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LESSONS IN LEARNING

Informal science learning in Canada

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"Without a scientifically literate population, the outlook for a better world is not promising."

—Art Hobson

Science is playing a growing role in public policy and in the daily lives of most citizens. As a result, science literacy skills are becoming increasingly important. A scientifically literate person understands basic scientific concepts, is aware of the strengths and limitations of the contemporary practice of science, and can access and evaluate science-related information.

Governments and individuals alike must grapple with complex issues such as global warming and stem cell research. Consumers must try to make sense of the allegedly scientific claims of advertisers, and patients face a dizzying array of treatment options. In short, most people confront science-based issues on a regular basis, and scientifically literate individuals are better equipped to engage with these issues and make important decisions that affect their health, security and economic well-being.[1]

By international standards, Canadian schools are doing an exceptionally good job of teaching science to Canadian youth. On the science portion of the most recent Programme for International Student Assessment (PISA) examinations, 15-year-old Canadians scored well above the average scores for the 41 developed countries that participated in the testing—and were outperformed only by students in Finland, Japan, China and Korea.[2] Despite these promising signs of competence in science among Canadian youth, Canadian adults appear to be struggling with scientific literacy. In international comparisons, researchers have estimated that fewer than 20% of Canadian adults can be described as scientifically literate.[3,4] As well, the results of the 2003 Adult Literacy and Life Skills Survey (ALL) indicate that fewer than one-third of all Canadians aged 16 to 65 have the analytical reasoning skills considered to be at the "desired threshold for coping with the increasing skill demands of a knowledge society."[5]

The Programme for International Student Assessment is an OECD (Organisation for Economic Co-operation and Development) survey of 15-year-olds conducted every three years in 41 industrialized countries. PISA is designed to determine whether students in these countries are well prepared to meet the challenges of the future as they reach the end of their compulsory education.

It is unclear why Canadian adults struggle with scientific literacy despite the strong scientific competence demonstrated by younger Canadians. It is possible that older Canadians did not have access to the same quality of science education as do young Canadians today, or that the science knowledge that students acquire in school does not effectively translate into science literacy. Some argue that in addition to the current science course offerings, which are primarily intended to prepare the next generation of scientists and engineers, there is a need for a separate stream of courses to prepare the next generation of scientifically literate citizens.[6] This approach may prove successful over the long term, but what steps can be taken to improve science literacy more immediately? In order to answer this question, it is useful to first understand why science learning is so challenging for so many people.

Why is learning science difficult?

"In order to switch from everyday perspectives of phenomena to a scientific understanding of those phenomena, the science learner has to restructure prior conceptions."

—Shelagh Ross & Eileen Scanlon

Many people argue that science is difficult to learn. One cause may be that the acquisition of science knowledge is often symbolic, abstract and counter intuitive, unlike the acquisition of everyday knowledge, which is usually pragmatic, personal and based on experience.[7]

The relationship between the sun and the Earth provides an illustration of the difference between everyday knowledge and scientific knowledge. Children see the sun rising and setting and develop a mental model of the sun travelling around the Earth. Once this mental model has been firmly established, children are taught in school that the Earth travels around the sun. This leaves children in a difficult position: in order to grasp the concept of the Earth moving around the sun, they need to accept that their own observations of the movement of the sun do not reflect the true nature of the relationship between the sun and the Earth. This task is not trivial. Students must undo a whole mental framework that they have used to understand the world. The effort to accept increasingly complex scientific knowledge that is often counter intuitive can discourage and eventually alienate students from the study of science.[8]

A person's prior knowledge can be an impediment to understanding science concepts when commonly-used words such as "volatile"—often associated with an unstable, hostile political situation—are used to describe scientific processes like evaporation. Words like "DNA fingerprint" and "mass" carry everyday meanings that conflict with their scientific meanings.[9] Many studies have identified these alternative meanings as a major hurdle in the process of learning science.[10]

Lessons in learning: Increasing science literacy among adults

Addressing the need for increased scientific literacy among Canadian adults will require an approach that is both accessible to adults who are no longer in school, and alleviates at least some of the challenges to learning science outlined above. The concept of free-choice science education can help to address both conditions.

Free-choice science learning is a form of non-sequential, self-paced and voluntary learning "that is guided by a person's needs and interests."[11] Free-choice science learning complements the compulsory, formal, curriculum-driven education system used in most schools, colleges, universities, and even in many workplaces. Examples of free-choice learning activities include: watching a science documentary on television; listening to radio programming (like CBC Radio's science show Quirks and Quarks); visiting a science centre, museum, zoo, aquarium or nature centre; or attending a public lecture on a scientific topic.

Building motivation

Free-choice learning is based on curiosity and motivation. In a free-choice activity, the outcome of the learning experience provides the motivation for a person to rethink his or her current ideas. For example, if Judy listens to a radio program and becomes intrigued by the debate about organic foods and genetically modified organisms (GMOs), she may decide to visit an exhibit on GMOs at the local science centre, pick up a magazine featuring a GMO article on its front cover, or watch a television documentary on the subject. This series of free-choice learning experiences is intrinsically motivated and provides sufficient reward to learn or relearn the science concepts involved.

Reinforcing understanding in many settings

Learning is most effective when new concepts and meanings can be built on previous experience and knowledge. Free-choice learning provides the opportunity for families, adults and school children to engage with scientific concepts, relating the concepts to everyday life and thereby enabling continual construction and reconstruction of knowledge. Consider for example, GMOs. A learner needs to construct many underlying concepts to understand GMOs. News reports and documentaries may provide an initial conceptual framework. An exhibition in a science centre can provide a venue to engage with the concept on a variety of levels, increasing the opportunities to build and reconstruct the meaning of genetic modification. Social interaction with friends, peers or family members further develops understanding through conversations and dialogue.

An audience-friendly connection to science

Science is often presented as "a consensually accepted body of knowledge."[12] People may be alienated from the study of science when they feel they are expected to accept conclusions without understanding the research and underlying evidence. The process of science inquiry is often remote from people's experience. The fact that much of our science knowledge is based on apparently conflicting interpretations—different assumptions and data that is collected in different ways—can contribute to a sense of confusion and alienation about science. Free-choice education settings, which will only survive if they are chosen by their intended audience, have to design their communication in a way that works for the audience.

Is free-choice science learning effective?

John Falk, who has devoted many years to the study of learning in free-choice learning settings, notes that: "Science is not easily confined to school hours and years. Both the process and content of science is ever changing. Because of this constant, in fact ever accelerating, rate of change, science is a subject that requires a lifelong commitment in order to remain literate and current."[13] Science learning continues into adulthood through museums and science centres, books, the Internet, the media, and through conversations with family, friends and colleagues in the workplace. These resources can offer an informal infrastructure of lifelong, free-choice science learning opportunities.[14] These experiences allow people to have contact with developments in science and build the knowledge and attitudes they bring to their role as citizens. But are these experiences effective means of developing real science literacy?

Unlike the formal school system, free-choice learning does not occur within a set curriculum against which knowledge acquisition can be measured. Although it is very challenging to measure the direct results of free-choice science learning experiences, progress is being made in assessing learning that is derived from experiences in science centres and museums.

The traditional view of learning sees it as the acquisition of facts or knowledge within formal educational contexts. Consequently, free-choice learning institutions like museums, science centres and libraries are often "seen as offering something that is not learning."[15] However researchers, educators and learning experts are beginning to agree that learning is a series of complex, lifelong processes which are greatly influenced by the social experiences of the learner. In order to understand and assess learning, it is important to consider the learning process, not simply measure the outcomes.[16]

Efforts to understand the learning process have led science centre researchers to look for evidence of learning beyond the usual measure of cognitive gains or an increase in knowledge and facts. Assessments of the learning experience in science centres and similar institutions show that visitors engage in activities and behaviours that lead to learning. For example, Minda Borun has studied learning among visitors of the Franklin Institute Science Museum and has shown that families visiting science museums engage in activities such as identifying, describing, interpreting and applying, all of which demonstrate learning.[17] Others have shown that people draw on their prior knowledge and personal experience to understand an exhibit, and to some extent, to understand the underlying scientific model of that exhibit.[18]

An example of behaviours that indicate learning and of how family interactions enhance learning.

The Naked Mole Rat exhibit. Visitors can see the rodents through Plexiglas windows in the underground tunnels in the soil of the exhibit. The surroundings contextualize the animals in their natural setting, an African scene.

Learning Level 1: Identifying

"They're mole rats" (adult male)

"That's a baby one, mom" (girl, age 9.5)

Learning Level 2: Describing

"It makes them look like they were just born a couple of minutes ago." (Boy, age 9)

"It reminds me of other animals that live underground" (adult male)

Learning Level 3: Interpreting and Applying

"The lifestyle…they're a colony, like the bees you learned about last night." (Adult female)

"It kind of reminds me of what people do when people try to get in front of each other. Because, like rats, we're dragging each other back by the tails..." (Boy, age 12)

Borun's analyses of family conversations during science museum visits suggest that "the individual's learning experience is enhanced and shaped by input from other family members. Families have a culture of shared knowledge, values and experiences. A family group that visits a museum can enrich its culture, storing knowledge for later sharing."[19] When researchers at a marine science centre looked at questions used by parents during interaction with their children, they found that children of parents who invited dialogue and reflection with open-ended questions learned more and had a more sophisticated understanding of science than children of parents who did not use open-ended questions.[20]

Great strides have been made in understanding and assessing the impact of science centre experiences on visitors' learning of, and engagement with, science. This research is still in its infancy. There is a need for further investigation of the value of such experiences in influencing the public's understanding and engagement with science.

Developing and maintaining a scientifically literate population is increasingly important in today's knowledge-based society. An effective free-choice educational infrastructure could make an important contribution to improving science literacy. Given the low level of scientific literacy in Canada's adult population, it would be valuable to build a more comprehensive understanding of the impact of free-choice science learning in order to improve these opportunities and experiences, and ensure that they are accessible to all who wish to engage in free-choice science learning.

Information on a range of free-choice science learning options can be found at:

www.canadiansciencecentres.ca
www.astc.org
www.azaorg
www.ecsite.org/new

List of science centres across Canada in alphabetical order

ASTROLab du MONT-MEGANTIC, Notre-Dame-des-Bois, QC
Boîte à science, Québec, QC
Bow Habitat Station, Calgary, AB
Camp spatial Canada, Laval, QC
Canada Science and Technology Museum Corporation, Ottawa, ON
Canada South Science City, Windsor, ON
Canadian Museum of Nature, Ottawa, ON
Canadian Petroleum Discovery Centre, Devon, AB
Canadian Space Resource Centre, Toronto, ON
Centre of the Universe, Victoria, BC
Discovery Centre, Halifax, NS
Doran Planetarium, Laurentian University, Sudbury, ON

Johnson GEO CENTRE, St. John's, NL
La Biosphère, Environment Canada, Montreal, QC
London Regional Children's Museum, London, ON
Manitoba Children's Museum, Winnipeg, MB
Manitoba Museum, Winnipeg, MB
Markham Museum & Historic Village, Markham, ON
Montreal Science Centre, Old Port of Montreal, Montreal, QC
Musée Armand-Frappier, Centre d'interprétation des biosciences, Laval, QC
Musée de la nature et des sciences, Sherbrooke, QC
Musée du Fjord, La Baie, QC
Newfoundland Science Centre, St. John's, NL
Northern Lights Centre, Watson Lake, YK
Oak Hammock Marsh Interpretive Centre, Stonewall, MB
Oil Sands Discovery Centre, Fort McMurray, AB
Okanagan Science Centre, Vernon, BC
Ontario Science Centre, Toronto, ON
Pork Interpretive Gallery, Saskatoon, SK
Planétarium de Montreal, Montreal, QC
Saskatchewan Science Centre, Regina, SK
Science Alberta Foundation, Calgary, AB
Science East, Fredericton, NB
Science North, Sudbury, ON
Science West Inc., Saskatoon, SK
Science World at TELUS World of Science, Vancouver, BC
Telephone Historical Centre, Edmonton, AB
TELUS World of Science Calgary, Calgary, AB
TELUS World of Science Edmonton, Edmonton, AB
The Exploration Place, Prince George, BC
Waterloo Regional Children's Museum, Kitchener, ON

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