to inspire and engage more diverse future scientists and engineers and improve science and engineering learning and teaching in our schools. Since its founding in 2006, CASE has grown to impact annually more than 340,000 students and teachers and nearly 1.5 million Museum guests through meaningful science learning opportunities onsite, as well as deeply integrated work in our partner schools and communities.

At the heart of CASE lies a set of core guiding principles that inform our approaches to science engagement and learning. Our multifaceted, youth-centered approach involves programming and partnerships with youth themselves, as well as their influencers: schools, families and communities. It is through this comprehensive strategy that we are able to effect a consistent guiding approach to engaging audiences in science. Across all of our diverse program areas exist a set of evidence-based foundational principles that guide our intention and practice in science teaching and learning. In particular, we believe in:

•Making science accessible for all of our guests
•Meeting guests where they are in their understanding of science and moving them forward
•Informed and reflective practice
•Engaging audiences in authentic science and scientific thinking
•Facilitating personal connections between guests and science content
•Modeling and supporting scientific inquiry and hands-on engagement
•Building relationships with individuals, groups and organizations

While the Museum welcomes guests of all ages, backgrounds, interest levels in science, and geographical location, a majority of CASE programming specifically targets two primary, broad sets of Chicago-area populations: 1) youth, educators and families in economically under-resourced schools and neighborhoods, and 2) youth from populations traditionally underrepresented in the STEM fields. The majority of our CASE participants are educated within the Chicago Public Schools district, in which 87% of students are from low-income families, and 12.2% are limited English proficient. About 40% of students are African-American, 45% are Latino, 0.4% are Asian/Pacific Islander, 1% are Multi-Racial, and 9% are White. As such, the primary target audience for our programming includes more racial minorities and lower income families than the city of Chicago at large.

In support of the needs of our local community, the Museum has transformed the way we work with students, teachers, families, communities and school systems. Programs aim to shape the attitudes about and participation in science by youth – especially minority youth traditionally underrepresented in the sciences –during their middle- and high-school years. By taking a comprehensive approach to science education, we aim to connect the Museum and the community in a sustainable partnership where learning takes place in many different locations. Our teams are vastly multi-disciplinary, housing expertise in classroom teaching, youth development, program evaluation, improvisational theater, science, social science research, engineering, and design. As a result, we are able to deliver a comprehensive suite of educational strategies to serve our diverse audience of learners.

Teaching and Learning
Teaching and learning programming plays an essential role in bridging gaps between the Museum and formal STEM education efforts. Targeting youth during the school day and supporting classroom educators as primary influencers of student science learning, these initiatives maximize the opportunities presented during field trips to MSI and fully

leverage the content and resources housed within the Museum for continued learning back in the classroom.

Student Experiences: For students on field trips to MSI, hands-on, content- and inquiry-rich Learning Labs provide exciting opportunities to experience scientific discovery in a fun way. In many cases, these are the only laboratory-based science experiences students will have during the school year, due to limited resources at their schools. More than 29,000 students participated in Learning Labs in the 2012-2013 school year, with a total of 346,000 students visiting MSI on field trips in the same year.

Institute for Quality Science Teaching and Learning (IQSTL): IQSTL seeks to improve student growth and achievement in STEM subjects by providing long-term, high-quality science teacher education for upper elementary and middle school teachers who struggle with science content knowledge, effective classroom strategies for science education, and science education leadership roles in their school community. The majority of our teachers, whether from CPS or other local school districts, are also in high-needs schools with limited access to quality science resources. Nearly 200 teachers participate in in-depth courses each year, with another 1,800 in shorter engagements. Since the program's founding in 2006, the Museum has trained teachers in more than 30 percent of Chicago public K-8 elementary schools.

Community Initiatives

MSI's Community Initiatives programs are critical to MSI's commitment to increasing access to science education for children in the greater Chicago area. By providing opportunities directly in the community and facilitating long-term engagement, we are extending our reach beyond the traditional boundaries of the Museum's walls. Our Community Initiatives consist of youth engagement serving audiences of children and teens at schools, community-based organizations, and in the Museum

Science Minors Clubs: During the past seven years, MSI has cultivated a network of community-based organizations and out of school time programs to host Museum-sponsored Science Minors Clubs to promote science education, inquiry-based teaching, and team-oriented learning. Annually serving more than 6,500 elementary and middle-school students in the greater Chicago and Northwest Indiana area, MSI provides more than 70 club sites with training, curricula, and lab materials, as well as field trips and other onsite opportunities to strengthen partnerships with the communities we serve. These clubs target 4th through 8th grade students at the neighborhood organizations where they already spend their out of school time in an effort to provide accessible, engaging opportunities tailored to local needs.

Science Minors and Achievers: The Museum's youth development programs for teens provide high school students with the opportunity to explore science topics, college aspirations, and STEM careers as they complete their schools' service learning requirements. Students gain leadership and public speaking skills during ten weeks of intensive education and training while exploring topics like robotics and rollercoaster physics. More than 650 teens have participated as Science Minors since the program began in 2004, contributing over 100,000 hours of service

__Left:__ Teens presenting science activities for guests; __Bottom:__ A teen explores electronics in the Fab Lab.

to MSI. Upon completion of the Science Minors program, youth who demonstrate the motivation and commitment to continue with more rigorous science topics and in-depth college preparation may enter the Science Achievers program. In addition to volunteering at the Museum, these youth participate in project-based learning experiences that have included sustainability and window farming, video game and mobile app development, and participate in workshops in MSI's own digital fabrication laboratory (Fab Lab). In the 2012-2013 school year, 148 youth participated in the Science Minors and Achievers programs.

Guest Experiences

A primary Museum goal is to ensure the Museum's 1.5 million annual guests have a variety of engaging and educational experiences throughout their visit. From immersive, hands-on lab activities to facilitated discussions of current science news, these programs bring science to life for guests of all ages. For example, guests learn about vision and anatomy by dissecting a cow's eyeball, discuss climate change using real data sets in our *Earth Revealed* theater, and become immersed in history during an onboard tour of the U-505 submarine. The unique intersection of improvisational techniques and inquiry presented through character-based shows in the Museum's Science Theater communicates science in a highly personal, adaptive, and engaging way.

Evaluation and Research

All CASE initiatives are supported by ongoing evaluation and research strategies. In addition to learning from and applying research-based evidence in our programs, MSI leads robust internal and externally-partnered program evaluation and learning research processes at various stages of each initiative. From front-end research and prototyping to summative studies, this approach enables us to continually provide input into our program development processes and to measure the impact of our programs on the target audiences we serve. Program evaluation in particular serves as an ever-present audience voice as MSI routinely modifies programming to reflect learnings from evaluation and strives to conduct studies with relevance to the larger science education community.

Identifying Barriers, Increasing Access

Our teams are acutely aware of the fact that providing high-quality science learning experiences is necessary for improving science education, but not sufficient. Often, there exist barriers to accessing such experiences, particularly in populations with limited resources, personal connections to, or interest in science. Further, youth from populations traditionally underrepresented in STEM fields often face unique challenges in engaging meaningfully with science. Embedded in all the Museum's approaches to reach and engage underserved and underrepresented audiences is a deep understanding that needs and barriers are not necessarily uniform across individuals, families, schools and communities. As such, there is no one-size-fits-all solution; rather, we employ a variety of strategies to increase the accessibility and relevance of the Museum to our guests. Of particular note, some of these approaches concern bridging a gap between Museum offerings and guests, while others are integral to the programs themselves.

No-Cost Programming: Outside of the museum-based learning facilitated within Guest Experiences, which is largely included in general Museum Entry, the vast majority of CASE programming is delivered at no charge to the participants. Further, the Museum supports secondary costs of participating on behalf of program participants in some instances. A significant example lies within both IQSTL teacher courses and Science Minors Clubs training; in both cases, participants receive lesson plans, reflection tools and large bins of the physical materials needed to implement the science activities learned at the Museum. Also, for the IQSTL course, MSI covers the expense of the substitute teachers required in the classroom on days teachers attend course sessions at the Museum. These approaches help to ensure that educators have limited barriers in implementing quality science teaching strategies at their school or after school site, and reduce the burden imposed on schools willing to release their teachers from class to participate in coursework.

Free Admission: The Museum offers 52 days per calendar year on which general admission is free for all Illinois residents. Each year's Illinois Free Day schedule is publicized well in advance and includes dates throughout the year to help guests plan visits that are most convenient for them. The free days are offered as part of a statewide ordinance for all museums and aquariums to help reduce or eliminate financial barriers to access. On all other days, Chicago residents are also eligible for discounted museum entry prices. Further, as part of efforts to support classroom learning, schools across Illinois who visit the Museum on a registered field trip, as well as homeschool groups receive free museum entry as well. Finally, in recognition of their service, active duty military, Illinois POWs, Chicago firefighters, Chicago police officers and Illinois preK-12 teachers receive free admission.

CPS First Day Attendance: As part of a multiyear partnership with CPS, the Museum provides every child in grades K-12 who attends the first day of school with a family pass. The pass is good for three museum entry tickets during that school year and is designed to incentivize first day attendance while also facilitating a family trip to the Museum, in particular for families for whom such a visit might be cost-prohibitive. In 2013, an estimated 376,000 students (more than 93% of the total CPS student body) attended their first day of school.

Black Creativity Programming: For more than 40 years, the Black Creativity program has honored the contributions of African-Americans to art, science, technology and engineering. Through Black Creativity, which includes the nation's longest-running juried exhibit of African-American art, the Museum offers programming specifically designed to encourage African-American children and their parents to utilize the Museum as a resource for exploring and discovering their inventive and creative genius. All Black Creativity programs are at no additional charge and, on their own, reach more than 25,000 students, their teachers and families in underserved Chicago neighborhoods each year. An annual highlight of the program is Black Creativity Family Day, held on the Martin Luther King, Jr. Day holiday in January. Taking place on an Illinois Free Day, the Family Day involves STEM career exposure, hands-on science and engineering activities and Museum exploration on a day when both youth and their adult influencers are off for the holiday.

Students build projects in the Black Creativity Innovation Studio

A Personalized Visit: Barriers to science learning for our guests are not limited to those influencing access to programs or to physical spaces like the Museum. Those barriers may be personal, emotional, and very specific to an individual, family or group visiting MSI. Prior bad experience, fear, or low confidence in science learning is commonly articulated by our guests on the Museum floor. Guest Experiences facilitators are trained and experienced in tailoring program content to their immediate audience by asking open-ended questions, using lay-friendly language, directly involving guests in the program, and creating emotional hooks for engagement.

STEM Career Exposure: Concomitant with the Museum's approaches to engaging diverse learners and guests in programming initiatives, we also work to present diversity in the educators and STEM professionals who interact with our audiences. Individuals with diverse cultural and racial/ethnic backgrounds, educational expertise and career trajectories are recruited for and supported in guest-facing roles. For example, through the Jr. Science Café program series and various career events, MSI explicitly provides opportunities for personal exposure to and interaction with STEM professionals who challenge numerous stereotypes of who scientists are and what science-related careers can be.

Learning Lab Scholarships: Learning Labs are offered at a nominal fee to schools to help offset the costs of program delivery. But in some cases, even that fee poses too high of a barrier for schools to participate; the Museum offers a limited number of need-based scholarships to schools that fit our selection criteria of financial need.

Bus Scholarships: In a manner somewhat similar to Learning Labs, reduced or free admission to schools and community-based organizations is not always sufficient to facilitate access. For some groups, the transportation costs of visiting the Museum can be prohibitive to the schools or parents, who often contribute to bus funds for their children's field trips. Free bus transportation is offered to schools and groups meeting our need-based criteria and supports general Museum visits as well as attendance of episodic large-scale programming like Family Days or career events.

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In Memorium: Alan J. Friedman

By Robert Mac West

It is with great sorrow that I report the unexpected death of fellow consultant and museum professional Alan J. Friedman on May 4, 2014. The cause of his death was pancreatic cancer. Alan was the longtime (starting in 1984) director and savior of the New York Hall of Science before embarking on a vigorous and influential consulting practice in 2006. He turned his academic training in physics (PhD from Florida State University) into a very successful career in informal science education, both as in-house staff and management and as a resource for worldwide science museums. His illustrious career is well documented on the web sites of the New York Hall of Science (http://nysci.org/the-physicist-who-saved-the-hall-of-science/) and (http://nysci.org/thinking-of-alan/), the New York Times (http://www.nytimes.com/2014/05/07/nyregion/alan-friedman-71-dies-revived-hall-of-science.html?_r=1), the Lawrence Hall of Science (http://www.lawrencehallofscience.org/story/remembering_dr_alan_j_friedman), The Museum Group (http://www.museumgroup.com/friedman/friedman.htm) and elsewhere.

On a more personal note Alan was a close colleague of mine, a fellow member of The Museum Group, a collaborator on varied and often challenging consulting projects, and an endless source of information and encouragement. Further, he was a supporter and frequent contributor to The Informal learning Review. His most recent article was in issue no. 124, January-February of this year – "Tactics for Surviving a Financial Crisis."

On Saturday, June 14, almost 200 of Alan's colleagues, friends, and admirers from across the U.S. gathered at the New York Hall of Science for a memorial to him and his career. Personal reminiscences and reflections on his influences, impacts, and unique personality were presented by: Margaret Honey, President and CEO, New York Hall of Science; Claire Shulman, Queens Borough President, 1986-2002; Seth Dubin, Trustee & President Emeritus, New York Hall of Science; Rick Bonney, Director of Program Development and Evaluation, Cornell Laboratory of Ornithology; Andy Fraknoi, Chair, Astronomy Department, Foothill College; Sheila Grinell, Consultant to science centers; Ira Flatow, Host, Science Friday; Mary Crovo, Deputy Executive Director, National Assessment Governing Board; Preeti Gupta, Director of Youth Learning and Research, American Museum of Natural History; Dennis Schatz, National Science Foundation & Pacific Science Center; Ron Ottinger, Noyce Foundation; and Mickey Friedman.

The Noyce Foundation formally announced a $500,000 grant to the New York Hall of Science to establish the Alan J. Friedman Center for the Development of Young Scientists. This will encompass both the Science Career Ladder program started by Alan in 1986 and the recently launched Science Career Ladder Institute. Noyce also announced a $250,000 matching Challenge to further advance the Center. To date, over $140,000 has been contributed or pledged toward that challenge. See http://www.nysci.org/friedmancenter.

The informal learning world is much the poorer for the loss of Alan Friedman.

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Building a Low Cost School-type Science Center in Hong Kong

By Ricky L.T. Tsui

"Science center" For most of us (at least for me in the past), the first associations that these two words bring to mind are: places for science experiences, huge spaces, and expensive, large exhibits; it never crossed my mind that science centers can be small and inexpensive while also providing valuable science experiences. In this article, I will share my experiences with Science Wonderland, a Hong Kong based project that I have had the honor to be involved in for the past two years. I believe this unique project can serve as a guide for others facing many of the same challenges.

Background and Challenges

On November 9, 2011, I received an email from a Hong Kong kindergarten education organization named Hong Kong Society for the Protection of Children (HKSPC) asking for information about an astronomy device for their students. One month later, we met for the first time (little did I know I would be meeting with a science preparation group consisting of 4 kindergarten principals and 2 administration coordinators in my office). What was more surprising was that they were talking about creating a small science center for their organization.

In order to fully appreciate the project discussed in this essay, I believe it is important to give a brief background of HKSPC and the general education policy in Hong Kong. HKSPC has been a non-profit organization in Hong Kong for over 80 years. It has 17 kindergartens with over 1500 students from K1 to K3 in total. In Hong Kong, science is not part of the official curriculum in kindergarten and, sad to say, it is not an important subject in primary or secondary schools now due to the new education "reform". Therefore, we all realize that if something is not done to spark the little fire inside the students at a young age, this science fire may not ever ignite.

We faced several challenges when designing Science Wonderland. First, there were space constraints. In Hong Kong, every square meter of space is extremely expensive. The only room HKSPC could renovate for the Science Wonderland was a toy room measuring about 100 square meters with an additional 100 square meters of a shared outdoor playground. How can you run a science center in only a 200 square meter space?

Second, as previously stated, science is not on the official curriculum for kindergarten in Hong Kong. With Science Wonderland, we are inserting science in the regular and official curriculum so that all the K2 and K3 classes can be exposed to science at least ten times per school year. Furthermore, a nongovernment funded science center for kindergartens is not available at all in Hong Kong. Therefore, in developing Science Wonderland, we had to ask ourselves, "What topics should we choose as we are now the pioneer exploring these fields?"

Third, more than 90% of the kindergarten teachers in Hong Kong do not have a science background in their tertiary education. Therefore, in reality, kindergarten teachers tend not to teach science to their students because they are not confident in their knowledge of the subject matter. Even if they HAVE to teach some science topics, you can imagine what the outcome will be.

Finally, the largest struggle we faced in starting and operating Science Wonderland was the extremely limited budget.

Choosing Science Topics

We used three criteria in order to choose topics to be covered in the Science Wonderland project. First, the topics had to be fun and interesting; we want the kindergarteners to have a positive association with science so they will continue to seek it out and explore it further. Second, the topics had to be current and lend themselves to hands on activities. Third, the material presented had to be applicable to daily life so that the kindergarteners could and would want to share their findings with their friends and families.

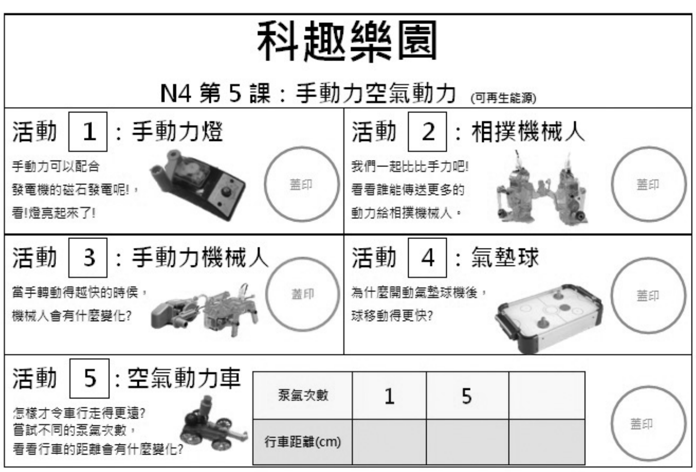
The topics we ultimately chose to include in Science Wonderland were renewable energy, astronomy, and general science discovery. In renewable energy, we would cover solar energy, wind energy, water power, and hand power. In astronomy, we would explore the Earth, Moon, Sun, Plane, Constellations, and deep space objects. In general science discovery, we chose to include the subtopics of food science, bubble science, electricity, air, image, color, metal, energy transfer by roller coaster, and microscopic worlds. Ten science topics will be covered with K2 students (about 4 to 5 years old) and another ten topics with K3 students.

Exploring the mixture of colors using a digital microscope

Solutions to the Other Challenges

The space and budget issues can be resolved by changing the exhibits every two weeks and by avoiding huge, costly exhibits. HKSPC is only able to hire one full time teacher to serve as the primary educator; other general staff help run the Center. Therefore, each general science discovery topic and each renewable energy topic will have four or five self-service booths to allow students to explore the same topics with different exhibit experiments or activities after they go through a briefing section at the beginning. Each student will have a stamp collection card on that topic (below). When they have completed an activity at one booth, they will receive a stamp on their card for that booth. They have to get all the booths stamped in order to complete that lesson. At the end, there is an explorative conclusion section where the students share their findings.

For astronomy, we bought a portable digital planetarium with a four meter inflatable dome from Digitalis Education Solutions. The software allows us to "go back in time" to special astronomy events and display them on the dome's surface. We can also zoom in and out to view any space object. One of the most important things is that we can write a script using simple commands to make our sky show for a particular lesson. All these can be easily controlled by a remote control or through an iPad. Most importantly, it is very affordable.



Card for collecting stamps on hand and air power topics

HKSPC organizes a minibus to bring the students of one grade from each kindergarten to the Science Wonderland. The kindergartens are all spread around Hong Kong, and it is more space and cost effective to bring the students to one place rather than to set up a center in each kindergarten.

Regarding the challenge of teachers in science initiative and competence, the best solution we found was simple and straightforward; it was to let them play with those science topics. We hosted a huge teacher "fun day" workshop for all 200 teachers and administrators in the HKSPC kindergartens. Sure enough, rather than finding that science is difficult, they found it to be fun and exciting. What a giant leap of confidence we saw!!! What is most important about this leap of interest in these teachers is that they will do the extended science activities with their students after visiting the Center. This will strengthen the students' knowledge even more.

Many future scientists are born at this Wonderland

Science Wonderland has been running for one school year. In our first year, we had over 10,000 visitors to the center and, more importantly, many future scientists were born. Below, I recount a few stories that amazed us from the students—remember they are only four to six years old!

<u>Water power car</u>

When teaching water power, the students pump water into the vehicle tank and, as soon as they release the car, water ejects from the back and the car moves forward. At the explorative conclusion section, one student raised his hand and told the teacher she was wrong because the car was not moving forward only because of water being pumped into the car. The whole room went silent. The student continued, "It also has air pumped into the car, not just water alone, and both air and water were ejected out together in order for the car to move forward." The teacher had to admit that the student was right.

<u>Electrostatic</u>

One of the booths requires the students to rub a plastic ruler on a cloth to create electrostatic, and then put it close to a pile of small pieces of paper. The paper is attracted to the ruler. Even after students had completed the activity, they wanted to further investigate what other plastic objects would have the same result. They used their plastic name tags and then objects made of other materials (such as pencils, handkerchiefs, and their hands) to repeat the experiment. The teacher informed us that the students kept doing this experiment when they went home.

Air power car

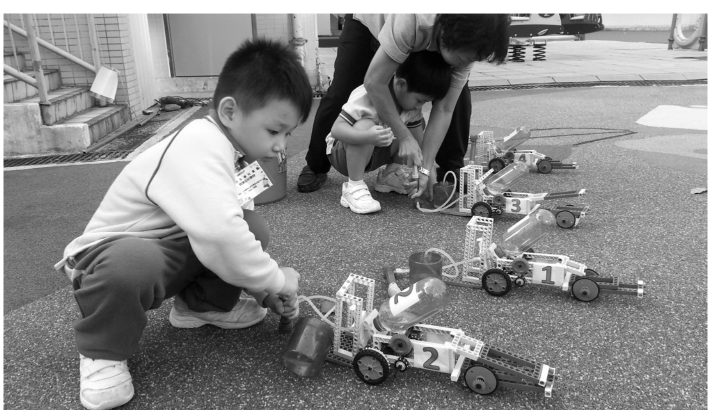
At this booth, students pump air into an air powered car a different number of times in order to determine which will go farthest. At the end, they concluded that pumping more times did not make the car go farther as they had initially hypothesized. They then found the reasons why the car did not go farther and shared their findings at the explorative conclusion section; they concluded that the floor was too rough and slowed down the car or that they had not pressed the pump hard enough.

Metal detector

We placed both metal and nonmetal objects in different boxes so students could figure out which objects were metal and which were not by using a metal detector. After finishing this booth, the students told the teacher that when they went through Customs while traveling between countries, they saw the Customs Officer using almost the same device to search people. They were then very curious to use the metal detector to find out which other objects in the room contained metal.

Astronomy

Many students were hardly able to control their super excitement when going into the inflatable dome of the digital planetarium. For most of the students, this immersive experience is the first time they are able to visually understand the relation among the Sun, Earth, Moon, and other Solar System planets. At the explorative conclusion section, one student told the teacher, "Now I understand when tomorrow morning I wake up, the Earth has already rotated on its own axis once."



Getting ready for the water and air powered cars

Long Road Ahead of Us

Science Wonderland is just a tiny step toward sparking the curiosity in science within these young students. I truly believe there will be many future scientists created because of this Wonderland. Next school year, Science Wonderland will go into Phase 2, in which it will be open for the public to come and participate in different science topics. I do hope this is just the beginning and that there will be many more Science Wonderlands around Hong Kong and around

Top: Solar observation under a giant solar viewer.
Bottom: Locating a constellation on a digital planetarium

the world.

Acknowledgements

I want to thank HKSPC for their trust in allowing a lot of my dreams come true through Science Wonderland. Above all, for the source of all my ideas, I need to thank the Creator of this Universe (The Trinity) as HE is my ultimate inspiration.

Ricky L.T. Tsui is the President of Achievers Track Co., Ltd and Consultant for HKSPC Science Wonderland. He is also an inventor and author of several astronomy books. See www.a-track.net He can be reached at rtsui@a-track.net.

UX: Designing for the User Xperience

By Robert L. Russell

Why are so many everyday technologies, such as smartphones, self-checkout, and interactive exhibits, so difficult to understand and use? The easy answer is because these technologies are not user-friendly; their appearances do not indicate how to use them.

Donald Norman called these "affordances." The appearance, the affordances, of a well-designed door handle tells you how and in what direction to open a door. Through his book *The Design of Everyday Things* (revised 2013) and related work, Norman helped inspire the User Experience (UX) design approach, which has wide applicability to the design of user interfaces for computers, websites, mobile phones, all varieties of consumer devices, and interactive exhibits.

Meanwhile, theory and research in cognitive science has made major contributions to how we learn. Piaget helped us understand that we are born to learn and that we think in qualitatively different ways as we develop. Vygotsky showed us the importance of people in the learning process and of support for or scaffolding of learning. Jerome Bruner has reminded us of the importance of narrative frames and storytelling. Dewey combined these perspectives by saying we need "time, talk and tools" for learning.

From Norman and these thinkers, I have extracted what I believe are some of the most importance guidelines that have immediate applicability in the design of user-friendly interactive exhibits, computer games, websites, and other interactive devices.

These guidelines are presented alphabetically:

<u>Aesthetics</u>: A simple, attractive design can enhance usability because it provides a more pleasant user interface. Aesthetics matter: attractive things work better.

<u>Accessibility:</u> A new interactive is like a new and unfamiliar product. For a productive and fulfilling user experience, design for simplicity and visibility. Design so users can easily see how to use the controls, understand the relation between actions and results, and observe the effects. Design for error so users can easily restart. Also, standardized exhibit graphics and interfaces help users generalize some functional knowledge from one page or activity to the next. Use large (if possible), iconographical widgets and label them with words. Avoid scrolling.

<u>Choices, control, feedback and success</u>: Users like to have choices, exert some control over their experiences, and get feedback on the consequences of their choices. Users' actions should produce rapid, clear results, and they should be able to try different actions and observe different results. Activities or experiences should allow for success, which means users reach a satisfying conclusion to their activity.

<u>Cognitive principles</u>: When possible, design so that the appearance of a device tells users intuitively what to do through graphic images or other intuitively obvious signs. Remind users where they are at in the task or experience.

<u>Cultural constraints</u>: Use colors and images that are familiar and meaningful to users in a culture (e.g., red means stop). These colors and images are arbitrary and must be learned, but are applied to a wide variety of circumstances.

<u>Consistency</u>: Use the same controls and informational formats (e.g., for exhibit signage) across devices so that users won't have to learn another arbitrary command or step.

<u>Evaluation</u>: Like any new product, an untested device can have serious flaws. Front-end and formative evaluation—finding out about what users know, what types of experiences they prefer, and how well prototype devices work—can help improve the relevance, functionality, and effectiveness of devices.

<u>Feedback</u>: Help users link actions and results, controls and effects, by using natural mappings. Provide quick feedback to users about the results of their actions and where they are at in the activity.

<u>Incentives:</u> Design interactive devices so that sheer participation is motivating – the reward comes from the user's engagement and interest in the activity. The reward is intrinsic. However, there may be things users have to do to get from one place or level to another, in which case external or extrinsic rewards may be appropriate, such as badges, points, or ratings.

<u>Memory constraints</u>: Psychological research has shown that we can retain about seven items (plus or minus two items) in our short-term memory. (For example, most people would have difficulty remembering 12 disconnected objects.) Minimize the user's memory load by making ob-

jects, actions, and options visible. A simple design supports ease of use because users can focus on their goal of using an exhibit or device (instead of fretting over a complicated user interface.)

Multiple entry points: Prior knowledge, life experiences and interests guide our experiences. Users often find an effective starting point in a learning experience with something familiar or a problem or question they find challenging. These starting points, some of which might be called "hooks," can often be identified through surveys with prospective users.

Multiple learning styles/Prior Knowledge: Users will bring different levels of knowledge, different interests and perhaps different preferences regarding how they prefer to learn. To the extent possible, an interactive learning device should provide a variety of different types of learning experiences to accommodate diverse learning preferences and users who have varying levels of knowledge of the content.

Natural mappings: Design the layout of a device (e.g., location of power on buttons, location of familiar commands on websites) so they are "natural" or where users expect to find them. By convention, users now expect to find some standard features of a web page in the same place across web pages. When gestural interfaces are used, the results should parallel what happens in the real world.

Narrative/storyline: Many successful games are driven by a storyline (e.g, rescue, winning the battle, completing the journey, winning the game, finding the solution in an experiment or problem). When possible, integrate concepts and facts into a storyline. Research shows that learners have greater retention when concepts and facts are embedded within a narrative frame or storyline.

Navigability: The device should be designed so that users can easily tell where they are, how to get back to where they started, and how to move ahead.

Reality: Use words, phrases and concepts familiar to users. Follow user-friendly conventions found in the real world.

Scaffolding: Integrate supports for learning or use into an interactive device. By building on external "scaffolding" or support (e.g., a teacher, peers) that is available, a user can stretch or extend his or her problem solving ability and understanding.

Social experiences: People have traditionally learned from others, including parents, teachers, mentors and peers. Whenever possible, build social experiences directly into an interactive learning device (e.g., social media connection, an avatar, iPhone's Siri) or design an experience for multiple users, which can motivate continued engagement.

Universal design: People of different ages, from different backgrounds, and with different abilities (and some with disabilities) will use interactive devices. Enriching the range of requirements that guide design will enrich the experience for all. Novices may find more explanations useful, while experts may like shortcuts. Design features for persons with disabilities (e.g., audio for the blind) can enhance the experience for others who enjoy audio access.

Visibility: Design visible features in the user interface that tell users what to do. When visual clues are lacking (or there are too many) users may not "see" how to use the device.

For examples of bad design: http://www.baddesigns.com

For access to design resources from Don Norman: http://www.nngroup.com/

For my articles on design guidelines for interactive exhibits: http://www.nc4il.org/papers.html

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2013 Museum Attendance Figures Published

The TEA/AECOM Global Attractions Attendance Report for 2013 was published online on June 3, 2014. This annual survey and analysis of attendance has two parts, one devoted to museums (in its second year of data collection) and one devoted to themed attractions (with data back to 2007). Here are some of the interesting data on the performance of the worldwide museum industry for calendar 2013.

•106 million visits to the top 20 worldwide museums, up 7.2%
•75 million visits to the top 20 European museums, up 4.6%
•58 million visits to the to 20 North American museums, up 1.6%
•53 million visits to the top 20 Asian museums, up 27.6%

AECOM's Linda Cheu, Beth Chang and Jodie Lock made some interesting observations on this data set, acknowledging that it is very young and that trends will not really become apparent for at least another year. They note that in mature European and North American museums attendance swings are due primarily to blockbuster exhibitions or other unique, time-limited programming. Asian museums, however, are growing and expanding, thus creating larger audiences.

They see Europe as the lead museum market (the Louvre in Paris is the top of the list), and only one science museum is in the top 20. In North America the lead performers are art, history and culture museums on the East Coast, but nine science museums and one children's museum are in the top 20. The Asian top 20 list includes eight science-related institutions.

The number of free (e.g., no gate admission charge) museums is impressive, given the variability in museum economic models. In particular, China is well on its way to making all public museums free, as well as building about 100 new museums annually.

The report may be downloaded from http://www.aecom.com/themeindex and http://www.teaconnect.org/pdf/TEAAECOM2013.pdf.

Top 20 Museums Asia

	Museum & Location	Change	2013	2012	Entry
1	National Museum of China, Beijing, China	38.79%	7,450,000	5,370,000	Free
2	National Palace Museum (Taiwan), Taipei, Taiwan	1.2%	4,412,000	4,361,000	Paid
3	Shanghai Science and Technology Museum, Shanghai, China	11.5%	3,580,000	3,210,000	Paid
4	National Museum of Natural Science, Taichung, Taiwan	15%	3,396,000	2,954,000	Free
5	National Museum of Korea, Seoul, South Korea	-2.4%	3,053,000	3,128,000	Free
6	China Science Technology Museum, Beijing, China	3.8%	3,020,000	2,910,000	Paid
7	National Fold Museum of Korea, South Korea	2.5%	2,706,000	2,640,000	Free
8	National Museum of Nature and Science, Japan	20.2%	2,420,000	2,014,000	Paid
9	National Art Center, Tokyo, Japan	15%	2,345,000	2,040,000	Paid
10	National Science and Technology Museum, Kaohsiung, Taiwan	4.1%	2,265,000	2,175,000	Paid
11	Zhejiang Museum, Hangzhou, China	75%	2,258,000	1,290,000	Free
12	China Three Gorges Museum (Chongquing Museum), Chongquing, China	14%	2,030,000	1,741,000	Free
13	Henan Museum, Zhengzhou, China	-1%	2,030,000	2,050,000	Free
14	Shainghai Museum, Shanghai, China	-0.1%	1,946,000	1,945,000	Paid
15	National Gallery of Victoria, Sydney, Australia	23.6%	1,942,000	1,571,000	Free
16	National Palace Museum of Korea, Seoul, South Korea	118.8%	1,847,000	844,000	Free
17	Hong Kong Science Museum, Hong Kong, China	33.4%	1,719,000	1,289,000	Paid
18	National Science Museum, Pathum Thani, Thailand	-2.1%	1,621,000	1,655,000	Paid
19	Science City, Kolkata, India	0.1%	1,538,000	1,537,000	Free
20	Suzhou Museum, Suzhou, China	0.3%	1,455,000	1,440,000	Free
	TOTAL	**27.6%**	**53,024,000**	**41,588,000**	

Top 20 Museums Europe

	Museum & Location	Change	2013	2012	Entry
1	Louvre, Paris, France	-4%	9344,000	9,720,000	Paid
2	British Museum, London U.K.	20.2%	6,701,000	5,576,000	Free
3	National Gallery, London U.K	16.8%	6,301,000	5,164,000	Free
4	Vatican Museums, Vatican, Vatican	7.8%	5,459,000	5,065,000	Paid
5	Natural history Museum, London, U.K.	6.4%	5,250,000	4,936,000	Free
6	Tate Modern, London, U.K	-8.2%	4,885,000	5,319,000	Free
7	Centre Pompidou, Paris, France	-1.4%	3,745,000	3,800,000	Paid
8	Musee D'Orsay, Paris, France	-2.7%	3,482,000	3,579,000	Paid
9	Science Museum, London, U.K.	10.9%	3,317,000	2,990,000	Free
10	Victoria and Albert Museum, London U.K.	1.8%	3,290,000	3,232,000	Free
11	Reina Sofia, Madrid, Spain	23.8%	3,185,000	2,572,000	Paid
12	State Hermitage, St. Petersburg, Russia	8.3%	3,120,000	2,882,000	Paid
13	Tower of London, London, U.K.	18.5%	2,895,000	2,444,000	Paid
14	Cite Des Sciences et de L'Industrie, Paris, France	-2.7%	2,570,000	2,641,000	Paid
15	Museo Nacional del Prado, Madrid, Spain	-14.9%	2,307,000	2,712,000	Paid
16	Rijksmuseum, Amsterdam, Netherlands	N/A	2,200,000	N/A	Free
17	National Portrait Gallery, London, U.K.	-3.9%	2,015,000	2,097,000	Free
18	Galleria Degli Uffizi, Florence, Italy	6%	1,876,000	1,769,000	Paid
19	National Museum of Scotland, Edinburgh, U.K.	-6.7%	1,768,000	1,894,000	Free
20	Tate Britain, London, U.K.	-10.2%	1,378,000	1,534,000	Free
	TOTAL	**4.6%**	**74,808,000**	**71,536,000**	

Top 20 Museums North America

	Museum & Location	Change	2013	2012	Entry
1	National Museum of Natural History, Washington DC	5.3%	8,000,000	7,600,000	Free
2	National Air and Space Museum, Washinton DC	2.5%	6,970,000	6,800,000	Free
3	The Metropolitan Museum of Art, New York, NY	2.7%	6,280,000	6,116,000	Paid
4	American Museum of Natural History, New York, NY	0.0%	5,000,000	5,000,000	Paid
5	National Museum of American Hsitory, Washington DC	2.1%	4,900,000	4,800,000	Free
6	National Gallery of Art, Washington DC	-2.4%	4,100,000	4,200,000	Free
7	The Museum of Modern Art, New York, NY	0.0%	2,800,000	2,800,000	Paid
8	California Science Center, Los Angeles, CA	31.5%	2,630,000	2,000,000	Free
9	Houston Museum of Natural Science, Houston, TX	0.0%	2,133,000	2,133,000	Paid
10	The Art Institute of Chicago, Chicago, IL	2.7%	1,500,000	1,461,000	Paid
11	Museum of Science, Boston	-5.3%	1,420,000	1,400,000	Paid
12	California Academy of Sciences, San Francisco, CA	0.0%	1,400,000	1,400,000	Paid
13	Museum of Science and Industry, Chicago, IL	-6.7%	1,400,000	1,500,000	Paid
14	U.S. Holocaust Memorial Museum, Washington, DC	-1.9%	1,374,000	1,400,000	Free
15	National Museum of the American Indian, Washington, DC	-14.8%	1,363,000	1,600,000	Free
16	The J. Paul Getty Museum, Los Angeles, CA	4.3%	1,356,000	1,300,000	Free
17	Udvar-Hazy Center, Washington DC	-7.1%	1,300,000	1,400,000	Free
18	Denver Museum of Nature and Science, Denver, CO	4%	1,300,000	1,250,000	Paid
19	Field Museum of Natural History, Chicago, IL	7.2%	1,286,000	1,200,000	Paid
20	The Children's Museum of Indianapolis, Indianapolis, IN	-4.3%	1,215,000	1,270,000	Paid
	TOTAL	**1.6%**	**57,727,000**	**56,816,000**	

Time Marches On for Science Centers

By Robert Mac West

This article started out relatively simply as an analysis of how COSI (the Center of Science and Industry in Columbus, Ohio) celebrated and took advantage of its March 29, 2014, 50th anniversary of opening as central Ohio's science center. As I looked at the events of around half a century ago in the science museum world, a second topic emerged – a quick study of the emergence of the 3rd generation (Friedman, 1996. 2007, 2010, and Rader and Cain, 2008) institutions focused on interactive rather than collections-based science and technology.

COSI's 50th

Although attention to COSI's 50th anniversary was a major part of the museum's public relations for several months, the actual celebration focused on the actual anniversary date – March 29. This very conveniently was a Saturday, making it possible for there to be a full day of events, announcements, and reflection on the museum's half century of service to its community. This was preceded on March 25 by Ohio Senator Robert Portman inserting a congratulatory message into the U.S. Congressional Record (http://www.gpo.gov/fdsys/pkg/CREC-2014-03-25/html/CREC-2014-03-25-pt1-PgS1726.htm).

Prior to the March events, an exhibit, 50 Years of COSI, opened in the Columbus Historical Society Gallery at COSI, on February 14. It featured photographs, building models, artifacts, exhibit reconstructions and a video that resurrected past exhibits and was open in the historical society's space through May 26. This celebration of COSI's history generated $350,000 in support.

March 29, however, was the big day. It included a day-long public celebration as well as four ticketed events. Of particular significance to the current staff and board of COSI was participation by the families of the founders (see below) and late director Roy Schafer.

COSI's day-long 50th celebration featured special activities for guests including COSI on Wheels demonstrations and interactive Science Spots, Rat Basketball, Electrostatic Generator, and special planetarium sneak peeks. COSI announced the scheduled fall reopening of the planetarium with an explosive rendition of the 1812 Overture, using hydrogen-filled balloons to create big booms and excitement. 5228 people attended the day-long celebration.

The Alumni Luncheon welcomed 230 volunteers, current and former employees and many good friends of COSI. The evening featured a large community party, the "Blast." The 550 guests ($100 per head) at Blast were also treated to a special demonstration of the planetarium planned to open at COSI this fall. The decades-themed party featured local bands Hat Trick and Shucking Bubba Deluxe and more than 24 local restaurants and caterers. The pre-Blast party in the WOSU@COSI studio with 189 participants heard directly from the founding family members.

All in all, COSI was very pleased with this day of celebration, reflection, and anticipation of the institution's future.

The COSI Chronology

This establishment of this science center was the result of efforts, in the late 50s and early 60s, of Columbus businessman Sandy Halleck's determination that his community would have a resource at least somewhat similar to those he visited elsewhere, including Chicago's Museum of Science and Industry. After several years' work, aided by other business leaders including Walter English and Herschel Stephan and the Franklin County Historical Society, COSI opened in the repurposed Memorial Hall on March 29, 1964.

Memorial Hall, the original COSI building

By the 1990s it was clear that COSI needed a larger and more modern facility. In 1999 the museum relocated across the Scioto River to a massive facility, almost three times the footprint of Memorial Hall. This included the former Central High School building plus very significant new construction, as can be seen in the accompanying illustration. There were issues associated with the much larger facility that resulted in staff and budget reductions as well as space closings (including the planetarium) in the first decade of the 21st Century. These are largely resolved and, as noted above, the planetarium will soon reopen in a significantly upgraded 221-seat facility, aided by a $1 million campaign now underway.

It is very interesting to look at how, late in its first half-century, COSI has rebranded itself from being a reasonably conventional science center to now being the Columbus Center of Science – the focal point for science educational, social, and creative activities via not only its own functions but those of numerous nonprofit, educational and commercial/industrial operations in the greater Columbus area. Its relationships with public radio station WOSU, the Ohio State University, the Columbus Museum of Art, the Columbus Metropolitan Library, and the long-term collaboration with the Columbus Historical Society are indicative of the way in which COSI has become a center not only of science but also of cultural, educational, and social activities in greater Columbus (http://www.cosi.org/about-cosi/partners).

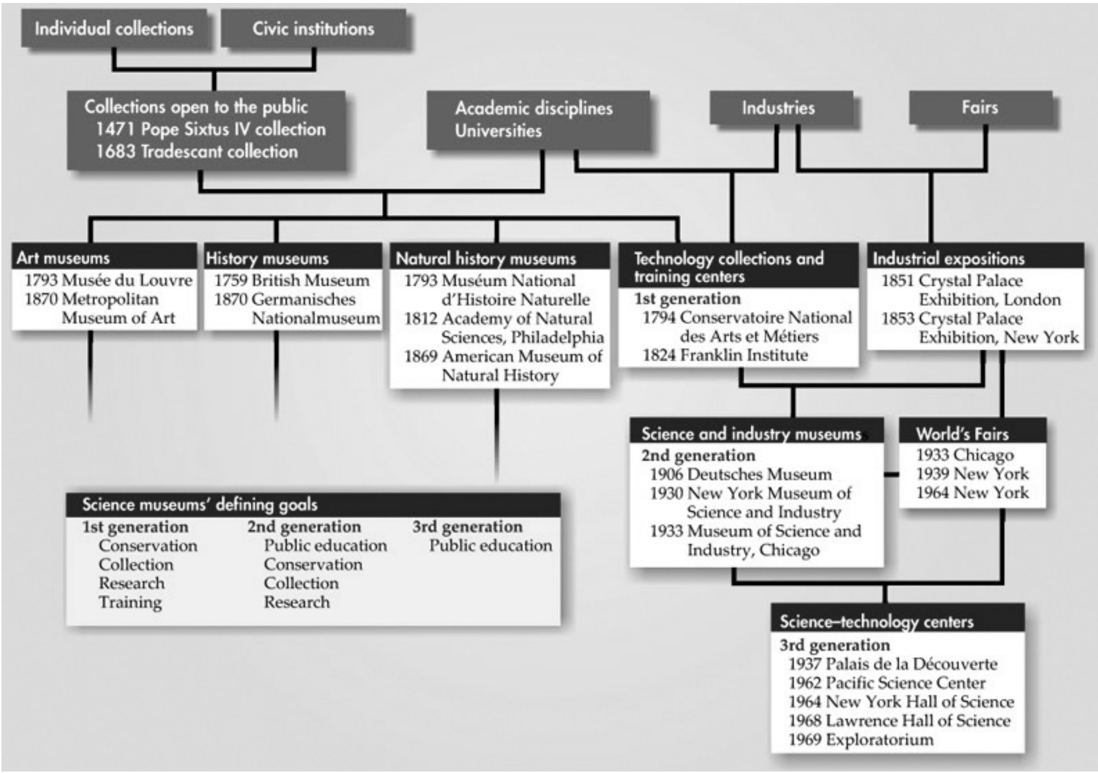
The new COSI building, including Central High School

The Emergence of Science Centers

As we look back at the development of public science institutions, half a century ago (approximately) there was a very significant event in the North American environment – the evolution of the science center from the science museum coupled with the emergence of the interactive science-technology center. Between 1958 and 1969 at least seven institutions either shed their primary responsibility for maintaining collections of scientific and technologic machines, materials, etc. to become primarily hands-on interactive science centers, or emerged de novo as hands-on interactive science centers. This is the array of institutions we'll look at here, which include COSI as one of the new arrivals. Several are included as 3rd Generation institutions in Freidman's Museum Family Tree.

1958 – OMSI, Oregon Museum of Science and Industry, Portland, Oregon
1962/3 - Pacific Science Center, Seattle, Washington
1964 – COSI, Center of Science and Industry, Columbus, OH
1964/5 – New York Hall of Science, New York, New York
1968 – Lawrence Hall of Science, Berkeley, California
1968/9 – Exploratorium, San Francisco, California
1969 – Ontario Science Center, Toronto, Ontario

While science centers were being configured, organized and implemented in the U.S. and Canada, North Americans were carefully observing trends in European science museums. There are many mentions of the impact and role models provided by the Science Museum, London, the Deutsches Museum, Munich, and the Palais de la Decouverte in Paris. Also, attention was paid to initiatives in the Museum of Science and Industry Chicago and to some extent the Museum of Science Boston. Two initiatives were established in India, though apparently not well understood in the western world – the Birla Industrial and Technological Museum in Kolkota which opened in 1954 and the Visvesvaraya Industrial and Technological Museum which opened in Bangalore in 1962, both at the very beginning of the science center movement. (And there undoubtedly are others, less prominent in the science center world, that were also part of this fascinating evolutionary event.)



Alan Freidman's Museum Family Tree

These are opening dates for the institution that fashioned itself as a science center. All have planning and funding histories that extend well prior to these public-opening dates. Some involved facilities already open to the public as collection-based museums while others were ideas that took form and emerged in the listed year.

The Exploratorium, due to its aggressive positioning and very effective marketing of its resources and experiences, is broadly seen as the prime stimulator of the modern science center concept. It is instructive to see that several science centers actually preceded it, though without the personality and presence of Frank Oppenheimer. Thus, we will here look at the 1958-1969 decade as that relatively brief period when, at seven different North American locations, science centers evolved/emerged/arrived. This was the movement that generated science centers throughout the world in the late 20th century.

Both OMSI and the New York Hall of Science evolved from at least partially collections-based institutions into their more dynamic configurations.

OMSI evolved through a series of Portland sites, starting in City Hall in 1906 with a collection of natural history specimens. The Oregon Museum Foundation, incorporated in 1944, displayed natural history objects in the Portland Hotel from 1946 to 49, then it moved to a private home and was given the name Oregon Museum of Science and Industry. In 1958 the museum and its very popular planetarium moved to Washington Park. The museum finally located at the current site, which includes an historic sawdust-fired power generation plant, in 1992. By this time, the interactive science-technology programming was dominant, though the museum still has a collection of over 30,000 objects and specimens.

The New York Hall of Science, originally known as the Museum of Peaceful Arts, opened in the Scientific American building in Manhattan in 1927 and relocated to the Daily News Building in 1930. It again relocated in 1935 to the then-new Rockefeller Center when Nelson A. Rockefeller became a trustee. After being closed in the 1950s, it re-emerged as part of the 1964 World's Fair in Queens. The building fell into serious disrepair, to be revived in its current configuration under the leadership of Alan Friedman from 1984-86. In the process of these moves it evolved into the broadly-based science center that it is today.

The Lawrence Hall of Science is the only of the early institutions to be based in a university environment. In fact, groundbreaking for the facility on the edge of the campus was on the University of California – Berkeley's commencement day in 1965. The LHS, even before this, presented programs at the 1963 World's Fair in Seattle, several of which ultimately became part of the Berkeley offerings. Since the formal opening in 1968 the LHS has had a close relationship with the local schools, both on-site and through an extensive outreach program.

In 1969 the Exploratorium occupied the historic Palace of Fine Arts, which was once part of the 1915 Panama Pacific International Exposition in San Francisco's Marina District, and only recently relocated to the San Francisco waterfront (see ILR 122). From its inception, it has been highly interactive, bringing science and art together in very creative ways, and presenting natural and physical phenomena to the public through a wide range of interactive exhibits and visual experiences. COSI, as detailed above, started in downtown Columbus, moving to its current location in 1999. The Ontario Science Centre and Lawrence Hall of Science are still in their original buildings, though OSC has grown immensely since it opened in 1969.

The Ontario Science Centre initially was intended to be part of Toronto's 1967 Canadian centennial celebration and it was officially named the Centennial Centre of Science and Technology. However, it did not actually open until 1969. Its original facility has been significantly expanded, in part due to aggressive solicitation of corporate funding.

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Asia-Pacific Museum Leaders in Discussion

By Robert Mac West

A well-attended session (Museum Leaders Discuss Current Issues and Concerns) at the Asia Pacific Science Centers and Museums (ASPAC) annual conference in Brunei, early May 2014, involved executives of eight diverse science museums discussing a series of pre-determined questions regarding the functions, operations, decision-making, and challenges and opportunities facing each of their institutions. This session was organized and led by me as President of Informal learning Experiences who, as a function of my current consulting business and previous executive positions, could frame the questions and then listen as an interested professional.

This summary of the ASPAC session provides a brief review of the responses to each of nine questions that were posed to three or four of the participating museum leaders. It clearly demonstrates the diversity of ASPAC science museums and the ways in which they confront and address various issues. It does not detail who answered which questions – rather it shows how many different ways institutions that operate in very different cultural, economic, political, etc., circumstances strive to provide essential services and opportunities for their communities.

The ASPAC Museum Leaders

- Mr. Sakorn Chanapaitoon, Acting President, National Science Museum Thailand, Bangkok, Thailand
- Ms. Maria Isabel Garcia, Curator, The Mind Museum,

Manila, Philippines
- Ms. Tengku Nasariah Ibrahim, General Manager/CEO, Petrosains - The Discovery Centre, Kuala Lumpur, Malaysia
- Mr. Stuart Kohlhagen, Acting General Manager, National Programs and Manager Research and Development, Questacon, The National Science and Technology Centre, Canberra, Australia
- Prof. Tit Meng Lim, Chief Executive, Science Centre Singapore, Singapore
- Dr. Geng Tu, Division Manager, Miraikan, Museum of Emerging Science and Innovation, Tokyo, Japan
- Mr. Neville Petrie, CEO, Science Alive! The New Zealand Science Centre, Christchurch, New Zealand
- Mr. Chee-Kuen Yip, former Chief Curator, Macao Science Center, Macao

Comment Summaries

<u>How does my institution measure success?</u>
Success is quantitatively measured in terms of both total visitor counts and admissions income. Some museums, even if government operated, must bring in at least 50% of their annual operating budgets while at the same time being good tourist attractions. Counts include the number of return visits as well as the duration of each visit. Museums conduct community and intercept interviews to gauge their impacts.

<u>What is our primary audience and how do we provide what they need/expect?</u>
The museums represented here have very different views of their audiences. They range from an emphasis on young children and teachers to the broad local public with tourists a significant element, to attempting to develop programming that will attract adults and teens. The primary audiences change as museums themselves change, respond to local pressures and expectations, and develop community partners that assist in stimulating participation in the museum. In general, participating museums are seeking to broaden their primary audiences, usually by offering new arrays of programs and experiences. These new areas can involve both new and expanded physical plants as well as expanded community relationships.

<u>How do we reach the population(s) that do not attend museums?</u>
There is general consensus that outreach, both physical and electronic, is an essential part of the museum's mission. In some cases the geographic reach of the museum is so large that electronic, video conferencing, connections with agencies that have broad reach, and programs that focus on conventionally unengaged audiences are essential. Strategies include, in addition to electronic outreach, offering on-site activities such as weddings, parties, family events, and such. Online initiatives such as YouTube and Facebook are increasingly important.

<u>What is the process by which we decide on exhibition and program topics?</u>
New and expanded topics are developed in consultation with both current and potential audiences as well as by assessment of what has been successful in other museums. Social media as a means of testing new ideas and approaches, although it also is important to consult internally regarding museum staff understanding of audience expectations and the institution's capabilities. Every effort is made to ensure that new initiatives are both entertaining and financially productive – e.g., that there is an adequate return on investment in any new exhibition or program.

<u>What are our significant funding sources and how do we respond to them?</u>
The museums represented in the session have a broad range of financial support, ranging from largely national or local government to private corporations to private philanthropy and earned income. Thus the responses to this question are variable. However, there is a general sense that there is pressure to increase earned income that is independent of the external funding sources and thus a real need for the museums to connect with local partners that share the need for solid educational opportunities. Sponsors are being sought for exhibits and programs, independent of the basic operating support sources. Further, museums are seeking new revenue sources such as travelling exhibitions, consultancies, and international partnerships.

<u>What is the greatest challenge facing my institution?</u>
This question was addressed by a new museum (Mind Museum in the Philippines), a museum that is replacing its facility that was lost to an earthquake (ScienceAlive! in New Zealand), and a national museum (Miraikan in Japan). Thus there are substantially different challenges being confronted. These include establishing the museum's role in the community and living up to expectations for attendance and revenue, operating programs efficiently in the absence of a physical plant while simultaneously working with the local government to plan for the future location, funding and role of the science museum, and appropriately representing national scientific accomplishments and objectives while continuing the serve the local audiences.

<u>What is our greatest recent success or failure?</u>
Successes were described much more than failures. These include audience diversification, usually via development of new dedicated spaces, exhibitions and programs, especially for younger children. Increasing attention is

being given to partnerships with both community and professional organizations, better outreach programming, and moving from nice to necessary as part of the scientific fabric of the community.

What would we do differently if we had to create our museum from scratch?

Responses here focused on location, dedicated spaces, and creating opportunities for change. The suggestion of locating in a shopping mall opens the museum to collateral activities that can generate more revenue as well as potentially being attractive to a younger audience. A new facility could have spaces, galleries, and activities clearly dedicated to specific demographic groups that are branded and marketed appropriately. Flexibility can be encouraged by an appropriately-designed facility that has the ability to go well beyond traditional exhibitions. Nonetheless, with these facility issues considered, it is important to continue to develop outreach programs and to be fully aware of essential content.

If you could do one new thing in the near future, what would it be?

This is a long list, with many nuances. Specific initiatives include developing better community partnerships and becoming essentially community-owned, taking advantage of the Maker movement, carefully assessing how STEM will determine the future, modernizing the theater, making good use of social media, and carefully "localizing" the museum's content and events.

This is a quick summary of an engaging two hour-long session that included both the executives' responses to the questions and also some significant interaction with the audience. In a very interesting way, there will be a broadly similar session at the 2014 ASTC conference in Raleigh, North Carolina. There John Jacobsen of White Oak Associates and I will facilitate a two-hour session titled "The CEO Debate 2: Museum Leaders Discuss Current Issues." This will involve CEOs of eight science museums discussing an array of issues arrayed in five categories – Purposes and Organization, Audiences, Activities, Change, and Revenues.

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Odd U.S. Community Names

Big Ugly, West Virginia, unincorporated
Boring, Maryland, unincorporated
Boggy Depot, Oklahoma, unincorporated
Cucumber, West Virginia, population 94
Goose Pimple Junction, Virginia, unincorporated
Happyland, Connecticut, unincorporated
Lick Skillet, Tennessee, unincorporated
Lovely, Kentucky, unincorporated
Normal, Illinois, population 52,497
Odd, West Virginia, unincorporated
Sweet Lips, Tennessee, unincorporated
Toad Suck, Arkansas, unincorporated
Truth or Consequences, New Mexico, population 6,411

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On the cover:

Educators in Chicago-area public schools come together at the Museum of Science and Industry (MSI) to participate in STEM activities geared toward upper elementary and middle school students. MSI provides long-term, high-quality science teacher education for teachers who struggle with science content knowledge, need more effective classroom strategies for science education, and are looking to become science education leaders in their school community.

Full article on page 10.