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ABSTRACT

In this paper, a science educator, a social studies educator, and a language educator begin by considering the question of multiculturalism in science education. When multiculturalism is understood as the process of understanding the contextual and situated nature of all knowledge, multiculturalism becomes not something which one puts in science education, but is inherently part of, and necessary to, understanding science and the scientific process. Science, like culture, is not an object to be described, but is negotiated, temporal, and emergent. For students of science to gain a deeper understanding of science and scientific progress the authors argue for more context and complexity in science education. Exploring culturally embedded assumptions regarding the nature of science through using the histories and philosophies of the natural science would help students better understand the dynamic, complex natures of the natural sciences. Multiculturalism should result in a more, rather than less, dynamic science. (PR)

Multiculturalism Redefined in Science Education

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A History of the Development of This Paper...R. Good, 2/27/93

Shortly after I was asked to participate in this symposium on multiculturalism in science education, I asked my LSU colleagues Petra Munro and Denise Egéa-Kuehne if they would join me in writing the paper. Petra's expertise in multiculturalism and Denise's knowledge of French philosophers, including Gaston Bachelard, were needed to supplement my own ideas on multiculturalism in science education.

After several meetings, we each wrote short papers on "multiculturalism redefined in science education" and I tried to integrate the ideas into a single paper. However, after considerable effort, I realized that a "cut-and-paste" approach failed to maintain the flow and originality of each paper; so the final paper is, in fact, three papers under the same title.

The first paper is an adaptation of Good and Schlagel (1992), the paper I presented at the Second International Conference on the History and Philosophy of Science and Science Teaching (HPS & ST). In the current paper, I reiterate the claim of no unitary epistemology for science, again using the ideas of Gaston Bachelard (French philosopher of science, 1884-1962), Ernst Mayr (American evolutionary biologist), and Richard Schlagel (American philosopher of science). Bachelard's ideas on the importance of difference are stressed more in this paper than the 1992 HPS & ST paper, relating difference to context and multiculturalism. Difference, context and multiculturalism are then related to research from multiple perspectives in science education.

The second paper is written by Petra Munro, a social studies educator who specializes in multiculturalism and gender studies at LSU. Petra raises questions about the nature of science that challenge common assumptions and "suggest new possibilities for enlarging our discussion of epistemological issues central to the science question." She questions current constructions of multiculturalism as equivalent to race or ethnicity (the "tacos, tepees, terriyaki, and tap dancing" approach), suggesting that this " add'n stir" approach "serves to maintain dominant conceptions of knowledge and science."

The third paper is written by Denise Egéa-Kuehne a language educator who specializes in French critical theorists. Denise elaborates on Bachelard's ideas about no unitary epistemology in science and the importance of context and difference in scientific research. By stressing the "cultural importance of intellectual factors," Bachelard noted that, "...the same word, denoting the same experience, the same idea, mean different things to different people, and that difference has a psychological, affective basis." Also, relating multiculturalism to science and science education, Denise points out that Bachelard believed, "the pluralistic philosophy of scientific notions is a guaranty of fecundity in teaching." She also points out that Bachelard was a science teacher as well as one of France's best known philosophers of science, graduating "from the most prestigious higher education institution for teacher education, the Ecole Normale Superieure."

Among the questions raised in these three papers are:

1. Is there a single nature of science?
2. What assumptions about nature are made by scientists?
3. How does an emphasis on context in science affect interpretations of multiculturalism for science education?
4. How has it come to be that science is not considered a cultural construction?
5. How might exploration of culturally-embedded assumptions regarding the nature of science, through use of the histories and philosophies of the sciences of nature, help students better understand the dynamic, complex natures of the natural sciences?

Multiculturalism Redefined in Science Education: Part One

by Ron Good, Science Educator

Our ideas and research in science education are influenced by our ideas about both the nature of science and the nature of science learning. History and philosophy of science can help to clarify the nature of science just as studies of students, especially their science learning, can help us with decisions about appropriate science curriculum and instruction. Two international conferences (1989, 1992) and a new journal (Science & Education) are evidence that science educators are becoming more aware of the importance of studying the nature of science. Any consideration of scientific literacy, such as AAAS Project 2061 (Science For All Americans, 1989) must include students' understanding of the nature of science. Science For All Americans (SFAA) focuses on three questions to understand the nature of science:

1. What is a scientific world view? (pp. 25-26)
2. What is the nature of scientific inquiry? (pp. 26-28)
3. What is the nature of the scientific enterprise? (pp. 28-31)

Lederman (1992) reviewed research on students' and teachers' ideas about the nature of science concluding that neither students nor their science teachers "possess adequate conceptions of the nature of science" (p. 345).

This paper attempts to clarify and extend the claim by Good and Schlagel (1992) of "no unitary epistemology" within the natural sciences. A brief review of the arguments in that paper are presented in the next section, followed by a discussion of "multiculturalism" in science and implications for science education.

No Unitary Epistemology in Science

It is common to think of the nature of science as if all the natural sciences are the same. In Toward A New Philosophy of Biology (1988), Ernst Mayr, a leading evolutionary biologist, argues that evolutionary biology differs from other sciences, especially physics, due to different assumptions, methods of inquiry, use of prediction and experimentation, and so on.

In The New Scientific Spirit (1934), French philosopher of science Gaston Bachelard (1884-1962) argues there is no such thing as the history of science, only various histories of regions of science. He stressed this importance of context in science by saying:

> When one looks at science, what is immediately striking is that its oft-alleged unity has never been a stable condition, so

> that it is quite dangerous to assume a unitary epistemology. Not only does the history of science reveal a regular alternation between atomism and energetics, realism and positivism, continuity and discontinuity, rationalism and empiricism; and not only is the psychology of the scientist engaged in active research dominated one day by the unity of scientific laws and the next by the diversity of things; but even more, science is divided, in actuality as well as in principle, in all of its aspects. (pp. 14 & 15)

History of science is really histories of many sciences. Schlagel (1986) points out, "...all scientific knowledge appears to be conditioned by the method and context of investigation" (p. 273). Bachelard (1934), Mayr (1988), and Schlagel (1986) stress the importance of context in considering the various "natures" of the natural sciences. Although generalizations can be made about the similarities of the various natural sciences, when context is taken seriously the many differences among the sciences become the focus of attention.

The lack of a unitary epistemology of the natural sciences should not be taken as evidence for relativism or postmodernism in science. Supporters of relativism a' la Feyerabend (1975) and postmodernism a' la Foucault (see Gutting, 1989) lead some persons to conclude that no confirmable or reliable knowledge is possible; the methods of the pseudo-scientists (e.g., astrologers) are as scientifically able as the methods of biologists, chemists, physicists, and so on.

Schlagel's description of contextual realism is embodied in basic assumptions by the authors of SFAA (1989) about nature and science:

> Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. (p. 25)
>
> Scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works. (p. 26)

These statements are similar to an earlier statement by Bohm (1957):

> ...we assume that the world as a whole is objectively real, and that, as far as we know, it has a somewhat precisely describable and analyzable structure of unlimited complexity. (p. 100)

Contextual realism takes into account the conditional existence of reality as well as the autonomous status within specific conditions (i.e., context).

Science As Communities of Scientists

Individual scientists are linked to others in their specialty (e.g., astronomy, biochemistry, geophysics, microbiology) by various means. Professional societies and journals have been the most common "formal" means of communication among different groups of scientists. These communities of scientists often have more than one journal and one annual meeting which they use to present their research results, making it difficult to "keep up" with new ideas even within their relatively small group. Each of these societies or communities of scientists has its own rules of operating and deciding which research should be given the greatest attention. Editorial boards for journals and program committees for professional meetings serve as "regulators" that determine which knowledge is of most worth. Of course, other things such as funding agencies (e.g., NSF and NIH) exert influence on the scientific communities, including what areas of research will be given prominence.

All of this is fairly obvious to the close observer of the enterprise called science. Just as there is no unitary epistemology of science, there is no single community of scientists, unless one wants to de-emphasize context in favor of generalizability. If the richness of context, including history, is emphasized, then difference rather than similarity becomes the focus. Contextual reality as a philosophy of science chooses to focus on the richness of context. This emphasis on context has been the trend in educational research, including science education, during the past decade or so. Choosing interpretive, context-bound forms of research has become increasingly common among researchers in AERA, NARST, and other educational research societies.

Meanings of Multiculturalism for Science Education

To this point we have tried to establish contextual realism as a reasonable philosophy of science, one that is consistent with the kind of realism that is argued for in Science For All Americans (SFAA). How does an emphasis on context in science (i.e., contextual realism) affect interpretations of multiculturalism for science education and related research?

Multiculturism in Social Studies

The "passions of pluralism" that Maxine Greene (1993) refers to seems to have more relevance to social studies education than to science education. Multiculturalism can be seen as a movement to recognize the importance of the histories, cultures, and so on of various nonEuropean ethnic groups in the U.S. Afro-Americans, Asian-Americans, Hispanic-Americans, Native-Americans, and other "minority" groups want their histories and cultures known and respected by all Americans, and schools are being asked to adjust their curricula accordingly.

Social studies are becoming more pluralistic as they accommodate curriculum and instruction to the multiculturalism movement. The American heritage is really many heritages. American history is really many histories. Greene (1993) suggests, "It may well be that our ability to tolerate the unexpected relates to our tolerance for multiculturalism, for the very idea of expansion and the notion of plurality" (p. 14).

Multiculturalism in the social studies emphasizes difference over similarity. Differences among the cultures and histories of Afro-Americans, Asian-Americans, and so on in the pluralistic reality of modern America are made apparent in the pluralistic passions of multiculturalism. Differences are celebrated and students are encouraged (forced?) to see history, politics, economics, and so on through multiple perspectives. Does multiculturalism as defined in social studies education have a parallel in science education?

Multiculturalism in Science Education?

We have finally come to the central question of this paper--How does an emphasis on context in science affect interpretations of multiculturalism for science education and related research?

The emphasis on differences among cultures can be seen as enriching the social context. Simplistic, monolithic interpretations give way to more realistic and more richly detailed histories of communities. The arguments of Bachelard, Mayr, and Schlagel against a unitary nature of science can be seen to parallel arguments for a kind of multicultural interpretation of the various natural sciences and their histories. Although similarities can be drawn, it is more instructive and productive to focus on differences.

Bachelard, in particular, stresses the important role of difference in contemporary science. According to Jones (1991), Bachelard suggests, "The revolutions of twentieth-century science have dethroned both reason and reality, and forced them into alliance, a strange alliance based on conflict, on opposition and difference" (p. 7). On Bachelard's thoughts about the role of difference in a person's thoughts, Jones (1991) says, "The knower is consequently always aware of a gap between what he knows and what there is to know, always aware therefore of differences, which he constantly strives to overcome only to find it again opposing him" (p. 18). The fundamental desire of Bachelard to cultivate differences is, Jones observes, "...deeply subversive of our habits as readers, trained as we are to seek unity and value consistency" (p. 169).

Multiculturalism can be viewed as a celebration of difference that presents multiple perspectives to us. For science education, recognizing the various natural sciences as related but different forms of inquiry, reveals a richness of reality that is lost when identity and generality are the focus of our efforts. Contextual reality, in Bachelard's terms, is a focus on the rich, multiple perspectives of difference.

Multiple Perspectives in Science Education Research

Progress in science is usually seen as agreement among scientists that certain ideas should be given prominence over other ideas. Differences of opinion are gradually reduced and a more-or-less "steady state" of agreement is reached among a particular community of scientists. The histories of the vaiious natural sciences provide evidence that progress is made in this regard.

In science education progress is not as easy to see. Whereas science assumes that things in the universe occur in consistent patterns, it is less clear that this is the case in teaching and learning science. Science education may not be able to assume "consistent patterns." If the fundamental assumption of consistent patterns is not available to science education, then making progress will be much more complex than in the natural sciences.

Can progress in science education be made through research? Perhaps, but progress will have to be defined differently than in the natural sciences. We may have to agree that multiple perspectives are inevitable, even desirable, after many years of inquiry. A "science" of science education may have to be defined quite differently than a science of nature. In fact, using the word science to describe the effort to establish a research base for science education may be a misuse of the word science.

Greene (1993) concludes her comments on the passions of plurality (multiculturalism) by saying, "Learning to look through multiple perspectives, young people may be helped to build bridges among themselves; attending to a range of human stories, they may be provoked to heal and to transform" (p. 17). Perhaps research from multiple perspectives in science education will strengthen our knowledge base; which is another way of defining progress.

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Multiculturalism redefined in science education research: Part Two

by Petra Munro, Social Studies Educator

When asked "what is science?" my immediate response as a social scientist is to rephrase the question "How did science come to be?" What made the emergence of science as a discipline possible? What conditions has science had to fulfill to be deemed as natural despite the fact that it is culturally and historically contingent? What are the social relations of power and knowledge that made science as a discipline possible? Sandra Harding (1993:11) contends that "the challenge is to articulate how it is that knowledge [in this case science] has a socially situated character denied to it". In other words, "how has it come to be that science is not considered a cultural construction?". These questions place us on shifting and unstable terrain. Although discomforting for some, this rupture in "science as usual" can suggest new possibilities for enlarging our discussion of epistemological issues central to the science question.

"Can we ever really get "beyond objectivity & subjectivity"?

Current debates within the philosophy and history of science as well as the social sciences are dominated by spiraling discussions of the crisis of representation in which "lack" of a unified, single truth necessarily relegates us to the abyss of relativity. I am suspicious of these simplicities. The dichotimization of these debates implicates them in the very dualism each seeks to absolve- objectivity in search of a single truth and subjectivity in the name of multiple truths. In remaining trapped in the very polarizations they seek to dismantle the dialogue has been reduced to a choice of subjectivity/relativism or objectivity/essentialism. In essence we are asked to trade one absolute for another. It seems to me that giving epistemic privilege to one just replaces "bad" science" with more "bad" science. The conversation has not been enlarged the discussion leaders have just changed.

I suspect that no scientist would disagree with Ruth Bleier (1987: 114) when she suggests that "it would be in fact naive to believe that scientists, unlike other human beings, are unaffected in their thinking by their life histories and by the values and realities of our culture". The focus on "whose science" (Harding, 1992), which underscores the culturally constructed nature of science, does not reject objectivity but reclaims it as "situated knowledge". The history of science in fact as Elliot Eisner (1992: 14) points out "provides ample evidence that what we regard as true changes." Feminists in particular have shown how science is shaped historically by dominant cultural ideologies regarding gender. For example, in the late 18th century the female cranial cavity was supposed to be too small to hold powerful brains; in the late nineteenth century, the exercise of women's brains was said to shrivel their ovaries. In our own century, peculiarities in the right hemisphere supposedly make women unable to visualize spatial relations (Jacob, 1988; Schiebinger, 1989). However, as Sandra Harding suggests, historical or sociological or cultural relativism is distinct from judgmental or epistemological relativism (Harding, 1992). For Harding, "strong objectivity" calls for scientifically examining the social location of scientific claims. From this perspective science cannot be separated from culture but is central to it.

If science, as it is commonly understood, were in fact universal and it's method absolutely objective would science as a field of inquiry exist? Is it not the very questioning of commonly assumed and taken for granted conventions that results in the generation of new scientific questions? For example, a recent article in U.S. News and World Report (March 1, 1993) attributes the new strategy called "convergent combination therapy" developed by Yung-Kang Chow for treating HIV infection, to "breaking the rules" of convential approaches. It was his ability to think unconventially, to step outside the traditional rules of science which enabled his reconceptualizing of using the very genetic adaptability of the virus as a "weapon" against itself. While some have seen this need for "multiple ways of thinking" as promoting epistemological relativity, others envision this as the central place from which we can achieve a truly objective science (Harding, 1992). I tend to agree with Donna Haraway when she suggests that "the production of a universal, totalizing theory is a major mistake that misses most of reality" (1990: 223) In light of this, the current focus on resolving the essentialist/relativist debate seems misguided. Again, the question we might be asking is "How is it that this polarization has gained currency to dominate the discourse ?" "What does this signify?" "Whose interests does this serve?" As Evelyn Fox Keller (1989) maintains:

> The question of whether scientific knowledge is objective or relative is at least in part a question about the claim of scientists to absolute authority. If there is only one truth, and scientists are privy to it, (i.e., science and nature are one), then the authority of science is unassailable. But if truth is relative, if science is divorced from nature and married instead to culture (or "interests"), then the privileged status of that authority is fatally undermined. (1989: 40)

Science as Cultural Ideology?

When science is understood as a cultural construct it seems redundant to ask "What would science education from a multicultural perspective look like?" My position would not be to argue for or against multicultural education in the sciences or in any discipline. Again, how can science not be cultural? My sense is that we are asking the wrong question. Again, my questions would be "How can science not be cultural?" and "Why and how has it come to be that science is considered value neutral and not a cultural construction?".

Asking these questions highlights the very role the discourse of "multicultural education" plays in maintaining the dominant "value neutral" conception of science. If multicultural perspectives will "add" culture (read subjectivity/relativity) then this reinforces and maintains the very notion of science as neutral (read objective).

Consequently, I believe we need to interrogate first how "multicultural education" has been constructed?

Current understandings of multicultural education are based on several premises. First, culture is treated as the equivalent of race or ethnicity. Culture is understood to be possessed by African Americans, Asian Americans, Hispanics and Native Americans. Thus, we have what I call the "tacos, teepees, terriyaki and tap dancing" approach to multicultural education. The basic premise being that the "problem" of multicultural education is solved when we "add" the right amount of knowledge about each ethnic group to the curriculum. Secondly, within the current discourse culture is understood as homogeneous. There is a Native American culture, which is knowable, bounded and independent. The differences within various ethnic groups based on gender, class, or sexual preference are reduced by speaking of "Native Americans" or "Asian-Americans" as if they were homogenous groups. Lastly, this view of multiculturism reinforces a view of culture as static. Historical and contextual factors are disregarded in exchange for a monolitihic view which reduces humans and their culture to foods, holidays, crafts, dress, and famous people. Of course all of this can be learned in the designated month of the year set aside for "honoring" these groups. Rather than increase our understanding of the complexity and interactive nature of culture current definitions of multicultural education effectively erase these generative possibilities.

Culture defined as race, static and homogeneous actually serves to reinforce an understanding of knowledge as a neutral body of facts.[1] Consequently, the "problem" of multicultural education will be solved when we add the right amount of knowledge about each group to the curriculum. Adding new "facts" also reinforces dominant views of knowledge since the categories of analysis remain the same and are not challenged.[1] Thus, the adding of African American, Native American, Hispanic or Asian scientists does just that, add more names.[2] Although this is certainly important, it does little to

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[1]For example, how is it that we have come to take for granted the division of human and natural sciences? This very organization of the world reflects a particular world view in which it is possible to conceptualize humans as separate from the physical world.

[2]I do not want to dismiss the importance of acknowledging the contributions of persons of color, however, I see this only as a first step to a truly multicultural science. In fact, in addition to the inclusion of women and "minority" scientists, a multicultural science curriculum should also incorporate and raise questions regarding: effects of science and technology on persons of color and women, "third world" achievements in scientific and technological innovations and explore forms of bias against people of color in research, as well as inequitable distribution of benefits from science. As science has increasingly become an integral part of society the consequences of scientific study can no longer remain detached from pure scientific study. This reasoning has in fact functioned to maintain "science as usual."

reveal the cultural assumptions embedded within the discipline of science itself. Gerda Lerner (1975) has refered to this as "compensatory history". The categories and conceptual frameworks of any discipline are still taken as the norm rather than being reconceptualized. Thus, this "add'n stir" approach to multicultural education actually serves to maintain dominant conceptions of knowledge and science.

So, what would science education from a multicultural perspective look like? Foremost, I think science education has to address the implication of the very assumption that science considers itself universal, not cultural. What does this tell us about science? Central to reconceptualizing science as multicultural is an interrogation of the very concepts that make it possible for us to understand science as we do for these are shared cultural understandings. Consequently, central to the teaching of science would be a critical examination of the relationship between language, culture and thought. In particular what role does language play in shaping shared cultural understandings of science. Concepts like "genetic engineering", "scientific revolution" or "nature as a machine" are not neutral terms but powerful metaphors which reinforce dominant beliefs about science as progress, controllable and neutral.

If we acknowledge that science can only be fully understand when socially and culturally situated, then one direction that "multicultural" science education could take would be to "historicize" science. By what process did scientific knowledge become an integral part of western culture? How has science shaped human social relations and consciousness? Is it possible to understand "western" science without also examining "non-western" science? It would seem one is only explainable in terms of the other. Second, would be to show the many cultures within science (Bio, Chem, physics). Lastly, how can different epistemological perspectives (those of women and other cultures) help to generate new ways of looking and seeing that can enrich and expand the process of inquiry which is the heart of science?

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Multiculturalism Redefined in Science Education Research Part Three

by Denise Egéa-Kuehne, Language Educator

This paper will expand on Ron's use of Bachelard's concepts to support his attempt to establish contextual realism as a reasonable philosophy of science. It will explore Bachelard's works further 1) to stress the danger Bachelard saw in assuming a unitary epistemology (i.e., "philosophy of science" in Bachelard's French context); 2) to discuss the importance he placed on context; and 3) on the plurality of cultural factors as defined by Petra and as related to rational identity. This paper will consider multiculturalism and multidisciplinarity, within science and outside the field. It will propose an approach to utilize the dynamic force complexity and differences can be. Finally, it will suggest implications for science education and science education research.

The Danger of a Unitary Epistemology

> *When one looks at science, what is immediately striking is that its oft-alleged unity has never been a stable condition, so that it is quite dangerous to assume a unitary epistemology*[1]. *(NES 14)*

Jones (1991, 10) recognized that for Bachelard, difference was an ontological necessity. Bachelard believed that reason and reality are strongly interdependent in modern science, but in a dialectical mode. This dialectical, discursive dynamic relationship between scientific reality and scientific reason transcends the rational self. The latter is "no longer sovereign, no longer autonomous, identical, and unchanging, but rather ...created and recreated by something other than itself" (Jones, 1991, p. 7).

Bachelard posed the problem of scientific knowledge in terms of obstacles, "epistemological obstacles," the first one being the search for generality, for a unitary epistemology. He blamed it as a cause of "inertia," "stagnation," and even "regression" (FES 13).

> It is often said that science craves unity, that it tends to look for similarities between phenomena which present a diversity of aspects, that it looks for simplicity and economy in

[1] In French, therefore in Bachelard's context, "epistemology" is synonymous with "philosophy of sciences." It refers to the philosophical study of problems (i.e., sociological, psychological, and so on) underlying science in general, or any one specific sientific area. In a broader sense, more common in the Anglo-Saxon context, "epistemology" is understood to mean "theory of knowledge" or "gnoseology."

> principles and in methods. This unity would be easy to find if science could be satisfied with it. (FES 16)

However, Bachelard believed that science cannot be satisfied with it, but rather that scientific progress is most significant when scientists stop looking for unifying epistemological factors. A rigorous scientific approach should be looking for more dynamic thinking, for precision and diversification, in order to escape restrictive certitude and unity, since homogenous systems are more of an obstacle than an impulse. Bachelard saw danger in what he called the "habit of reason," whereas "formalism may, for instance, degenerate in an automatism of the rational, and reason becomes as if absent from its own organized structures" (RA 13). He also considered it important to "disrupt habits of objective knowledge and [to] make reason uneasy" (FES 247).

Bachelard questioned "whether a general and immutable reason [would] ever be able to assimilate all these astounding thoughts" (NES 176), not merely to structure them, but also to put them under the control of its own structure. It was Meyerson's hope. However, Bachelard strongly disagreed with Meyerson and hoped for the very opposite. "Instead of this communion with a global reality to which the scientist would joyfully return, as he would to an original philosophy" (NES 177), Bachelard wondered whether

> it would not be better, in order to understand the intellectual evolution, to pay attention...to the thought in search of dialectical opportunities to escape itself, to break out of its own bounds. (NES 177)

In such a case, this thought process could not but be characterized as creative. In fact, in order to overcome "epistemological obstacles," the scientist must face "the continuing need to renounce his own intellectuality" [Bachelard's emphasis, and gender use] (FES 248).

In the cartesian tradition, science tried to "build complexity out of simplicity in a systematically logical fashion" (NES 139). A contemporary scientific approach should look for existing complexity concealed behind the appearance of simplicity. It should strive to search for pluralism beyond seemingly identical phenomena, beyond immediate experience which might lead to spurious conclusions of apparent unity. Bachelard contended that "such opportunities do not occur spontaneously ...One must read them within the substance itself, within the context of its attributes" (NES 139).

Importance of context
from the macro level (social) to the micro level (scientific experiment)

Any discourse on the scientific method will always be a discourse of circumstances. (NES 135)

Indeed, Bachelard stressed the importance of context in science, whether discussing concepts and methods, or conducting an experiment and drawing conclusions on research, and he agreed with Perrin when he declared:

> Any concept will eventually become useless, will even lose its very significance, the further it is removed from the experimental conditions in which it was formulated. (Perrin, cited in NES 135)

Bachelard saw concepts and methods as "all dependent on the domain of the experiment" and therefore recommended that "the whole scientific thought must change before a new experiment" (NES 135). He strongly believed that "any discourse on the scientific method will always be a discourse of circumstances," and that "it will never describe a definite constitution of the scientific mind" (NES 135). To illustrate his position, he gave numerous examples of recent developments in scientific research, and insisted that

> Even in the details of scientific research, before a well defined experiment which could stand being recorded as such, as truly one and complete, a scientific mind never runs short of ideas to vary its conditions. (FES 16)

On the contrary, these conditions should be multiplied and refined, and scientists should determine "multiple axiomatics to face a proliferation of experiences" (RA 133). In fact, more recently, scientific research has exploded in multiple locations, and in multiple directions, thus "necessarily 'exploding' traditional epistemology" (MR 210). Bachelard gave numerous examples to illustrate this point, mostly in chemistry and physics, such as the 600 isotopes discovered or created within a decade, and described by Riezler (1942, p. 132) as an "explosive evolution." On such occasions, the new scientific developments offer such a broad plurality of consequences, that they may entail a discontinuity of knowledge, and a new departure point for epistemology. A student of Bachelard's, Serres reported changes in the sciences which happened so fast that scientific "truths" became obsolete overnight. He cites examples in mathematics; Brillouin and the theory of information; then later the theories of turbulence and chaos, fractals and attractors; and Schrödinger (What is Life), Monod and Jacobs in France, precursors of biochemistry.

Bachelard gave numerous examples and discussed them in great detail in the chapter entitled "Common knowledge and scientific knowledge" in The Rational materialism (1953). I retained one, for its impact at the time it occurred, and for its consequences and ramifications in the present, and in the future. Irène Joliot-Curie's discovery can be summed up in two short lines, yet it paved the way for the production of artificial radioactive elements, and brought her and her husband the Nobel prize for chemistry in 1935. Their discovery was called "a miracle" by Hevesy at the 1948 Paris

Colloquium on "Isotopic exchanges and molecular structures," and Pollard and Davidson deemed that it resulted in an "astonishing development" of the field of human knowledge. Pollard and Davidson point out that between 1933 and 1945 the number of artificial radio-active elements increased from 3 to 300. In May 1948, F.B. Moon apologized in the preface to his book "Artificial radioactivity" (1949) for his inability to provide a complete list of radio-active elements: "The field is developing so rapidly that such lists are soon incomplete." A consequence is an unavoidable discontinuity in the field of science. Bachelard writes:

> In the midst of such a swarming of discoveries , can one but see that any attempt at continuity is bound to be too coarse, and tc overlook the specificity of details. (MR 211)

Scientists must remain alert to this unavoidable and prolific discontinuity, and to this "specificity of details." Bauer most emphatically pointed it out in his preface to the French National Center for Scientific Research (C.N.R.S.) on the "Chemical connection" in April 1948. He remembered Heitler and London's (1927) fundamental memoir and wrote: "This memoir marks a true break in the history of Chemistry. Since then, progress has been swift." On these occasions, scientific discoveries offer such a "plurality of consequences" (MR 211) that "a discontinuity of knowledge" becomes tangible.

To that effect, Bachelard was in favor of maintaining a degree of subjectivity. For he doubted that there is one way only to go about eliminating subjectivity from a given "notion," and wondered whether this "notion" would take on a different meaning, or a different "function," according to which measures were taken to eliminate subjectivity. He maintained that it is necessary to consider the plurality of potential demonstrations for one same problem. He added that subjectivity determines a variety of perspectives which should not be ignored or erased with a simplified initial statement.

Multiculturalism and rational identity

The cultural route goes from the perceived reality,
to the scientific experience, including every one of the
physical characteristics which help or hinder culture. (RA 19)

Bachelard believed that "it is through reflection that the actual guaranties of objectivity appear. However this reflection cannot be limited to the efforts of the subject. It is essentially cultural" [Bachelard's emphasis] (RA 137).

Bachelard believed that culture is a factor in as much as the "contingency of knowledge" (RA 14) is, or is not, present. He stressed the "cultural importance of intellectual factors" (RA 66). Bachelard often used "culture" in the sense of "education." However, for our purpose, either meaning is valid. Only when variations of knowledge are no longer permitted or recognized according to their context, is culture no longer a factor. However, if a unitary epistemology is rejected and the context is considered, then culture and its variations become of paramount importance. Bachelard went on to illustrate this philosophy of the hierarchy of "cultural thoughts," the thoughts which are "active" in a given culture (RA 15). The concepts of time, distance, and temperature, illustrate such cultural variations across race, ethnicity, age, space, time, discipline, and even within one same scientific field, such as chemistry, physics, or biology.

Bachelard also discussed the concept of "regional rationalisms" [Bachelard's plural], the concept of "determining distinct regions" (RA 119) in the rationalist organization of knowledge, against the philosophical tradition of a rationalism looking for total unity--against unitary epistemology.

Bachelard referred to Descartes' paradigm of the "inventory of knowledge" (RA 14). It was a methodical review of acquired knowledge. However, according to Bachelard, it made sense only in as much as it forced us to become aware of our rational identity. This rational identity is closely linked to culture, and in order to become aware of it, one must be able to sift through the diversity of individually acquired knowledge. Such an awareness of our individual "inventory of knowledge" is in turn dependent upon an awareness of the structuring of the knowledge thus accounted for, and of the cultural factors which influenced this structuring. According to Bachelard, "the cultural route goes from the perceived reality to the scientific experience, including every one of the philosophical traits which help or hinder culture" (RA 19). As a consequence, Bachelard contended that "the scientist's mind is not..., *tabula rasa*, it is thoroughly prejudiced, marked by preconceived ideas and values" (BP 79). Both the history of science and the classroom experience of science teachers show that "the same word, denoting the same experience, the same idea, means different things to different people, and that difference has a psychological, affective basis" (BP 79).

A transactive approach to multiculturalism in science education

All the sciences, one after the other, were changing, and moreover, profound transformations were underway in their relationships with men and the world. (Serres, 1992, 29)

Serres, an example of multidisciplinarity himself, graduated from high school with degrees (Baccalauréat) in mathematics, and in philosophy; he received graduate degrees in math (under Bachelard), classics, and philosophy; he passed entrance examinations to both graduate schools of science and humanities. For him, it represents the ideal education. It is no surprise then that he is a staunch advocate of multidisciplinarity and multiculturality at all levels. A student of Bachelard, he was also a student of Canguilhem and Foucault. In 1990, he was elected a member of the Académie Française--a kind of Supreme Court of knowledge--and is as famous and influencial in the United

States, where he has been a full professor at Stanford University since 1984, as he is in France, where he holds a professorial chair at the Collège de France. According to him, the most serious problems which confronted the sciences during these past thirty years have not concerned either biology, or chemistry, or physics, as isolated fields, but they have been interdisciplinary. He recently declared (1992b 24): "When Tchernobyl exploded, it was not a Russian problem," it also was French, German, Spanish, Italian, etc. On several occasions, Serres has stressed the epistemological shift from local to global. All areas of science need to be concerned with the totality of the planet, be it mathematics, logic, physics, chemistry, biology, geology, etc.

Serres sees as a problem the fragmentation into specialties, and believes that claims of singularities most often carry potentials for confrontations, and oppositions. Within the field of science, Ron mentioned the multiplicity of scientists communities and the problems posed by the ensuing fragmentation, dispersion, competition and rivalries.

On the other hand, Serres perceives a plurality of "appurtenances," an openness to the "other," as a richer source of knowledge as well as a potential for peace. He considers himself a "metis," a "quarteroon" (Serres, 1992a, 46), mixing sciences and humanities. He recalls all the scholars who, through the ages, practiced similar linkages (Plato, Aristotle, Leibniz, Pascal). He points out that the separation between the "scientific ideal" and the "temptation of the humanities" is only relatively recent, dating from the Age of Enlightenment, and is perhaps even as recent as the advent of the contemporary university.

He believes that with some distance, the relationships between and amongst fields of knowledge and research should be evident, and that a synthesis is necessary where there is only "exploded culture." In her paper, Petra has already presented a critic of the "add'n stir" approach , and has shown how what Gerda refers to as "compensatory history" is vastly insufficient. The categories still remain fragmented and isolated.

At any level of multiculturality or multidisciplinarity, I would suggest a different approach. Bachelard pointed out that the "theory of chemistry" was "founded in union with the theory of physics" (MR 213), and at the beginning of this century, a new science appeared called chemistry-physics. In 1953, he described "physico-chemical sciences" as sharing a "common rationalism" (MR 214). The emergence of new fields such as biochemistry and molecular biology, have shown that two different fields may influence each other. There may be a certain amount of interaction between them. However, a mere transfer of information, or addition of knowledge from one field to another is insufficient to account for such events. An interplay between the fields takes place, where both fields contribute to composing meaning, and to constructing knowledge. In the act of understanding phenomena, a transaction takes place where understanding and meaning are composed by both fields, and the end result actually is a new event, larger than the sum of its parts. I believe that this transactive approach to multidisciplinarity or multiculturality, within as well as outside the sciences, would lead to a better understanding of the processes of learning, teaching, and research in science education.

Implications for science education

The pluralistic philosophy of scientific notions
is a guaranty of fecundity in teaching. (RA 18)

Bachelard believed that "the pluralistic philosophy of scientific notions is a guaranty of fecundity in teaching" (RA 18). A teacher himself, graduated from the most prestigious higher education institution for teacher education, the Ecole Normale Supérieure, Bachelard gave much importance to the pedagogical aspects of scientific concepts. He often stated that he was more of a teacher than a philosopher, and that "the best way to measure ideas is to teach them" (RA 12). He also recalled the well known paradox that "teaching is the best way to learn" (RA 12). He believed that the act of teaching and self-conscious knowledge are tightly linked. He saw teaching as the superimposition of one intellect upon another, causing a "reaction" between the teacher's pedagogical clarity and the mind of the disciple being taught, and resulting in a "restructuralization" of the latter (RA 12). In the act of teaching, the rational consciousness of knowledge of the teacher is superimposed onto the empiric consciousness of the student. According to Bachelard, this is "the shortest, and most instructive itinerary" (RA 14). Learning is then a reviewing process of the "composition" or structuring of knowledge. The deeper the review, the closer it leads to a review of the composition of the very being, or to be more exact, declared Bachelard, it leads to "the composition of the very being in the beautiful forms of rational thoughts" (RA 15).

This personal structuring of knowledge follows the cultural route mentioned above. This route is marked out by "ideas as they evolve through the teaching process, placing them systematically in the interpsychological field whose poles are the teacher and the student" (RA 19). In that space, the interaction between teacher and student shapes knowledge according to their respective cultural contexts. Therefore, the structuring of this taught rationalism will have to be verified, "like a <u>value</u>, the value by which we realize that <u>to understand marks the emergence of knowledge</u> [Bachelard's emphasis] (RA 19). The teacher is the mediator who helps the students understand, within the context, maintaining the dialectic between reason and reality. "Thus the interrationalism which is being constructed and which can be perceived in the dialectic between teacher and students, is philosophically richer in teaching [and learning] than formalized realism" (RA 20). However, Bachelard pointed out that it is only but a moment, albeit an important one, of the whole process of teaching and learning.

Other events have rendered the question of multiculturalism and multidisciplinarity in sciences more acute, especially in the second part of this century. Serres pointed out that between 1940 and 1960, while sciences grew by leaps and bounds, problems of scientific responsibilities and ethics grew proportionately. Before Hiroshima, science had always been "good," providing "technology and remedies, forever the savior, adjunct to labor and health, reason and enlightenment" (Serres, 1992a, 31). There were no dispute on any possible relationship between sciences and anything questionable. "Everything happened as though the city which housed those who labored on the scientific evidence were populated with good children, naive, industrious, and meticulous, blessed with good will, and with no political or war agenda whatsoever. Yet, were they not contemporaries of the Manhattan project which prepared the bomb?" (Serres, 1992a, 30). Serres believes that after the explosion on Hiroshima, it is of vital importance to "re-think the scientific optimism" (Serres, 1992a, 29).

While sciences were developing at a fast pace, it was a time of great enthusiasm among scientists, with the advent of "Big Science." However, it is common knowledge that even prior to WWII, some physicists had abandoned their field of research. They feared that their work was contributing to the manufacture of the bomb. Majorana, a sicilian atomist who abandoned his research, was one of them. A few years later, in another specialty of science, Monod confided to Serres:

> For a long time, I laughed about the physicists wrestling with problems of conscience because I was a biologist at the Pasteur Institute; because I was creating and proposing remedies, I was always working with a clear conscience, whereas the physicists could have gone over to the manufacture of arms, or to violence and war. However, now I can see that the demographic wave of the third world could not have happened without our intervention. Therefore, I ask myself as many questions as the physicists did about the atomic bomb. The demographic bomb may be even more dangerous. (Monod, cited in Serres, 1992a, 31)

For Monod, knowledge was his ethic. Yet he had posed a major question, that of scientific responsibility. Now science has come face to face with moral, ethics, sociopolitics, and philosophy. Should the question of its transactive relationship with these other disciplines be an integral part of science education and research?

Since, according to Bachelard, "one of the functions of science education is precisely to elicit a dialectic" (MR 21) it should be not only an area of content teaching, but also a tool to bridge the gap, or establish a dialectic between multicultural and multidisciplinary differences. Bachelard wrote his books on science and science education with more in mind than merely instructing his readers. He was hoping that they would also change them. Trying to grasp the dialectics developed between matter and energy, and waves and particles, he hoped his readers would also learn "to maintain difference, handle complexity, and be shaken out of the reductive, identity-ridden habits of ordinary life and thought" (BP 7).

References

Gaston Bachelard

References to Bachelard's writings are in the text, using abbreviations. A key to these abbreviations is given below.

RA Bachelard, G. (1949). Le Rationalisme appliqué. Paris: Presses Universitaires de France.

HDS Bachelard, G., Schrödinger, E., Auger, P., Guyenot, G. de Santallina, Dubarle, R. P. (1952). L'Homme devant la science. Textes des conférences et des entretiens organisés par les Rencontres Internationales de Genève. Neuchatel: Editions de la Baconnière.

MR Bachelard, G. (1953). Le Matérialisme rationnel. Paris: Presses Universitaires de France.

FES Bachelard, G. (1957, third edition). La Formation de l'esprit scientifique. Paris: Presses Universitaires de France.

NES Bachelard, G. (1958, sixth edition). Le Nouvel esprit scientifique. Paris: Presses Universitaires de France.

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Multiculturalism Redefined in Science Education: Conclusion or More Questions?

In this paper, a science educator, a social studies educator, and a language educator began by considering the question of multiculturalism in science education. As we conclude this paper (certainly not the discussion) it seems our considerations have included seeking a deeper understanding of how science is "in" culture. When "multiculturalism" is understood as the process of understanding the contextual and situated nature of all knowledge, "multiculturalism" becomes not something which one puts "in" science education, but is inherently part of, and necessary to, understanding science and the scientific process. Science, like culture, is not an "object to be described" (Clifford & Marcus, 1986) but is negotiated, temporal, and emergent.

Schlagel's, Bachelard's and Serre's focus on context as central to understanding science highlights the "dynamic, discursive" process which is essential to science. Bachelard (1956) noted that homogeneous systems are more of an obstacle than an impulse to progress in the various sciences that study nature. Rather than see "multiculturalism" as an obstacle to reliable knowledge, Bachelard's concept of "epistemological obstacles" suggests that if we ignore the diversity that can be gained through situating science in historical, epistemological and cultural contexts we risk not achieving a dynamic view of science. Dynamic science means science's ability to "break out of its own bounds." The focus on "difference", in much of the multicultural literature, can be understood in science (or any other discipline) as not solely an issue of race or ethnicity, but in the sense of Derrida's use of the term as a "vehicle to break apart all unities."

For students of science to gain a deeper understanding of "science" and "scientific progress" the authors of this paper have argued for more context and complexity in science education. Exploring culturally embedded assumptions regarding the nature of science through using the histories and philosophies of the natural science would help students better understand the dynamic, complex natures of the natural sciences. Current understandings of science as a transmittable body of knowledge would be reconsidered in light of a "transactive approach" which acknowledges context and the interdisciplinary nature of knowledge. Teaching science as dynamic and context-dependent (multicultural) would entail conveying to students how "science" has come to be and continues to evolve, rather than teaching science as a bound, discrete discipline. Such an approach to science education would not focus on "culture" as "out there", but as a way of thinking which continually asks us to question taken-for-granted assumptions central to "understanding" the scientific process. Understood in this way, multiculturalism should result in a more, rather than less, dynamic science.