Bridging the Gap or Building Bridgeheads?

The Equivocal Position of Scientific Literacy in North-South Dialogue

by Marilyn Mac Donald

L'auteure explore les concepts du savoir scientifique et démontre son importance pour les femmes du Nord et du Sud.

I should forewarn you that this is a speculative paper, an exploration of the teaching of the natural sciences, in both their pure and applied forms. It is about what Lemke has referred to as *talking science:*

> helping to create, or re-create, a community of people who share certain beliefs and values.... Every scientific statement we make, every scientific argument, and all our reasoning as we do science are instances of talking science ... marshalling the semantic resources of a powerful and specialized way of talking about the world. (x-xi)

The increasing acceptability of scientific literacy as a measure of governmental commitment to both the empowerment of the marginalized in human societies, and the protection of the environment is worrisome.

It is also about a constructivist approach to the teaching of such science, the assumption that no learner is a *tabla rasa*, but rather (as Magoon, in 1977, was one of the first to suggest) that each is a "knowing being," for whom learning both involves the ongoing organization of a complex set of concepts and relationships, and is consequential in behaviour and production of meaning. But it is also about the flip side of the bulk of constructivist research, research which has centred on either the uncovering of student misconceptions, inconsistencies, and lack of systematization, or the development of tools and techniques as correctives (Cheek). Why we do not know more about the reverse relationship? How does learning, or nearly learning, to talk science affect our other-talk—that of the everyday—and, consequentially, our sense of agency, of self-esteem, of probable effectiveness, of legitimacy and of connection? Who, as Godway and Finn put it, does this "we" become in possibly conflictual conceptualizing/idealizing of community?

To explore such consequences from the teaching of the natural and applied sciences, I suggest that we could consider a small part of the scientific process—the conveyance of novel concepts through the use of metaphor—and the ways in which such metaphors, when borrowed from the colloquial, are appropriated into the language of science. My contention is that such metaphors, represented as bridges of understanding between the novice learner and an apparently progressive, transcendent, and effective body of scientific/technological knowledge, might more properly be considered as bridgeheads. That is, the options are limited for learners whose conceptions have been invalidated by scientific terminology—reject their own/accept the scientific or vice versa, amalgamate the conceptions, or reject both while either searching for an alternative or accepting confusion and frustration (Cheek). To the extent that they are unexamined incursions of worldviews of dominance, accepted in whole or in part, such metaphors both serve as boundary markers between professional and charlatan, and render unstable the beliefs and values which might oppose them.

Finally, I contend that the increasing acceptability of scientific literacy as a measure of governmental commitment to both the empowerment of the marginalized in human societies, and the protection of the environment is worrisome. For example, it may behoove those of us who are involved in, or support, efforts to get women "into" the existing framework of natural/applied science to go that further step, to consider what might happen if we succeed (Boneparth; deCastell; Franklin; Nelson and Chowdhury).

Scientific literacy: the quest for an equitable Grail

In 1996, the Gender Working Group (GWG) of the United Nations Commission on Science and Technology (UNCST) recommended for adoption by all countries of the world a Declaration of Intent on Gender, Science, and Technology for Sustainable Development. The six goals of this Intent included:

> (1) basic education for all, with particular emphasis on scientific and technological literacy, so that all women and men can effectively use science and technology to meet basic needs;
>
> (2) equal opportunity to acquire advanced training in science and technology and to pursue careers as technologists, scientists, and engineers;
>
> (3) gender equity within science and technology institutions, including policy- and decision-making bodies;
>
> (4) equal consideration of the needs and aspirations of women and men in the setting of research priorities and in the design, transfer, and application of new technologies;
>
> (5) equal access to the information and knowledge,

particularly scientific and technological knowledge, that they need to improve their standard of living and quality of life;

(6) recognition of local knowledge systems, where they exist, and their gendered nature as a source of knowledge complementary to modern science and technology and valuable for sustainable human development. (Gender Working Group)

This Declaration of Intent seemed to be a clear sign of the confluence of what had, from the late 1940s until the late 1980s, been two separate streams of activities at the UN, namely the conservation of environmental resources, and the achievement of full and equal rights for women and men (McCormick; Pietila and Vickers; Winslow). As such, it represented an end to a dissociative framework in which it had been possible to consider limitations to women's rights to informed participation in family planning in the interest of the global environment, while at the same time sponsoring environmentally-destructive structural readjustments in order to stimulate economic growth in the trickle-down interest of the global sisterhood of man. And the Intent appeared to have, in scientific literacy, something which would both empower women from North *and* South (since under ten per cent of the populations of industrialized, and under one per cent of those of developing countries were likely to be scientifically literate) (UNDP), and be acceptable to the majority of country delegates attending UN Conferences, particularly as a nonbinding commitment (see, for example, Chapter 24.3 (c) of *Agenda 21* (Capeling-Alakija) or Strategic Objective K.2.256(h) of *Platform for Action* (Fiol-Matta). What is scientific literacy, to be so unproblematic?

It had been possible to consider limitations to women's rights to participation in family planning in the interest of the global environment, while sponsoring environmentally-destructive structural readjustments to stimulate economic growth.

Scientific literacy, like the wider idea of literacy from which it derives, is linked to such concepts as career potential, effective citizenship, and everyday coping (National Research Council; Roberts). It implies a threshold measure, some minimal collection of text-based communicative skills, knowledge, and attitudes considered necessary to function within a culture. To that extent, it is a moving target, adjustable to particular roles, societies, and cost/benefit analyses. This collection would include:

(1) a basic vocabulary of scientific and technical terms and concepts, (2) an understanding of the process or methods of science for testing our models of reality, and (3) an understanding of the impact of science and technology on society. (Miller 187)

And, in the majority of cases (e.g., Rosier and Keeves), the science in scientific literacy continues to refer to physics, chemistry, biology, and earth/space studies (e.g., geology, geography, astronomy, meteorology), and not to the social sciences (e.g., psychology, sociology, anthropology, economics, archaeology). This is a surprising blindspot, given the purported emphasis on science, technology, and society (e.g., Bybee; Cheek; Solomon and Aikenhead), but perhaps less incongruous if one bears in mind professional territorialities and boundary work (e.g., Abbott; Claeson *et al.*; Geiger; Mac Donald; Porter; Rossiter 1982, 1995).

Scientific literacy, generally measured by written responses to short-answer or multiple choice questions such as "_____ is the blueprint of life," is strongly correlated with level and content of education. For example, in a U.S. study, for a group of people whose highest level of education was high school or less, and/or who had taken one or fewer high school or college science and/or mathematics courses, the scientific literacy rate was at or below three per cent. However, even for a group of those who had taken nine or more science/mathematics courses, this rate only rose to 24 per cent (Miller). Thus, scientific literacy seems to present a solvable problem (given curricular and resource adjustments) with immediate and positive social returns (e.g., economic growth, healthy and safe households, and a trained labour force with supportive attitudes towards technological progress). And governments, in conjunction with teachers' and scientists'/engineers' associations, non-governmental social justice organizations, and education researchers, have indeed tried a number of innovative approaches at both the national and international levels to increase scientific literacy (e.g., American Association for the Advancement of Science; Black and Atkin; Dufour and de la Mothe; Gender Working Group; Keeves; McGinn and Borden; National Research Council; Rosier and Keeves).

So, assuming that governments live up to the promises of the United Nations Conference on Environment and Development (UNCED) and the United Nations Conference on Women (UNCW), how can learning the basic vocabulary, the process and methods, the social impacts of science (even given the omission of the social sciences) be other than empowering for women?

Metaphor and understanding: the difficulty of translated meaning

Metaphors, like similes, analogies, and irony, are part of figurative language, in which a word or phrase is used intentionally in other than its proper (literal/essential/primary/common/current) meaning. Such usage is often intended to fill a semantic void, to destroy old meanings in order to build new ones, to rely on context and the willingness and capability of those receiving the figurative message to extract the pertinent resemblances which vitalize the substitution (Lakoff and Johnson; Mio and Katz; Ricouer).

From (at least) the late 1500s, with Francis Bacon's inclusion of analogy in his formulation of a scientific method, to the present, figurative language has been a necessary (albeit occasionally disreputable) part of scientific knowledge creation (Gramm; Hesse; Koestler; Sontag; Tauber). As Leatherdale argued in relation to the Lavoisiers' (note: I am assuming that he was referring to both Antoine and Marie) late-1700's recognition of the parallel between the burning of a candle and the breathing of a mouse:

The use of discriminatory metaphors to convey scientific concepts has put in question the objectivity of some aspects of the physical and life sciences. In addition, metaphors may obscure or trivialize essential dissimilarities.

> the analogical act in fact probably usually achieves a strategic formulation of some key laws and/or facts into an ordered relation, like an invading army subjugating capitals and major towns and leaving the subjugation of the provinces until later. (17)

Examples of scientific metaphors include the heart as a pump, the atom as a solar system, and the geographical co-occurrence of plants, animals, and microbes as a community (I will discuss this last example below) (e.g., Glynn and Duit; Glynn *et al.*; Hesse; Hoffman; Kittay; Lakoff and Johnson; Pickering; Tauber; Van Noppen *et al.*).

Katz found that scientists were considered eleventh out of 32 occupations for likelihood to use metaphor, just below artists, poets, clergy, actors, literary critics, salespeople, politicians, political critics, writers, and professors. However, they were considered the least likely to use irony (just below doctors and judges), perhaps reflective of perceived occupational commitments to truthfulness and/or objectivity (and possibly reflective of how widespread is the acceptance, even amongst non-scientists, that "talking science" is a unique method of communication).

Certainly, such creativity in the formation and transmission of scientific knowledge has its problems. One of the ideal characteristics of scientific language is the consistency of its terminology (e.g., Ricouer; Leatherdale), the understanding, for instance, that a metre is an internationally-agreed upon quantity of space unaffected by geographic location, nationality, or the hopes and fears of any particular observer. As Mura argued, the use of discriminatory metaphors to convey scientific concepts has put in question the objectivity of some aspects of the physical and life sciences. In addition, metaphors may obscure or trivialize essential dissimilarities between common and scientific usage, and may, by implicitly linking into an underlying conceptual system (e.g., a mechanistic or competition-centred worldview), render alternative understandings implausible (Katz; Tauber).

Consider, for instance, the differences for women both North and South if the scientific metaphor of community gains greater legitimacy than the meaning of community as used in social justice movements:

> the term used in ecology to denote the different organisms associated together under particular environmental conditions.... Early in the 20th century there were two major lines of development. The Zurich-Montpellier school of plant sociologists made comparative statistical studies of the composition of plant communities. American and British ecologists studied the processes of change (or succession) whereby the modifications of the environment effected by one community result in its displacement by another.... Clements (1874–1945) maintained that communities were so integrated and underwent such determinate development as to be themselves complex organisms ... this holistic view has been ... displaced by the idea that communities are species massed together and regulated by competition and their individual physiological requirements. (Bynum *et al.* 73).

> both common sense experience and sociological interpretation tell us that modern societies are made up of multiple "communities-within-communities" practices, crafts, roles, traditions, discourses, languages—all of which generate meanings, evaluations, norms, expectations and so on.... The revised conception of community ... must embrace rather than suppress diversity and fragmentation.... How does this ... help us to theorize gender? It directs our attention to a range of communities—workplaces, families, consciousness-raising groups—organized on a variety of lines—geographical, evaluative, relational, functional. And it reveals the relevance of a multiplicity of practices—paid and unpaid work of many kinds.... In such a society, a woman will have a relatively continuous experience (albeit one which is affected by other aspects of her position such as her race, class ,or work situation) of the ways in which her femaleness affects her place in various communities.... (Frazier and Lacey 201)

And, given the increasing demand for environmental knowledge, and the increasing pressure to locate such knowledge in the natural and applied sciences (Mac Donald), the scientific usage is likely to predominate.

Yet, like the territorial disputes between the natural and the social sciences mentioned earlier, such usage may be more deliberately than accidentally exclusionary. The development of scientific language and sense of (professional) community has often relied on the vernacular, by adopting common words and either limiting or redefining their meaning, to demarcate the lines between the true professional, the non-scientific supporting occupations (e.g., technicians), and the unscientific charlatans and quacks (Mac Donald). So chemist, for example, came from alchemy, which in turn came from Arabic investigations, over five centuries ago, into the nature of transformations of matter. And chemistry, as "the study of the elements and the compounds they form and the reactions they undergo" (Allen 192), depends on a consistant understanding of element as something not reducible to a simpler substance by chemical means (the tautology of this constraint is usually ignored) (Allen). Other meanings of element, such as the four substances (earth, air, wind, fire) of ancient and medieval European philosophy, the bread and wine of the Eucharist, atmospheric conditions, or even usages from other sciences and technologies (electrode, basic unit in set theory), are ruled out, or delegitimized, in a modern chemist's worldview (Allen).

Such delegitimization is accomplished at all stages of scientific socialization (e.g., Abbott; Latour and Woolgar; Longino; Mumby; Pickering). This includes, for example, the origin stories which are part of chemists' occupational culture, transmitted in the formative high school years in such textual presentations as:

> Some of the chemists of the time [500–1600 AD], especially those in Europe, were known as *alchemists* and were thought to possess magical powers. Among other things, alchemists searched for ways to transform cheaper metals such as lead and zinc into gold, which was thought to be the perfect metal. Obviously, they never accomplished the impossible, and many good alchemists were executed for their failure.... Modern chemistry had its foundation in the late 1700s when the use of the analytical balance became widespread. At that time, chemistry became a quantitative science.... (Malone 4)

Thus, the message seems clear—the medieval alchemist, by a metaphoric twist, can stand for the modern chemist, but only by reformation, foregoing magic (holism? intuition?) in favour of quantification, observation, and balanced (objective?) evidence. And therefore, death apparently no longer accompanies the modern chemist's career choices. In addition, the people absent from that origin story—the non-Europeans, for example (and probably women, although the gender of the alchemist/chemist is unspecified)—may have been some other kind of chemist "of the time," but are rendered unnecessary to an explanation of why chemistry is what it is.

One arena in which this struggle for meaning becomes clear is in the higher grades in elementary/primary public school, at a point where students are about to "transfer from the stage of schooling where they are taught science by a class teacher, to the stage of schooling where they are taught by a specialist science teacher ... generally seen to be related to the beginning transition from the Piagetian stages of concrete to formal operational thinking" (Rosier and Keeves 3–4).

At this point in formal education, science has been introduced as a formal set of subjects, and retention rates are still relatively high for both girls and boys. The following examples, taken from a collection of Grade 5 and 6 public school students' essays and examinations, demonstrate some of the semantic confusions and translation errors that can occur:

> •One horsepower is the amount of energy it takes to drag a horse 500 feet in one second.
> •Lime is a green-tasting rock.
> •Most books now say our sun is a star. But it still knows how to change back into a sun in the daytime.
> •To most people solutions mean finding the answers. But to chemists solutions are things that are still all mixed up. (*Society of Canadian Women in Science and Technology Newsletter* 3)

The humour in each of the above is derived from the ways in which novice learners have sought to reconcile their pre- or extra-curricular understanding of the world with some univocal (and probably inherently disruptive) scientific concept. While only the first is more metaphoric than nominal, I include the last three as examples of the ways in which students respond to a conflict between scientific and personal conceptualizations.

Horsepower is considered in physics to be the amount of work done in a particular time interval, where work is the amount of force exerted over a particular distance. Specifically, one unit of horsepower is defined as 33,000 foot-pounds per minute.

Derived from, and used in, a time and culture where horses were a major source of agricultural and industrial power, the term was an apt representation of the concept of the equivalency of physical forces. That is, horse or waterwheel, commoner or king, all acted on the material world in a similar and predictable fashion, and the metaphoric value of the term came both from its immediate common sense (deals with big forces and heavy work, of the sort that horses do), and from its jarring of societal understandings of power (since such forces transcend embodiment, uniting the living and non-living worlds). Yet such a term can become problematic for someone raised in a more intensively machine-based society. That is, horses, as anachronism, may seem more likely to be dragged, to be inert, than to drag, to have power. And, although unaddressed by this particular novice learner, a corollary of the equation of work with physical force may be that labour in offices and homes, or labour by the weak, might also be negligible. Certainly, when I have asked students in both adult upgrading and regular high school courses whether their lived understandings of power, work, and force agree with those used in physics, the answers have overwhelmingly been in the negative, ranging from indignation to resignation.

In the other quotations, each learner has adopted a somewhat different approach to the reconciliation of what they know and what they are being told. For one person, scientific reality appeared to explain more thoroughly, or provide deeper insights into, the lived reality of everyday experience. Thus, one knows that the sun provides warmth, light, and a sense of time, but it reputedly ("most books now say") is also one of a multitude of small and ineffective night lights (obviously not-suns). Since it seems incomprehensible that "our" sun could be both sun and star, there must be a switching mechanism, a cognition-based agency ("it still knows how to change"), to account for the sun's reliability. For another learner, the reconciliation was possible by absenting her/himself from either position. The acidic green lime at home "is" the alkaline, white, and artificial calcium oxide of a school text or laboratory, but only by a disruptive act of understanding, through the conflation of sight and smell/taste ("green tasting"). Finally, one person defended her/his lived knowledge (the folk understanding of "most people") over that of a minority (chemists), by emphasizing folk knowledge's greater likelihood of success (e.g., "finding the answers" as compared to the chemist's "mixed-up" understanding).

If the responses of these children are any indication, then the translation between everyday and scientific languages is problematic. As (or if) they pursue a natural-science/technology education and/or occupation, most students will learn to simply accept (parrot, regurgitate?) those scientific representations, to stop trying to incorporate the scientific meaning into their constructed views of how the world works. And it is at that point that more boys than girls, more men than women remain confident in their abilities to do science (Keeves). I would argue that it is at this point that the greatest risks to empowerment are posed by a simplistic understanding of scientific literacy.

And here is perhaps the most speculative of the suggestions which I have put forward in this paper. Does learning to suspend disbelief, to go along with apparently meaningless explanations of seemingly irrelevant topics have any other outcomes than turning many people off the natural and applied sciences? Just as Willis argued in relation to the schooling of lower-class English schoolboys, or Arnot and Weiner suggested in their edited collection on *Gender and the Politics of Schooling*, or Ball concluded about education in general:

> the real political task in a society such as ours is to criticize the working of institutions which appear to be both neutral and independent; violence which has always exercised itself obscurely through them will be unmasked, so that we can fight fear. (Foucault, qtd. in Ball 7)

And it is this connection to violence that we need to consider in determining the meaning and achievement of scientific literacy acceptable to women from both North and South.

Elgin cited a study in which urban American men and women were asked to rank certain acts in order of perceived violence. Included were the shooting of a looter by a police officer, and the burning of a draft card in an anti-war protest. Most men in the study chose the latter, most women the former. Elgin's explanation was that, while both the men and women considered violence to involve the deliberate use of intense, negative force, the men linked violence with doing something avoidable (not part of the job description, done out of conscience) and the women with doing harm (direct damage to a living being). Such buried differences in meaning should be referred to as a reality gap. We must be sure that the agendas for scientific literacy prevent rather than create such gaps, that learning to talk science bridges the already-existing gaps between indigenous, local, and scientific knowledges by creating community in the colloquial rather than the scientific sense.

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