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Fields of Knowledge: Harvesting Scientific Understanding

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prepared by James M. Bradburne and Drew Ann Wake

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Just over one year ago, the Science Museum in London hosted a conference on the Policies and Publics for the Understanding of Science and Technology. Participants came from all over the world, and the debate was informed, thoughtful, and restrained. Beyond the restraint, however, a fundamental contradiction that hovered over the delegates.

Ranged on one side were a group of international scholars responsible for what have been called scientific literacy studies. These studies share one point of departure: they seek to define the level of scientific literacy among the general public. In most of these studies, scientific literacy is defined by three measures.

1) The subject must know the correct answer to a group of questions stemming, in the main, from the disciplines of physics, chemistry, geology and biology;

2) the subject must answer a group of questions about the scientific process; and

3) in some cases, the subject must answer questions about the ways science and technology have an impact on everyday life.

This general methodology was followed, with roughly the same questions, in studies in Canada, the United States, Britain, France and Japan. And everywhere the results made headlines. It was discovered, with some shock, that only 5.6% of American adults and 7.1% of

British citizens met all of the criteria for scientific literacy. All over the Western world, reviewers recoiled from the inevitable conclusion: "Good Lord, we are a nation of idiots!"

Let us examine the beliefs of the science literacy school more closely. The enthusiasts make two assumptions. In the first place they assume that science is a consistent body of information which can be held to be universally true. Thus Durant et al have written "Science is an enormous and enormously complex body of knowledge. Much of this knowledge is essentially unproblematic, in the sense that all competent experts agree about it..."

From this immense body of scientific knowledge, the science literacy experts extract certain facts that they identify as fundamental to the thinking of any informed citizen, and these facts become an intellectual yardstick by which the people of any nation can be measured. "We wish to discover how much science people know, and how far their beliefs may differ from formal or official science.", writes Durant. "In neither case do we see how this can be done without forming some estimate of people's understanding against the bench-mark of science itself."

The universal standard can be a harsh judge of the public understanding of science. Like the stern schoolmasters of old, it delivers only a pass/fail verdict. There are no extra marks for creativity. There are no indulgent smiles for a keen grasp of, for example, Early Cretaceous invertebrate paleontology. For the science literacy specialists, to fail the test is to fall below the minimum standard of a scientifically-aware citizen. One of the leading exponents of this approach, Jon Miller of the Public Opinion Laboratory at Northern Illinois University, commented "I doubt that anyone would argue that a citizen who failed the minimal set of items included in this measure would be very effective in following major issues in science and tehcnology."

However, some of the scholars at the London conference did argue just that. Dr. Brian Wynne, the Director of the Centre for Science Studies and Science Policy at the University of Lancaster, set out a body of data that was sharply at odds with the science literacy school. Dr. Wynne and his team of researchers had interviewed

sheep farmers in the Cumbrian highlands after their farms were closed in the wake of the disaster at Chernobyl.

They found that the farmers possessed a great deal of scientific information about issues in their own realm of experience, such as the science and economics of sheepfarming. Moreover, this expertise was sometimes at odds with the advice of the government appointed scientists who were sent out to 'enlighten' them. Dr. Wynne's evidence indicated that the scientific approach of the sheep farmers may be "less generally authoritative, but was more specifically accurate" than the information of the government scientists.

At the end of his study, Dr. Wynne concluded that members of the public do not experience scientific information separate from the knowledge or expertise they have in other areas of their lives. Quite the opposite, they actively blend old and new information to construct a fresh scientific understanding. To describe this process, we might make use of the metaphor of uncorking a bottle of champagne. Like carbon dioxide dissolved in the bubbly, the scientific understanding of members of the public is invisible - until the moment that the knowledge is required to cope with a set of real life experiences. In the case of the Cumbrian sheep farmers, their understanding of the science of sheep farming and nuclear physics came to a head when the disaster at Chernobyl forced the closure of their farms.

Underlying the work of Dr. Wynne and his collegues is an assumption about the nature of scientific understanding that is sharply at odds with the views of the science literacy school. Dr. Wynne describes scientific understanding as both circumstantial and social.

The implication of this view is that a scientifically literate society seeks citizens who can make reasoned and intelligent decisions by weighing a variety of factors. Some of these factors are scientific and technical, others may be social, economic or political. A conclusion that holds in one set of circumstances may be invalid in another place at another point in time. Thus, the validity of any particular conclusion cannot be measured on a single scale. This suggests that the conclusions of science may be universal, but scientific understanding is not. The public understanding of

science is complex and mutable: changable and changing.

And so, throughout the London conference, scholars debated two sharply conflicting ideas of the public and its understanding of science. In the view of the science literacy school, the public is passive, often unable to capture the body of scientific information required to construct an intelligent opinion about issues. The other view suggests that average citizens are able to to grasp, build and manipulate complex ideas - especially when they pertain to a subject that is important to their own survival, or the survival of their community.

Now this debate is not merely an academic argument, to be hung out on the clothesline every time an international conference is held. On the contary these assumptions are critical because they affect the course of action that is to be taken to produce a broader public understanding of scientific issues.

If the science literacy school is correct, and there are certain facts that must be understood in order to produce a population comfortable with science, then we must develop programmes that will diffuse this knowledge more effectively throughout the population. And by and large, this process of diffusion must take place from the top down. The haves must provide to the have-nots.

If, however, we believe that our citizens are already equipped with ideas and information, curiosity and skills, then our goal must be to enhance and encourage their experiences. We must find ways to uncork the champagne, so that people explore and share the ideas that are already important to them. This is, by its nature, a grassroots process, in which the energy explodes from the bottom up. The public determines the topics that should be explored. The public charts the direction of the exploration.

So much for theory, what about practice? For the last two years, we have had the opportunity to work as consultants on a project designed to increase the public understanding of science in the province of Alberta, in Western Canada. Before we describe our work, let us digress for a moment to tell you about the Science Alberta Foundation and its mission.

Of all of the provinces of Canada, Alberta has a particularly strong background in the fields of science and technology. It is the home of Canada's oil industry and thus has the highest proportion of geologists and engineers in Canada. The City of Calgary, moreover, has the highest per capita income in the country, a reflection of the benefits that have accrued from oil and gas in this energy-conscious era.

But Albertans are aware that this boom will not last forever; the province's energy resources are now declining. If we are to survive, new economic generators that will have to be found to sustain the province through the next century. No one is more aware of this than James Gray, the Executive Vice President of one of Canada's most innovative, home-grown oil and gas companies. In 1989, Mr. Gray announced the formation of the Science Alberta Foundation, with the mandate to raise the level of public understanding of science and to encourage more young people to consider careers in science and technology.

In the beginning, the Foundation's emphasis was on building a network of new facilities for communicating science information. In his opening speech, Jim Gray announced:

"We can build an integrated network of science centres. We can build large centres in the cities of Calgary and Edmonton, and satellite centres in Northern and Southern Alberta. We can exchange exhibits, construct joint exhibits, book lecturers and scientists. We can deliver exhibits and programmes to small communities in rural Alberta."

This was, by definition, a top-down idea that shared some of the assumptions of the science literacy school. The large urban museums and science centres would develop travelling exhibitions and circulate them through smaller communities in the province, thereby introducing all Albertans to new ideas in science and technology. The network was to be centralized and dependent on the skills of a small group of professionals who would select the relevant science information and prepare for an audience of non-scientists. At the time, none of us imagined how dramatically our ideas would

change.

The first surprises came as the result of a survey that we conducted to help us to evaluate the audience for the science programmes that would be shipped around Alberta. In conjunction with the Coopers and Lybrand Consulting Group, we designed a telephone survey destined to reach almost a thousand Albertan homes. Our questions were designed to evaluate what science subjects Albertans find interesting, and to identify the science-related activities Albertans engage in, and with whom.

As soon as we made the first cut of the data, it was evident that we were not looking at an audience that was unified either in terms of interests or behavior. The profiles of our four basic audience groups - rural men, rural women, urban men and urban women - suggested that each segment was going to make very different demands on our science network.

Let us briefly cite some of the results. Both urban and rural men show a high interest in science, and particularly in the pure and applied sciences. Physics, chemistry, engineering and computer science get a high positive response. Men, and particularly urban men, are the least interested in medicine and biology. Women on the other hand, in both urban and rural areas, tally a high interest in biology, medicine and the environmental and social sciences. In the hard and applied sciences, however, women show considerably less interest.

This data suggested to us that both men and women in Alberta are enthusiastic about science, but they frame their enthusiasm in markedly different ways. Indeed, when we looked at the overall results for men and women, their reponses were so distinct that we wondered how an Alberta marriage stays together. What do they talk about over dinner?

Similarly, there were marked differences between our urban and rural audiences, consistent with Brian Wynne's suggestion that people develop an interest in science subjects that affect their social, political and economic lives. Albertans living in rural areas show much greater interest in subjects like agriculture, forestry, conservation __ and the weather.

By the time we concluded our survey, it was becoming clear to us that we could not create the top-down, centralized science network that we had originally outlined. We could not treat all Albertans as an undifferentiated mass. What was interesting to one Albertan was clearly dead boring to his neighbour __ or his wife. Moreover, the differences between rural and urban Albertans would make it impossible to develop exhibits in the city and send them off to be appreciated by farm families. Scientists may see science as a consistent body of verifiable knowledge, but the public sees science as a smorgasbord, to be sampled according to one's own inclinations.

Our database received dramatic confirmation when we visited communities throughout the province to test the concept of a science network. Everyone we spoke to - town councils, womens' organizations, student groups - used the opportunity to tell us that their concept of a science network was very different from our own.

Let us take a moment to tell you about our meeting in Drumheller, a town of three thousand that lies over an hour from the nearest large city. There we met with a group of citizens representing a broad spectrum of civic organizations, both scientific and non-scientific. They told us in no uncertain terms that the concept of a top-down network based in the cities would not meet their needs. They had one point to make, and it was a political one: The people of Alberta want to be generators, not receivers, of scientific education. They want to decide what ideas should be communicated and how they should be communicated.

To prove their point the took us out into the harsh and exquisite terrain of the Western badlands, showing us how the dramatic stratigraphy forms a timeline through millions of years of geological history. We visited the magnificent bonebeds where paleontologists are piecing together the flora and fauna of the Cretaceous period. We scrabbled down into abandonned coal mines and tramped over terrain that illustrated seven separate ecological regimes in as many miles. And we were convinced: the people of Drumheller had their own unique science story to tell.

On our return to the city, the Board of the Science Alberta Foundation reviewed our data, and made three

decisions that stood the original concept of a centralized, top-down science network on its head.

1. First, the Board decentralized the political control of the network. Board members abandonned the notion of a network based in one or two cities, and began to encourage the development of small, regional science councils run by local enthusiasts. The first of these councils was set up in the district of Vulcan, where five farm villages banded together.

2. Secondly, the Board deinstitutionalized the network. Rather than using its funds to establish a network of museums and science centres, the Foundation decided to make a large proportion of its funds available to community organizations, so that they could develop exhibits and programmes to meet the needs and interests of local people. Correspondingly, the emphasis has shifted from constructing a few large buildings to using left-over space in existing buildings all over the province: the corner of a public library, an empty storefront, even, in one case, an abandonned aircraft hangar.

3. Finally, the Foundation deprofessionalized the network. The Board dispensed with the assumption that only experienced scientists, science educators and exhibit designers could create the high quality materials that a provincial network would require, and began to actively develop programmes that will allow citizens from every walk of life to build science exhibits and programmes.

Overnight, the emphasis shifted from top-down, to bottom-up. In effect, the Foundation threw down the gauntlet: if the communities insisted that they were able to develop public science programmes as well as the professionals, they would have the opportunity to prove it.

Now, to be frank, the idea of a grassroots movement for science education caused some consternation in the museum and science centre community. Even we occasionally worried that we were theorizing our way out of the most interesting work we had ever had. But there were no such concerns at the community level, where individuals and groups organized themselves to take advantage of the Science Alberta Foundation's

programmes. We would like to take a few moments to discuss some of the most unusual and exciting of these initiatives.

1. The Matchbox Science programme challenges every child enrolled in junior high school in Alberta to develop a science experiment or exhibit that can fit into a matchbox. To date, a number of young people have developed interesting solutions to the problem. One young person put an egg in the box, with instructions to squeeze the egg as hard as possible. Why doesn't it break? It is a simple experiment, and vastly cheaper than most of our professionally-designed exhibits.

At the end of the year, the top forty Matchbox experiments will be cloned and distributed to schools and libraries throughout Alberta, the first step in what we hope will be a provincial hands-on science collection. In effect, the young people of the province are becoming experienced exhibit designers, responsible for communicating what they have learned to future generations.

2. The Science-In-The Streets programme offers grants of up to $10,000 for the development of interpretive programmes that use the unique resources of a region of the province. This programme has stimulated a wide range of responses. In the west, a group of retired coal miners are reopening an abandonned coal mine, so that they can explain hard rock mining technology to young people. In the east, a group of farming villages have banded together to put on a science summer festival. In addition to demonstrations and displays, each participating family will be given two weeks to solve a scientific challenge. One of the rules states that every team must include one person under the age of five.

The importance of these initiatives is twofold. First, by requiring communities to use existing resources and local volunteers, the programme encourages self-reliance. Science education is not something you import, it is something you create. Secondly, by forcing communities to set their own priorities, the grants stimulate co-operation between organizations. Recently, three rival environmental organizations submitted a joint proposal for a nature walk that will link to the community school.

3. The Networks Programme offers up to $50,000 for the development of innovative approaches to a province-wide science network. These grants are a challenge, because they force communities to think of opportunities that will benefit not only the immediate area, but the people of the province as a whole. In the far north, for example, where one community can lie hundreds of miles from the next, ten small towns have banded together to build a mobile science laboratory that will travel to schools, industries and wilderness parks. This is a flexible facility that will allow each community to investigate science subjects that are pertinent to its surroundings.

Another initiative: the farm wives of Alberta have created a network of ranches and farms that will educate city children about life on the modern farm. And this goes beyond petting geese. The city kids are expected to tramp through the fields running experiments on soil conservation, pesticide control and water quality. These farm wives want to foster a new appreciation of the complexities - scientific, technological and economic - of high tech farming at the end of the twentieth century.

And what about the citizens of Drumheller? They have designed a science summer camp. Young people will be bused in from all over Alberta to spend a week studying the geology, paleontology and ecology of the badlands. And in their usual feisty way, the people of Drumheller informed the Science Alberta that if they do not receive Foundation funding for their idea, they intend to build the camp anyway.

From our perspective, there is one startling aspect to these projects. They are unique to their time and place. Not one is the kind of educational experience you would see in an urban science centre. Not one community, for example, found itself in desperate need of a Bernouilli Blower or a Van der Graaf generator.

Instead, these programmes pose "real life" questions. Unfailingly, they integrate several scientific disciplines, they pose dilemmas that are economic and political. Community people may not be interested in the raw facts of science, but they are acutely interested in the way science meshes with their everyday lives.

So what have we learned in a year and a half?

First, we have learned that people have widely differing interests in science and technology depending on their gender and the region in which they live. These differences must taken into account as part of any programme for delivering scientific and technological information.

Secondly, we have learned that experience gives people an authentic and legitimate understanding of particular domains in the realm of science. This experience should be recognised and encouraged as the foundation of an enriched scientific and technological culture.

At the present time we are exploring ways to take this idea one step further, to examine if people learn best when knowledge is embedded in a context is relevant to their experience. We believe that the appropriate context may demonstrate an active ability to exercise the skills we normally associate with a scientific approach: abstract thinking, deduction from hypotheses, and the testing of alternatives.

Finally, our experience in Alberta has raised questions that are profoundly political in nature. To discuss scientific knowledge is to raise the issue of who has the right to produce this knowledge. The science literacy school suggests that the path to scientific knowledge is the official one of schoolrooms, universities and laboratories, and that only the elect, clad in the labcoats that are the alb and chasuble of the ordained scientist, have the right to affirm scientific knowledge.

The Alberta experience, on the other hand, suggests that there are other paths to scientific knowledge, that people absorb scientific information through their work and their neighbourhood. The people of Alberta would assert that this knowledge gives them the right, even the duty, to become full-fledged partners in the communication of science.