A day at the museum

Science centres and museums play an increasingly important role in bringing science and technology to the public

Blue, yellow, fluorescent lighting, computer terminals in every corner, exhibits resembling a Fisher Price toy or a wooden building kit—museums and science centres nowadays appear to be a cross between a computer technology exhibition and a child's dream of a playground. They reflect many of the efforts that are currently being devoted to making science and technology interesting for the younger generation, the one that will give rise to the scientists and engineers of the future. But also as science and technology increasingly impact on society, the 'shelf-life' of formal education is becoming shorter and informal lifelong learning is becoming more important. The result is a flurry of activities instigated by politicians, scientists and educators to bring science to the people and increase their understanding. National Science Week, science buses touring the countryside and visitor days in research institutes are just a few examples of how they are reaching out to the public and, importantly, to the next generation of students.

Museums and science centres form a prominent base for the communication of science, but despite their comparatively long history, the art of exhibiting science is relatively in its infancy. Dating back to the late 19th century, museums were then the theme parks of the day and important collections have been amassed in such mighty institutions as London's Science Museum, Munich's Deutsches Museum, the Smithsonian Air and Space Museum in Washington and the American Museum of Natural History in New York. Particularly during the last decade, the USA has pioneered the creation of more informal interactive science centres, most famously with the Exploratorium in San Francisco in 1969. Today, virtually every major American city boasts its own version, some 300 in all. Europe has also

witnessed a similar trend, to the extent that the distinction between museums and science centres is becoming blurred. The challenge for both is to make learning

Models of cells in the Deutsches Museum.

enjoyable, so that they can successfully compete in today's crowded leisure-time marketplace. But apart from just being

During the last decade, the USA has pioneered the creation of more informal science centres, most famously with the Exploratorium in San Francisco

attractions for kids, science centres and museums also play another important role in the continuing education of teachers and provide the necessary knowledge,

experience and material for making modern science appealing.

One of the more recent additions to the European museum landscape is the Wellcome Wing of the London Science Museum, which opened in June 2000 with a display that was 5 years in the making. The futuristic architecture, the dim blue glow cast by the rear glass wall and the preponderance of fluorescent lighting endorse its claim that it is 'devoted to contemporary science and technology'. Temporary exhibitions on the ground level enable the museum to rapidly respond to current topics—stem cells, foot and mouth disease, and genetic fingerprinting have all featured—while the real heart of the gallery is the permanent 'Who Am I?' exhibition one floor above. Deborah Scopes, one of its four curators, explained that the initial remit of the Wellcome Trust was to combine genetics and neuroscience, which the museum decided to interpret into an exhibition about everybody's favourite subject: themselves. 'It's what people can relate to,' she said. Indeed, the 20 display cases all centre around an individual theme and introduce such complex subjects as emotions, cloning and inheritance by asking 'What disgusts you?', 'Could there be another you?' and 'Where did you get your looks from?', respectively. 'We take an original artefact from the lab [...] but we always try to relate it back to humans,' Scopes said.

Science museums, by definition, are constrained by the fact that they are there to hold collections of historical interest as well as to promote public understanding of science. Exhibitions thus tend to dwell on the past more than the present, and on the practical more than the theoretical since the artefacts lend themselves to the illustration of technical achievement more readily than to the illustration of

The entrance to the Wellcome Wing at the National Museum of Science and Industry in London.

scientific ideas. But to be honest, most artefacts of 20th century science are mind-bogglingly dull and utterly uninformative to behold. Refreshingly, 'The Wellcome Wing is unique [in science museums] in that it is narrative-based,' continued Scopes. 'The story comes first and the object second.' Therefore, the electrofusion machine from the Roslin Institute, which generated Dolly the sheep, nestles in the case devoted to cloning alongside a stuffed starfish, which 'clones' itself as part of its life cycle. And importantly, the museum hosts regular 'Live Science' sessions where scientists bring the artefacts to life by carrying out experiments in front of an audience.

Each display case stands alongside a flip-book of information for those stimulated to delve deeper and child-height interactive 'bloids' with a total of 110 computer games and activities to further demonstrate the principles involved. Each visitor can take in as much or as little as they wish. 'Studies show that the average person is equivalent to a 14-year-old in a museum,' Scopes said in explaining the rationale behind how they pitch a topic. But they also need to take into account that their 'public' is not a cross-section of society: the audience is

smaller than that reached by television and radio and generally better educated. And visitors are in a free-choice environment where they set their own agendas, following their own interests and browse until they hit upon something that inspires their attention. 'The average stay in this gallery is 22 minutes,' Scopes announced proudly, which apparently makes it one of the best attractions in the whole museum.

If properly designed, museums can awaken an interest in science, something that goes beyond the quickly forgotten 'Oh, wow' response. The Wellcome Wing approaches this head-on with 14 pieces of commissioned art interspersed and sometimes integrated within the exhibits. At the entrance, visitors are confronted with 'effective, defective, creative', a bank of televisions depicting

6-day-old baby on the floor provokes a very emotive response with its solid substance contrasting sharply with its aura of vulnerability. 'Girls just want to cuddle it,' Scopes said. 'And one woman insisted that it be removed as it looked like it had been abandoned.' Such instinctive responses help to shape deeply felt beliefs about the effect of science on society that persist long after the visit is over.

The London Science Museum certainly blows away the preconception that these institutions are fusty places unreactive to the times. Although this is due in part to the realisation that museums have a significant role to play in public education, the recent surge in the number of interactive science centres has also made museums re-assess their philosophy. Freed from any historical perspective, science centres typically present bite-sized chunks of science where each interactive exhibit embodies a single scientific principle that visitors are encouraged to work out for themselves. The reaction to this trend has been mixed: to their detractors, science centres are little more than amusement arcades where children with short attention spans dart noisily between exhibits in uncontrolled Brownian motion; others view them as accessible and engaging environments compared with the more didactic approach of a traditional museum.

One of the original and more successful science centres in the UK is At-Bristol, which received over 1 million visitors last year. The Explore gallery is devoted to a whole range of scientific principles and the biological section is focused on the theme of 'self' once again with a display entitled 'Your amazing brain'. Memories, emotions, consciousness and the senses are the main topics, demonstrated through, for example, optical illusions, measuring sweat responses in reaction to various images and relaying a conversation as it would sound to people with hearing difficulties. Catherine Aldridge, At-Bristol's

The challenge for science centres and museums is to make learning enjoyable, so that they can successfully compete in today's crowded leisure-time marketplace

ultrasonic scans which alternate between healthy fetuses and those with muscular dystrophy, bluntly questioning whether we should screen and abort such 'defective' fetuses. Similarly, a cast iron

Education Manager, explained that the gallery is aimed at 7- to 16-year-olds and was designed in consultation with educational psychologists. 'We'll video a child on an exhibit, replay the video to them

and ask them to explain what they got out of it at each stage,' she said.

The real strength of science centres is often their strong links with the community. Behind the scenes, a fully-equipped laboratory with a full-time technician is used by classes and also families to learn about a wide range of science topics including DNA and genetic fingerprinting. 'Fifty percent of our visitors to the laboratory are more than a 90 minute drive away, so we have a huge catchment area,' Aldridge commented. The local community also participate in regular 'Air and Share' discussion forums broadcast on the web from a specially designed studio, the latest focusing on renewable energy sources. Instigating a dialogue between scientists and society is obviously a priority for At-Bristol and they have so far trained 12 physicists in the art of science communication. 'The scientists are assigned a mentor and learn how to develop a presentation geared towards the public, particularly focusing on audience participation,' Aldridge explained. 'The last one we had was on "cold" with lots of liquid nitrogen, making ice cream—the audience loved it.' They plan to expand this scheme, hopefully to include some biologists in the future.

A child at a display in La Cité des Sciences et de l'Industrie's medical exhibition.

Across the Channel, the modern glass and steel architecture of La Cité des Sciences et de l'Industrie in Paris also reflects the innovative spirit of this science museum. Since it opened in 1986, it has continually created new tools and approaches to more effectively educate its visitors. Initially, its goal was to transmit hard science in an academic way, but its new pedagogical strategy is to use entertainment and spectacular exhibitions to teach both science and its impact on society. For instance, a current exhibition 'The transformed man' explains medical technologies, such as new prosthetics and nanotechnologies, which could help prolong human life. Moreover, ethical questions arising from science are a predominant feature of the museum's exhibitions.

In addition, the museum, also known as La Villette, has started programmes specifically geared towards visiting teachers and their students. Special internships guide teachers on how, for example, to set up classroom discussions on social issues and students' press workshops. A team of administrators, teachers and instructors also offer various student programmes. The basic level consists of exhibitions available to the general public and to teachers who want to complement a classroom curriculum. A more in-depth programme was first offered in February this year where students could visit for a full day of events and choose from one of seven science topics, ranging from biology to physics. During the day, the class visits exhibitions, meets with

Inside the Wellcome Wing.

minimal human involvement. Now, we have teachers seconded here for 4 years, museum instructors and even artists.' For example, to complement 'The transformed man' exhibition, students are asked to distinguish between robots and real life actors pretending to be robots.

To their detractors, science centres are little more than amusement arcades where children dart noisily between exhibits in uncontrolled Brownian motion

museum instructors and participates in the Biolabo, a 1-hour laboratory class where, for example, they extract DNA from onions. At the third and highest level, about 30 national and international classes and their teachers are invited each year to spend 4 days at La Villette to study a scientific theme in depth.

According to Caroline Allain, director of the education department, what is ultimately making these new programmes so successful is the balance between work and fun. 'We use spectacle more than before, games and human contact,' she said. 'At the beginning, there was only

At all levels, hard science is purposely mixed with social issues. 'The development of new technologies raises ethical questions that citizens should consider. So, I think that it's necessary that we give the children additional information,' Anna-Lyse Mathieu, a museum instructor, said. A presentation in the Biolabo, 'It's your turn to judge', transforms students into a jury that judges bioethical concerns. The instructors present actual cases, such as post-mortem *in vitro* fertilisation where students debate and vote whether a wife can be impregnated with her deceased husband's frozen sperm. After the debate,

Students in the Biolabo, La Cité des Sciences et de l'Industrie.

the instructors conclude with a presentation of the verdict and the law relating to the issue.

Students also have the opportunity to go to other museums to examine the subject from a non-scientific angle. One museum theme, 'Double look on the living', concentrates on how recent developments in science and technology have changed our perception of ourselves and our environment. To appreciate this impact of science, students go to a Parisian museum of modern art, le Centre Pompidou. 'This is very important to help students link the science they learn in school and science in their everyday life,' Allain said. La Villette is planning to extend this social education to a European level and has sent a proposal to the European Commission to set up a Youth Forum on bioethics.

If the modern architecture of La Villette and the Wellcome Wing reflects the new approach for luring the public to science, the old façade of the Deutsches Museum, the grand old dame of science museums, reflects its more historical approach. Built on an island in the heart of Munich during the Industrial Age at the start of the 20th century, it now holds the largest collection of any European science museum. 'We see natural history as an evolutionary process,' said Jürgen Teichmann, director of the museum's education department, explaining its philosophy and strength. 'This is actually a great advantage of our institution in that it is able to combine history with actual research.' The museum's latest exhibition of pharmacology, for

instance, displays a German pharmacy from the beginning of the 20th century that, according to Teichmann, draws a lot of attention as visitors are indeed interested in how things looked 100 years ago.

The best approach is to engage university students as instructors and guides

The museum's emphasis is more on technology than science *per se*, but it has risen to the challenge of including modern science. Since the 1960s it has gradually added the life sciences, such as exhibitions on medical technology and

pharmacology, and is currently establishing a molecular biology laboratory for visiting students to carry out experiments. However, there are new challenges for the educators and exhibition designers. 'In physics, it is actually easier to make the effects attractive,' Teichmann said. 'It is indeed a characteristic of modern sciences that they are not so descriptive.' So the museum needed to find new ways to make these topics attractive for children. 'Pharmacology is a great experience in a visual sense, but it is more difficult to make it interactive,' he said, describing the problems with their latest exhibition. They overcame this by planting medicinal herbs and trees at the entrance and having a large model of a cell that visitors can enter, giving them 'a sensual experience by walking through a cell'.

Clearly, science museums and science centres are complementary to a large extent and there are clear signs of convergence between the two. Most museums are recognising the value of interactive exhibits while the centres are recognising the value of themed exhibitions and the social context of science. It is obviously not enough just to have kids press buttons, pull levers, turn wheels or touch computer screens if the aim is for them to actually learn something about science or experience its fascination. Equally, simply displaying a collector's item in a showcase with a card explaining its function does not work either if there is no opportunity for hands-on experience. This is not to say that the Deutsches Museum does not feature interactivity and fun. Instructors

The old pharmacy in the Deutsches Museum's pharmacy exhibition.

Websites of some science centres and museums

North America:

American Museum of Natural History, New York <http://www.amnh.org/>
 The Field Museum of Natural History, Chicago <http://www.fmnh.org>
 The Exploratorium, San Francisco <http://www.exploratorium.edu>
 Smithsonian National Air and Space Museum, Washington, DC <http://www.nasm.si.edu>
 Boston Museum of Science, Boston <http://www.mos.org/>
 Houston Museum of Natural Science, Houston <http://www.hmns.org/>
 Maryland Science Center, Baltimore <http://www.mdsci.org>
 Fort Discovery, Augusta <http://www.nscdiscovery.org/>
 Museum of Discovery and Science, Fort Lauderdale <http://www.mods.org/>
 Science World, Vancouver, Canada <http://www.scienceworld.bc.ca>
 Discovery Centre, Halifax, Canada <http://www.discoverycentre.ns.ca/>

Europe:

National Museum of Science and Industry, London, UK <http://www.nmsi.ac.uk>
 At-Bristol, Bristol, UK <http://www.at-bristol.org.uk>
 Museum of Science and Industry, Manchester, UK <http://www.msim.org.uk/>
 Deutsches Museum, Munich, Germany <http://www.deutsches-museum.de/>
 Deutsches Technikmuseum, Berlin, Germany <http://www.dtm.de>
 Phänomenta, Flensburg, Germany <http://www.phaenomenta.com>
 Landesmuseum für Technik und Arbeit, Mannheim, Germany <http://www.landmuseum-mannheim.de>
 Cité des Sciences et de l'Industrie, Paris, France <http://www.cite-sciences.fr>
 Palais de la découverte, Paris, France <http://www.palais-decouverte.fr/>
 Futuroscope, Poitiers, France <http://www.futuroscope.fr/>
 New Metropolis, Amsterdam, The Netherlands <http://www.newmet.nl/>
 Museum of the History of Science, Florence, Italy <http://galileo.imss.firenze.it/>
 Tietomaa, Science Centre, Oulu, Finland <http://www.ouka.fi/tietomaa/>
 Tom Tits Experiment, Södertälje, Sweden <http://www.tomtit.se>
 Vitensenteret, Trondheim, Norway <http://www.viten.ntnu.no/>
 Technorama, Winterthur, Switzerland <http://www.technorama.ch/>
 Israel National Museum of Science, Haifa, Israel http://www.netvision.net.il/~sci_muse/

Australia:

The Investigator Science & Technology Centre, Adelaide <http://www.investigator.org.au/science/>
 The National Science and Technology Centre, Canberra <http://www.questacon.edu.au>
 Scitech Discovery Centre, Perth <http://www.scitech.org.au/>

Asia:

Singapore Science Center <http://www.sci-ctr.edu.sg/>
 National Science Museum, Tokyo, Japan <http://www.kahaku.go.jp/english/>
 National Science Museum, Seoul, South Korea http://www.nsm.go.kr/center/html/index_e.html

Africa:

Kwa Zuzulwazi Science Centre, Durban, South Africa <http://www.kwazuzulwazi.co.za/>

demonstrate how paper is made, how a steam engine works and how bricks are produced. The exhibition on bridges and waterworks, for instance, not only holds models of how bridges have been built from Roman viaducts to modern suspension bridges, but also experiments where students can change a river's flow or play around

with miniature dams. 'We can learn a lot from the science centres and we have to learn from the science centres,' Teichmann said, 'but we are able to critically illustrate the historical development.' Nevertheless, many ideas actually have come from science centres, and Teichmann, a former high school teacher and professor of the

history of the natural sciences at the University of Munich, is constantly travelling in Europe and the USA, visiting his colleagues at other museums and science centres to share experiences.

But kids simply having fun in a museum is not enough; an exhibition needs to effectively transmit knowledge and enthusiasm about science. Actually, a museum is 'suboptimal' for learning, Teichmann said, although the motivation and fascination of students are clearly higher, simply because the event takes place outside school. 'Our experience is that if we have a structured preparation and follow-up, this has the largest effect [on learning],' he said. 'This is, I would say, the important thing about it.' And this is the teacher's domain, not the museum's, although they can and do help in providing educational material.

There is clearly a role for museums and science centres in public education and a combination of both—the interactivity and the critical context—is the most effective approach. One emerging trend to be encouraged is the increasing appearance of real-life scientists in both types of institution, as even the most thoughtfully constructed inanimate display can benefit enormously from being explained personally. The best approach, Teichmann thinks, would be to engage university students to act as instructors and guides as they are certainly best suited to transmit the excitement of science to young children. 'There are many resources that one could use,' Teichmann said about the role of universities. 'If we can get the universities' students interested, this will work fantastically [...] I think that would be great.'

Susan R. Owens, Aude Lecrubier & Holger Breithaupt

DOI: 10.1093/embo-reports/kvf123