Cultural Influences on the Discipline of Chemistry

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Over the history of humankind, people have engaged in activities we associate in some way with chemistry. But people have done so within a framework of their own culture, not within a Western science cultural framework in which the discipline of chemistry exists. To understand the cultural framework of chemistry taught in universities today, we need to step out of the comfort of our own scientific culture we live in today. In other words, the cultural influences on chemistry are found by looking at alternative cultures. I am following the old adage, “If you want to learn about water, don’t ask a fish.”

History is a convenient vehicle to help us understand cultural influences. Because our scientific culture today has strong Greek roots, let me first explore Aristotle’s ideas about matter and then follow those ideas when they are placed in a different culture, Arabic culture, for instance. We shall then see what gets lost in translation between Greek and Arabic cultures. This discovery will shed light on some cultural influences on today’s chemistry and will have direct implications for the instruction of students.

Greek Culture

Aristotle’s ideas about matter rejected an atomic-like model of matter in favour of a continuum model. His model is summarized by Figure 1, representing the four elements, which when combined in various proportions produce different qualities of matter.

Figure 1 here.

It is important to note a Greek presupposition about the nature of evidence concerning what matter is: appearances define the reality of matter. In other words, “If it looks like gold, then it must be gold.” This presupposition is found in the following Greek recipe for making emeralds, translated from an ancient Greek papyrus into today’s vernacular (Partington, 1965).

> Mix together and put into a pot 2 grams of malachite, 2 grams of azurite, 130 cc of the urine of a young boy, and 180 cc of solution of ox-gall. Put into the pot all the 24 pieces of stone, each weighing 0.27 grams. Put the lid on the pot and lute it around with clay. Heat for 6 hours over a gentle fire of olive wood. When you see the lid has become green, do not heat any more but allow to cool and take out the stones, when you will find that they have become emeralds. (pp. 17-19)

In 331 BCE (Before Common Era) at the mouth of the Nile River, Greece established an outpost at Alexandria, Egypt, which soon flourished as a scholarly centre. Its bountiful library collection of Greek knowledge was recorded on sheets of papyrus, just like the recipe for emeralds. Later in Alexandria, a Greek word was coined to describe the genre of recipes for transforming one quality of matter into a different quality. The word was “chêmeia.”

Unfortunately, the library at Alexandria burned down in 390 CE (Common Era) which destroyed the chêmeia papyruses. However, this knowledge was passed on from generation to generation orally.

Arabic Culture

Scholarly interests flourished in Arabic cultures. Universities tended to be erected shortly after their armies conquered new lands. Arabic scholars held a different presupposition about the nature of evidence concerning matter compared with the Greeks. Identical our presupposition today, Arabic scholars believed, “It’s gold if and only if it meets a series of defining tests.” During the Arabic colonization across North Africa into Spain, Alexandria was taken in 641 CE. Arabic scholars learned the oral stories about Greeks transforming metals into gold and producing emeralds and other precious stones.

As Arabic scholars listened to the Greek stories, they learned the information in terms of their own worldview about matter, not in terms of the Greek worldview. Consequently Arabic scholars actually thought the Greeks had somehow made emeralds out of stones. What a colossal cultural misunderstanding! Out of this misunderstanding the field of alchemy arose (al-chêmeia).

Culture of Chemistry Today

Alchemy eventually became a field within natural philosophy, due in part to Newton’s fascination with it. This knowledge system then evolved eventually into chemical philosophy, thanks to van Helmont, Boyle, Becker and Stahl, Black, Cavendish, Priestley, Lavoisier, Dalton, Davy and others. In 1831 the newly founded British Association for the Advancement of Science (BAAS) replaced the name “natural philosophy” with “science” for political reasons, and soon after, the term “scientist” was coined (Orange, 1981; Yeo, 1981). To accommodate participants (“Men of Science”) at yearly meetings, concurrent sessions were organized around certain themes. This organization of concurrent sessions was greatly influenced by the administrative structure of the new University of Berlin, founded by Wilhelm von Humboldt in 1810, which partitioned Natur Wissenshaft into the disciplines of chemistry (Chymie), physics, geology, zoology, botany, etc. (Fuller, 1997). In effect, the discipline of chemistry was formally established in the Anglo world.

Perhaps we should contemplate the question, “What presuppositions do we hold so strongly today in chemistry that we are convinced they are reality (as the Greeks did)?” In chemistry, for instance, we believe that nature is mathematical, its ultimate expression found in quantum mechanical descriptions of the atom. To explore our presupposition concerning mathematical reality of nature, we need to step out of the culture of chemistry into a different culture to see what gets lost in translation from one culture to another.

The worldview embraced by chemistry is often at odds with other worldviews, for instance, Aboriginal peoples’ worldviews. Scientists often describe Aboriginal knowledge of nature as superstitious because its spiritual dimension runs counter to scientists’ ontology of idealized rationalism (e.g., the world is made up of objective mathematical relationships, such as the quantum mechanical description of the atom). On the other hand, Lakota Elder Deloria (1992, p. 40) stated, “What could be more superstitious than to believe that the world in which we live and where we have our most intimate personal experiences is not really trustworthy, and that another mathematical world exists that represents a true reality?” From Deloria’s perspective, chemistry is superstitious.

Different knowledge systems are predicated on different worldviews. Both Aboriginal and Western sciences employ empirical data and rational ways of knowing in creative and intuitive ways (Aikenhead, 1997; Cajete, 2000), but each has a culture-laden rationality that differs to varying degrees in several ways (respectively):

- *social goals*: knowledge (ways of living) for survival, versus knowledge for its own sake.
- *attribute of nature*: mysterious versus knowable.
- *intellectual goals*: co-existence with the mystery of nature by celebrating mystery, versus eradication of mystery by describing and explaining nature in ways familiar to Western scientists.
- *axiology*: harmony with nature for survival, versus power & dominion over nature for social and economic progress.
- *association with human action*: intimately and subjectively related, versus formally and objectively decontextualized from normative prescriptions of human action.
- *concept of knowledge*: ways of living that are place-based; versus a collection of concepts, principles, and techniques that aspire to a universality goal.
- *notion of time*: circular versus rectilinear.

- *validity*: content validity as evidenced by tens of thousands of years of survival based on that content, versus predictive validity that is the cornerstone of the epistemology of Western science.
- *general perspectives*: holistic, intuitive, spiritual *wisdom*; versus reductionistic, intuitive, mechanistic *explanations*.

Is it any wonder that many Aboriginal students who embrace Aboriginal worldviews feel as if they are in a foreign culture when they attend chemistry classes?

Implications for Education

A small proportion of students in any culture seems to share a worldview endemic to Western science. Thus, they naturally become attracted to science. This proportion is approximately 5 to 10 % in Anglo countries where science and technology are generally embraced as cultural icons (Atkin & Helm, 1993; Cobern, 1993; Costa, 1995; Lyons, 2003; Reiss, 2000). But the other 90 to 95 % of the school population who do not hold a science-like worldview will view chemistry content through the lenses of their own worldviews (e.g., aesthetic, religious, etc.) and therefore, many reject chemistry's mathematical mechanistic descriptions, for instance, as being foreign to their own way of making sense out of the world (Cobern, 1993).

University chemistry students self-select into chemistry because they share many presuppositions about nature with their professors. Thus, the proportion of these students in a chemistry program is 100 %. In pre-med or pre-nursing chemistry courses, however, the proportion drops to about 10 % (Aikenhead, 2005). As a consequence, chemistry is a foreign culture to these students. The more foreign the culture of chemistry appears to be, the less students feel open to studying the discipline.

To attract more students into chemistry, particularly students who conventionally have been marginalized by the culture of chemistry (AAAS, 1977; Bianchini, Cavazos & Helm, 2000; Costa, 1995; Scantlebury, 1998), we must locate school-age students who embrace a science-like worldview towards the natural universe and then encourage them to succeed at mathematics and abstract science courses. If they are expected to reject their self-identities as women or as Aboriginal persons, however, the culture of chemistry will not be an inviting one. The challenge to chemistry educators becomes one of respecting, rather than dismissing, students' worldviews, while at the same time making the discipline of chemistry accessible to them.

A moral issue for school chemistry educators is to develop a defensible chemistry curriculum for the 90 % who find chemistry culturally foreign and even repulsive. Students usually find intellectually challenging courses that emphasize chemistry as a human endeavour and integrated with other disciplines to be highly interesting and relevant. The goal here is to enculturate these students into their community/national culture, not into the discipline of chemistry. Yet these humanistic-oriented courses are usually discredited as inappropriate prerequisites to university entrance. Schools are forced to offer traditional pre-professional training courses aimed at preparing students for first-year chemistry, rather than for everyday life (Aikenhead, 2006). Chemistry in schools becomes a screening device for university entrance, rather than an educational experience that prepares students for life-long learning. Is that morally defensible?

Even though people do learn science content in their everyday world when they have a personal stake in making a decision related to the phenomenon (Ryder, 2001), this learning is not often the "pure science" transmitted by a traditional science curriculum. Research has produced one clear and consistent finding: *most often canonical science content is not directly useable in science-related everyday situations*, for various reasons (Cajas, 1998; Chin et al., 2004; Furnham, 1992; Gott, Duggan & Johnson, 1999; Ryder, 2001). In other words, the empirical evidence from this research contradicts scientists' and science teachers' mythical claims that science is directly applicable to a citizen's everyday life. What scientists and science teachers probably mean is that scientific concepts can be used to abstract meaning from an everyday event. The fact that this type of intellectual abstraction is relevant only to those who enjoy explaining everyday experiences this way (i.e., those who have a worldview that harmonizes with a worldview endemic to Western science) attests to the reason most students perceive science as having no personal or social relevance. Students are not taken in by this myth of the everyday application of science perpetuated by the scientific community.

Conclusion

Knowledge systems such as the discipline of chemistry reflect the epistemology (e.g., reductionism), axiology (e.g., the Judeo-Christian ethic), and ontology (e.g., Cartesian duality) of the chemists who developed those knowledge systems in the first place (e.g., alchemists, natural philosophers, and 19th century chemists). These scholars had to think and communicate within certain cultural practices. Knowledge systems reflect such cultural practices.

Most students' worldviews, however, do not harmonize with a worldview associated with chemistry, and therefore, most students do not share the same epistemology, axiology, or ontology with their chemistry teachers and professors. Much is lost in translation between the culture of chemistry espoused by their teachers and textbooks, and the culture of most students, particularly Aboriginal students.

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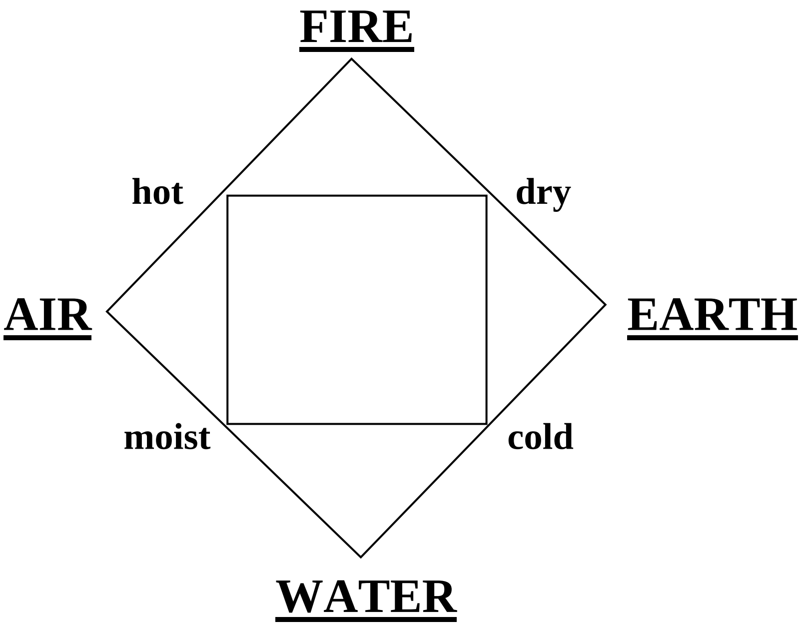

Figure 1: The Four Elements