The Curator's New Clothes

Reinventing the role of the museum professional

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To begin, we would like to thank the Canadian Museums Association for their invitation to join you for your annual conference in this city of sunshine. Three years ago, the CMA invited us to address you on the subject of the Science Alberta Foundation, an organization that had been founded the year before to stimulate the growth of a network of science museums and science centres across Alberta. The goal of Science Alberta was to effect a profound change in the public understanding of science, to create a science culture that would touch all Albertans.

When we spoke with you three years ago, the vision of Science Alberta was undergoing a radical transformation, from a top-down to a bottom-up organisation. Let me describe briefly the circumstances under which this transformation took place. The Board of the Science Alberta Foundation set off on its mission with the assumption that its primary role would be to raise money and give it to the province's major museums and science centres, which would in turn create science exhibits and programmes and send them to smaller communities.

This was, very clearly, a top-down strategy. But it didn't last long. Shortly after beginning the feasibility study, we embarked on a tour of small communities of the province. In Drumheller, a group of citizens angrily denounced the proposed network because it would relegate them to being receivers of the ideas and programmes developed by large urban institutions. In contrast, they proposed a network in which any community or organization in Alberta could apply for funding to develop its own exhibition or programme, and the Foundation would be responsible for shipping these back to the large city institutions.

This plan was a bottom-up network, was predicated on the idea that the Foundation would award funds on the basis of merit alone. In effect, small towns in Alberta would pit their fortunes against the largest museums and science centres in the province.

The Board of the Science Alberta Foundation took this criticism in good grace and re-examined the Foundation's starting point. From the beginning they had committed themselves to creating a broadly-based science culture for Alberta, and they realized that a structure that was bottom-up could be the key to developing a model of science education for the twenty-first century. The challenge was this: how could you structure a Foundation so that it was the catalyst for community initiative? After months of consultation with communities across Alberta, the Board developed a strategy that had these key features.

First, the network was to decentralize the access to science and technology exhibits and programmes, so that rural and small town residents would have equal access to stimulating ideas.

Secondly, the network was to deprofessionalise the development of exhibits and interpretive programmes, so that a broader range of citizens would have the opportunity to make a contribution.

Finally, the network was to deinstitutionalise the task of science communication, transferring some of the responsibility for science interpretation away from the large museums and science centres, toward individuals and communities willing to play a role in the public communication of science.

Over the last three years the Science Alberta Foundation has pursued this three-tiered strategy of decentralization, deprofessionalisation, and deinstitutionalisation. In the process, the Foundation has raised some fundamental questions about the traditional museum enterprise and its practice.

A. The Museum Mandate

In order to understand the evolution of the Science Alberta Foundation's approach, we should begin by referring to the way museums usually work within contemporary society. The mandate of museums is expressed most succinctly in the definition that ICOM has given: that the role of the museum is to collect, conserve, study, interpret and exhibit. This definition was a natural outgrowth of the nineteenth century world in which a relatively small educated elite delighted in its role as steward and communicator of specialist knowledge to an uninformed public. But does this nineteenth century vision meet the needs of an educated society, one that is hurtling toward the twenty-first century? We think not.

In a speech given at the ICOM triennial meeting last year, we suggested that, in science museums at least, the first two aspects of this mandate - collecting and conserving - are undergoing a dramatic transformation. Increasingly, the course of modern scientific and technological development depends on processes rather than products. It derives from materials that may be invisible. Often the key to interpretation cannot be found within the object itself. In short, in the age of biotechnology and lasers, fibre optics and computers, the idea of conserving a technological "collection" may well be obsolete.

Today, we would like to focus on the final three roles of the museum: to study, to interpret and to exhibit. There is nothing in these objectives that is by its nature elitist. However, all too often the contemporary museum has defined these functions as the narrow preserve of a select group of individuals: museum curators, designers and educators. It is they who decide on the subject matter of new exhibitions. They shape the scholarship, define the approach, design the exhibits and programmes. The results are often a tour de force, but often they do not represent the curiosity, the interests and the vision of the community.

On most cases, their work has relegated the audience to participating as *receivers* of the museum experience. The challenge of the Science Alberta Foundation was to stand this traditional mandate on its head, encouraging citizens to become *the generators* of the experience.

So much for the strategy of the Science Alberta Foundation, what of the tactics? The Foundation developed two complementary strategies to stimulating a bottom-up network. The first were Special Projects, exhibitions and interpretive programmes designed to demonstrate skills to people who had not been involved in science interpretation before. The second was a Grants and Awards programme that encouraged Albertans from all walks of life to propose their own science communications programme. Taken together, it was hoped that these strategies would stimulate a broad cross-section of Albertans - rural and urban, men and women, young and old - to see themselves as full participants in the process of creating a science culture.

On the following pages we would like to describe some examples of the programmes that have been developed, first as Special Projects and secondly as initiatives from the community.

B. Special Projects.

Our first Special Project was an exhibition entitled The *Body In The Library: Forensic Science and the Art of the Murder Mystery,* a subject we chose because of its links to popular culture. The exhibition was, in effect, a three-dimensional murder mystery in which visitors were challenged to research a number of scientific clues to discover who was behind the murder of a scheming young entrepreneur.

This exhibition challenged many of the traditional assumptions of museum and science centre exhibitions. Taking the role of the curator, for example, we chose a number of skilled individuals from the community. We sought the help of the Chief Medical Examiner of Alberta, who drew up a murder to our specifications. The Royal Canadian Mounted Police found and fabricated the exhibits. Librarians and lawyers from across the province developed interpretive programmes. Only two members of the twenty person team, ourselves, had ever worked on a public exhibition before.

The exhibits, when they emerged, functioned very differently from the norm. For one thing, the visitor was not allowed to stand back and absorb the conclusion of the experts. Instead, they were asked to be participants in the process of solving a scientific dilemma. In effect, our non-professional curators, scientists and police officers, designed an exhibition that mirrored their professional lives. Of the myriad of pieces of evidence, for example, only a few were actually germane to the case, a frustrating fact of life for most officers of the law. Moreover, there was not one single correct answer to the murder. As in experience of many forensic scientists, the scientific evidence could be interpreted in a number of ways.

Then too, the visitors were expected to do their own research. The exhibit areas included books so that visitors could carry out their own investigation. I recall hearing a twenty-year old woman sending her boyfriend off for more books, and she called after him: "And don't forget a dictionary of medical terms." In effect, this exhibition shifted the locus of responsibility for study away from the curator, toward the visitor.

In a final break with tradition, we decided to circulate the exhibition through the province's library network instead of science museums and science centres. The public library is one of the most pervasive institutions in Canadian culture. Almost every community in Alberta, no matter how small, has a public library and a high percentage of the citizens who hold library cards. So we reasoned that we could capture our potential audience as they made their weekly trips to the library.

What reception did this exhibition have in the communities of Alberta? Better than we ever imagined. *The Body In The Library* went on the road in October, 1991, and has now visited more than twenty libraries in cities and small towns across Alberta. Bookings now extend three years into the future. Moreover, the exhibition seems to appeal to everyone. The exhibits have been designed so that no one in the community can be sure of the identity of the murderer. As a result, townspeople develop an escalating interest over the course of a month. Arguments erupt at cocktail parties and barbecues. Visitors return four and five times to confirm their hypotheses. Many write intricate conclusions of a page or more in length. We have even received solutions by fax.

Did the strategy have the desired effect? Did it encourage others to become involved in science programming for the public? I am happy to say that the exhibition seems to have been a stimulus for all the groups that assisted us in developing it. When the exhibition opened, the Chief Medical Examiner told us that he had discovered that design and interpretation were easy skills to pick up, and so he and his staff were going to apply for a grant from the Science Alberta Foundation to build their own Museum of Forensic Science, featuring a programme entitled *Death In The Gym.*. They won their grant, and the new museum opened in September.

The legal Society of Alberta also chipped in to develop a programme called *Crime and Consequence*, which is offered jointly in schools and at the Law Courts in downtown Calgary. And the librarians! The librarians who were originally recruited for their expertise in the genre of detective fiction have become enthusiastic supporters of science in non-fiction form. A Saturday afternoon interpretive session, *The Future Scientists' Club* was established in Edmonton last year and has now spread across the province.

C. Grants and Awards.

The other horn of the Science Foundation's strategy was to design a Grants and Awards programme to encourage the man-in-the-street to become a science communicator. There were four features that made these grants different from those offered by other foundations.

First, the application had to be made by a recognised community organisation, with the backing of its local government. This meant that the community as a whole had a stake in the development of a science network.

Secondly, the award would be made on the basis of merit only. This meant that large institutions were in direct competition with farm wives, teachers and community associations. This was all very fine and well on paper, but when, in the first year, a number of farm wives and teacher won grants - and some well-established institutions did not - a shiver ran through the museum and science centre community.

Third, the funding was to go only to programmes; money was not to be used for "bricks and mortar". This stemmed from the realization that in the traditional institutional framework, a large part of the operating budget was required for maintenance and infrastructure costs. The Foundation wanted every penny of its investment to count toward creating new tools for science communication.

Fourth, and key for the museum community, was the stipulation that the rights to the material resulting from grants would be owned jointly by the Science Alberta Foundation and the grant winner. This rider arose from the Foundation's desire to ensure that the best exhibits and programmes could be distributed throughout the province.

Over the last three years, forty community projects have been awarded grants. Three of the projects are representative of the high level of accomplishment achieved by Albertans in what was for most, a new and challenging field.

Dinosaur Country Science Camp. One of defining characteristics of a museum, according to ICOM, is its emphasis on study. One of the most enthusiastic of our grants and awards winners was the town of Drumheller. Located in the badlands of Alberta, Drumheller already has a reputation as an important locus of the science fraternity, since it is home to the celebrated Tyrrell Museum. But the people of Drumheller dreamed of playing their own role in science education: they wanted to build a science camp that would bring children and families from across Alberta to explore the unique scientific attributes of the badlands: the delicate ecological balance, the archaeological resources, the history in coal mining and agriculture.

The people of Drumheller mobilised a small army to back the plan. The Chamber of Commerce, the schools, scientists from the museum, the environmental groups, all threw themselves into planning the camp. Their brief to the Foundation exceeded two hundred pages, including the precise tab for laundering sheets. It was an impressive achievement and it won the Dinosaur Country Science Camp the Science Alberta Foundation's largest grant.

The camp is now entering its third season in operation and continues to draw hundreds of young people from across Alberta as well as an impressive contingent from as far away as Germany and Japan. The camp is committed to learning by participating in valid scientific work, so campers participate in on-going research, mapping tipi rings and defining pocket forests. Not to mention the workshop on cow pie ecology. For the most part, these activities are not a make-work programme for high school students; the data contributes to research projects being conducted within the professional scientific community.

Now, Drumheller is a community that is home to an internationally-recognized museum, and one might expect a certain competition between the professional and non-professional science educators. But, on the contrary, the history of the two groups is one of collaboration and relative harmony. This cannot help but enhance Alberta's science culture.

Fleece and Fibre. And how effective is our man-in-the-street when he turns his hands to creating interpretive programmes? Well, the grants and Awards programme has had some strong entrants

Dorothy Broadbent and her husband raise goats on a farm located outside of the town of Ponoka, in central Alberta. Last year Dorothy applied for a small grant - $1000 - to develop a kit that would describe the science and technology of the wool industry. Hundreds of hours went into collecting specimens of wool from different breeds of goat, developing hands-on activities so that children could experiment with their insulating properties, and creating a manual that would enable the kit to be used by teachers across the province. The crate, for it has expanded far beyond Dorothy's original vision, has been a runaway success and is in almost constant use.

For those of us in the museum community, the *Fleece and Fibre* programme is similar to the discovery boxes developed by the educators in our natural history museums. There is one startling distinction however, and that is the fact that Dorothy Broadbent's programme is deeply rooted in her own experience. Moreover, she has taken this programme to hundreds of Alberta communities during the past year. This experience, coupled with the conviction that this is material of immediate value to the community, cannot be matched in a traditional museum setting. Dorothy Broadbent's work is proof that the non-professional can master the complexity and challenges of an interpretive programme successfully, and communicate science every bit as effectively as her professional colleagues.

Matchbox and Shoebox Science According to ICOM, another important responsibility of a museum is to exhibit. The *Matchbox and Shoebox Science* programmes challenge every child enrolled in elementary and junior high school in Alberta to develop a science exhibit that can fit into a matchbox. Unlike science fair projects, where the object is to encourage children to demonstrate what they know, children entering the *Matchbox Science* competition must build an exhibit that allows others to explore a scientific concept. The participants design exhibits, write copy, and illustrate their ideas.

To date, a number of young people have developed interesting solutions to the problem. One of my favourite of the *Shoebox Science* exhibits was Bungee Ken, a doll that was trussed up with an elastic. The children stood at the top of a staircase and dropped Ken over the edge, and then graphed the bounces. It is a simple idea, and vastly cheaper than most of our professionally-designed exhibits. Last year seven of the forty provincial winners came from a tiny community near the American border. Every one of the seven showed ingenuity, resourcefulness, and economy that would be the envy of any professional exhibit designer.

Our goal with the *Matchbox* and *Shoebox* science competitions was to give the children of the province a role in spreading science culture to their peers. At the end of the first year, the winning forty *Matchbox* and *Shoebox* exhibits are now circulated to children throughout Alberta. In effect, the young people of the province are becoming experienced exhibit designers, responsible for communicating what they have learned to future generations.

These three examples offer a cursory overview of the forty grants and awards that have born fruit in Alberta over the last three years. To date, three years after its inception, projects from the Science Alberta Foundation have reached, both directly and indirectly, almost 15% of the population of the province. These projects have been created by communities in a wide geographic span of the province, from Fort McMurray in the north to Pincher Creek by the American border. They demonstrate a wide range of scientific knowledge and enthusiasm: from archaeology to lasers, from wildlife science to computers. In only three years, over 500 Albertans have been involved in creating and delivering public programmes in science and technology. The skills of research, interpretation and exhibit development, traditionally the domain of the museum professional, are now shared by scientists, teachers and farm wives from across the province.

So what have we learned? Science Alberta's experience suggests that knowledge, and a passion to communicate that knowledge, are the key factors in developing effective tools for science education. In the past, we in the science museum prided ourselves on having unique skills, of being custodians of the communication of science and technology. Our experience in Alberta has forced us to re-examine this assumption, questioning three of the key roles museum professionals have played: curator, interpreter and exhibit designer. It would appear that these skills are no longer the domain of the few, but may be claimed by many.

Rather than a defeat, this can be seen as an opportunity. The model of the Science Alberta Foundation suggests that if we can admit citizen scientists into the fold, we can carve a new role for the museum and science centre. We can reinvent the museum as a hub where science exhibits and programmes from across the community meet . At the same time, we revitalize our own mission. We believe this partnership, a collaboration between professionals and non-professionals, is a vision for the twenty-first century, when it will be imperative to build a science culture that transcends the traditional barriers that have divided us from our audience for so long.

Poles of Interaction

Invention, revelation and learning in the science centre

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To begin with, I would like to recall the opening speech of this conference, given by Luis Monreale, in which he appealed for a multi-disciplinarity, and a reconciliation of the rift that he laid at the feet of Descartes: between measurable reality, on the one hand, and 'clear and distinct' ideas on the other. We too want to speak of this polarity, the polarity between facts and ideas, a polarity that is part of the history of science, of science learning, and of science centres, since the birth of rational science in the 17th century. For reasons that will become clearer below, I will call these two poles the pole of revelation, and the pole of invention.

The science centre community is now a quarter of a century old. Twenty five years have now passed since Robert Oppenheimer and his band of thinkers and tinkerers at the San Francisco Exploratorium began to explore ways of translating scientific principles into three-dimensional form. Now is a good time to pause and consider the state of our art, and to ask ourselves what kind of exhibits we are building, and what effect they are having on our visitors

If we are very brave, we will consider the question that Michael Shortland raised in his article in *Nature* five years ago "..what - if anything - do children learn in them?" It is our opinion that the last quarter of a century has seen the development of two kinds of science exhibits, representing two opposing philosophies about how people learn about science. We further believe that these two poles have become entrenched, possibly to the extent that creative thinking about the design of science exhibitions has been almost stifled. Finally we are convinced that neither of these philosophies serves our visitors as they should, if we are to create a scientifically literate - no, a scientifically creative - culture for the 21st century.

Let's take a moment to look at the two kinds of exhibits we have developed over the past quarter century:

The most common form of science exhibit, found from Toronto to Tokyo, is the stand-alone, so-called 'interactive' exhibit. Each of these exhibits is designed to illustrate a single, specific scientific principle to the visitor; each is engineered to demonstrate the same fact every time, without fail. We can call these 'exhibits of revelation', as they are designed in the spirit of revealing to the visitor a scientific principle or phenomenon, and form part of a mainstream of thinking in rationalist science. The meaning of the revelation is often supplied in the form of explanations, whose authority is the authority of science.

However, these exhibits cannot often be used as tools for creative scientific thinking. In a paper given at the Science Museum in 1990 we outlined three reasons why not.

First, many of our exhibits communicate principles, not processes. These exhibits are a physics text in three dimensions. They encourage visitors to think in terms of a canonical hierarchy of scientific laws. Each of these exhibits represents a single experiment, which inevitably ends with the same result. The result, all too often, is that the visitor has no intellectual engagement with the subject matter.

Secondly, many of our exhibits fail to communicate the structure of scientific thought. These exhibits focus on conclusions, devoid of process, as if results leapt *sui generis* into the scientific mind. Our visitors never see the false leads, the disillusion, the failures. These exhibits misinform the public of the true nature of the scientific enterprise, making it seem as though there is a simple one-to-one relationship between hypothesis and result.

Thirdly, our science exhibits tend to treat science as a series of discrete breakthroughs, unique events in time. This approach denies the continuity of scientific thought through history, and masks the links between science and technology. Take the Bernouilli Blower for example. No respectable science center would be without one. Everyone loves the beach ball bouncing cheerfully on a jet of air. Yet, very few visitors understand the technological implications of the principle it demonstrates. It is true that some museums have mounted a model of a 747 next to the beachball, but I dare you to find more than one visitor in a thousand who understands the connection between the two.

Finally, our science exhibits put the visitor in the role of receiver, rather than generator, of scientific thought. The visitors participate, to be sure. They push, pull, blow and bellow, but only rarely do they actually investigate a question that is of personal interest to them. The underlying message to the public is that only scientists can define the subject matter of science.

As Richard Gregory has said 'the fun of our science centres should in fact be the fun that scientists themselves derive from science'. These exhibits therefore often deprive our visitors of the chance to participate in the most dramatic and satisfying aspect of scientific behavior - the opportunity to pinpoint a paradox and hazard an explanation.

On the other pole of the spectrum are science programmes that encourage visitors to learn through open-ended exploration.

These exhibits, particularly popular in England and the United States, offer the visitors simple problems to solve. For example, a visitor may be given a set of blocks, from which they are invited to build a bridge or a house. They then test these structures to see how much weight they can hold. The proponents of this approach often deliberately avoid giving visitors any information that will help them understand the principles on which these structures are based. No Gustave Eiffel, no Paolo Nervi. Instead, enthusiasts of this form of science learning believe that the process of solving the problem <u>alone</u> will enable the visitors to derive the theory of bridge-building or house construction.

When these activities are properly guided, and staff members are present to encourage visitors to articulate and explore their observations, this understanding may in fact take place. All too often, however, these open-ended exhibits consist of a play experience that does not leave the visitor with a greater understanding of science or technology. Any solution is a good solution. Any bridge is as good as the Brooklyn bridge. This may be entertaining, indeed, there may even be a lot of general learning going on, but we argue that in several key respects this is far too diffuse an experience to be considered science learning.

In the 1987 article quoted above, Michael Shortland was critical of the notion that science learning can take place solely through play. In a discussion of an exhibit of blocks that encourages visitors to build a bridge, he points out that the visitor may not learn anything at all about bridges from the conclusion, or worse, he may with authority draw an erroneous conclusion about the principles involved. 'Putting blocks of wood together manifestly does not explain how a bridge or an arch holds firm. It may, to be sure, prompt an explanation. It may equally suggest a false one.'

So here we are, at the end of twenty-five years of exhibit building, with science exhibits largely fall at both poles of a continuum. At the one end we have exhibits that communicate bits of scientific information, but prevent the visitor from engaging in a process of questioning and discovery. On the other, we have open-ended problem solving exhibits that do not encourage the visitor to incorporate existing scientific knowledge into an exploratory process.

Is there a way to mediate between these two solitudes, to develop science exhibitions that incorporate scientific fact and encourage a reasoned process of exploration? We believe that there is. Moreover, we believe that the means whereby we create such exhibits is an intrinsic part of the scientific process itself. To explore this process, we turned to the history of science, seen through the writings of scientists themselves.

Not surprisingly, the epistemological spectrum spanning revelation to invention, and its debate, exists within science as well, and dates from the period in which science was obliged to fight off rival claims to knowledge in the late 1600s.   Communication and communicability is essential to the practice of science, and the authority of science can be said to depend on a kind of shared witnessing. The history of witnessing goes to the earliest centuries of proto-science, and became of fundamental importance in the early 17th century as the claims of a nascent experimental science had to supplant the claims of rival systems such as alchemy and astrology.

The public demonstration of the truths of science, necessary in order to combat "false belief" in rival systems, nevertheless masked the real nature of scientific investigation. Although the private experiments of Hooke, Boyle and others were necessarily fraught with uncertainty, and still carried with them the possibility of mistaken hypotheses, technical failure or defective materials, in order for these private experiments to become public knowledge, they had to be presented on the public stage. The stage was the Royal Society, and the Society wanted results on which they could discourse, and sharply reprimanded Robert Hooke when his experiments failed; "He made an experiment of the force of falling bodies to raise a weight; but was ordered to try it by himself, and then to shew it again in public."

Following several centuries of neo-platonic speculation, the rationalist scientist, while privately recognising the tentative nature of means he used to seek out the putative mechanical nature of the universe, nevertheless had to vouchsafe the validity of his results. Observation was certainly central to their experimental practice, but public corroboration of results was essential to triumph over rival explanations. Because of this need to claim public authority at the expense of rival systems, since the seventeenth century, the *public* emphasis in our culture has remained largely placed on the *results* of scientific enquiry, rather than on the process of generating questions, linking disparate phenomena or formulating hypotheses which underlie the real authority and certainly the real practise of scientific work.

The message remains with us to this day; scientific practice, fraught with false starts, mistakes and failure, is to be confined to the laboratory, while scientific truth is a matter of public record.

In this century, the debate about the relationship between 'proved' or 'revealed' science and the creative process has grown more heated. At the turn of the century, the pioneers of the new physics were of course fully conversant with new developments in their field. However, a few scientists like Einstein stressed the critical role played by what he called 'invention' in the creation of new theories.

In a critical passage in a letter to his friend Michele Besso Einstein argues that science is more than an exposition of revealed facts, stating that the physicist Ernst Mach's weakness , 'lies in the fact that he believed more or less strongly, that science consists merely of putting experimental results in order; that is, he did not recognise the free constructive element in the creation of a concept. He thought somehow that theories arise by means of a *discovery*, and not by means of *invention*.'

Here Einstein gives the two poles of scientific reasoning, revelation and invention a specific order and a logical priority. He believed that it was critical, first, to grapple with a body of knowledge, to understand it in depth. This knowledge was not only the knowledge of physics "for the critical thinking of the physicist cannot possibly be restricted to the examination of the concepts in his own field', but a profound reflection on the whole of knowledge. Only then could the scientist invent, developing thought experiments to cast new light on conflicting and confused data. This tension, between the constraints of knowledge and creative freedom is at the heart of the scientific process. Richard Feynman put the same point differently. 'the whole question of imagination is misunderstood by people in other disciplines. They overlook the fact that whatever we are allowed to imagine in science must be be consistent with everything else we know.' Scientific creativity, he said, 'is imagination in a straightjacket'

Is it possible to take this philosophy of invention and bring it inside the four walls of the science centre? Is it possible for a museum visitor, a non-scientist with a moderate education, to grasp scientific information that is normally the domain of the professional scientist? Further, can the visitor then explore and manipulate this information to become a creative scientific thinker? 'Impossible! cry the skeptics, science is so complex even scientists cannot keep up, so how can our visitors?'

As professional scientists or science communicators, it has also been our habit to say 'No'. As Richard Gregory has pointed out, most of our science centres are still wedded to a museology of revelation. 'Indeed it is amazing' he writes 'how little science there is in traditional science museums! In most it is impossible to find essential principles of science, or of science thinking... such as the distinction between induction and deduction; or of probability or testing hypotheses'. Fewer still stress the importance of invention and its skills of extrapolation and creative thinking.

For scientists like Feynman and Einstein there was no doubt about the average citizen's ability to tackle the challenges of scientific thinking. In Einstein's view 'The whole of science is nothing more than a refinement of everyday thinking.' Feynman just said simply 'We are not that much smarter than each other.' So if we were to follow their lead, and to develop a science exhibition which allows our visitors to be full intellectual participants in the experience of a scientific subject, what would it look like? We would like to draw from our experience with the Science Alberta Foundation in Canada to suggest one approach that might be taken.

In 1990 we began work on a science exhibition called *Beyond the Naked Eye: The Inside Story of the Human Body*. The subject matter of the exhibition, radiology, was chosen for three reasons.

First, as a subject intimately connected with human health, it was of intense interest to our audience.

Second, the subject required a basic understanding of the pure sciences, particularly physics. It is not possible to fully appreciate the meaning of an x-ray, a CT scan or a magnetic resonance image without a basic knowledge of how these technologies create an image of the human body.

Third, radiology is a science that draws heavily on interpretive skills. Radiologists have few pat answers. they may examine a dozen or more images looking for small clues that, taken together, tell a story. Even then, the diagnosis can be wrong.

In short, we chose this scientific discipline because in it the skills of inference and deduction are just as important as knowledge.

Our hypothesis was this: if Einstein was correct, and science is in fact a refinement of everyday thinking, then members of the public should be able to grasp the salient facts about radiology, and learn to make diagnoses that are as acute as those made by the medical profession. How did we go about it?

The exhibition is divided into five sections, each of which explores one of the radiological sciences: from x-rays to nuclear medicine. Each of the sections begins with a table where visitors are encouraged to learn how the technology works.

Our exhibit on CT scans, for example, includes three exhibits that look at the fundamental principles of computed tomography, and a fourth exhibit that tests how well the visitor has grasped the principles. In the case of CT, the visitor is given an apple that has been injected with a spot of dye, and challenged to find the location and size of the 'brain tumour' inside it by making no more than three horizontal cuts. Knowledge about the principles and limitations of CT are communicated to the visitor, but in a hands-on, self-guided way.

When visitors have learned to read the images, they are free to explore the four tables that contain case studies of patients. They are give the patient's case file, and are challenged to make a diagnosis. But there is a trick: in one out of every four case studies, the diagnosis does not follow directly from the medical images. These special cases require a careful reading, the construction of various hypotheses, and extrapolation from the data. In short, they call for what Einstein calls 'invention'. These special cases are difficult enough that some medical students have made a misdiagnosis - practice, perhaps, for the years ahead.

Is the public able to handle the exhibition? It may be early to tell, as the exhibition has only been open a month, but it has already proved to be extremely popular with the public. Most of our visitors, even children as young as ten, have proved capable of grasping how medical imaging technologies work. Moreover, the rate of success with the diagnoses has been rather high. What about the tricky cases? Yes, the public has proved capable of ferreting out explanations that require creative extrapolation. Even relatively young visitors have proved able to make logical deductions from the data, critiquing their solutions and looking for hypotheses that better explain the patients condition. So far, this would appear to confirm that our visitors are capable of creative scientific thought, of Einstein's invention.

Two factors seem to increase the success of the visitors.

First, the better they understand the principles of the technology, the more confident they feel about their conclusions. Indeed, those who skip the introductory tables rarely grapple effectively with the case studies. This, we would argue, represents a step forward from science exhibits that encourage exploration without reference to established scientific knowledge.

Second, we have found that families, or groups of students working together, have particular success in solving the complex cases. It seems that group members encourage one another to seek new solutions. But this should come as no surprise to those who recognise the central importance of discourse in the doing of science.

To conclude, in this paper we argue that, if seen as part of a spectrum in which revelation and invention form a pair, and appear in different measure according to the activity, interactive science centres, while not denying the importance of epiphany, must strive to communicate the importance of the activity of science, of creative thinking, of the scientific invention that characterises Einsteins and Feynmans, and that is so needed if the next generation of scientists is going to rise to the challenges of the next century.

Now, more than ever, we need to move towards a museology of invention, a museology that not only recognises the activity of every visitor to the science centre, but gives to them a determining role in the creation of scientific understanding, and a means to recognise for themselves the creative act. A museology of invention must swallow and amplify the museology of revelation that has preceded it, just as the quantum physics of Einstein and Feynman swallowed, amplified and built upon the physics of Newton and Mach, giving all of us shoulders on which to stand and invent a scientific understanding.

In an address to delegates at this year's ASTC conference in Toronto, Dr. Neil Postman, author of the book Amusing Ourselves to Death, told North American science museum professionals that it was their task to provide new grand narratives, in the manner of the medieval church, as a means of combatting the surfeit of information that renders our visitors powerless. We would suggest that, on the contrary, our role is not to pursue this museology of revelation, in which are charged with providing a new revealed religion to comfort our flock from the pulpit of science. Instead, we suggest that we promote a museology of invention, a museology which empowers the visitors, encourages their creativity and endorses their intelligence and competence to be actors in a technologically complex world, to be generators not just receivers of new knowledge.