School Science For/Against Corporate-friendly Citizenship

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ABSTRACT

There is, unfortunately, considerable evidence and theoretical support for the contention that school science is structured to serve interests of the world's social-economic elite, rather than children to be educated. In short, it seems to be designed to reproduce and, indeed, enhance global social-economic stratification. Its net effects appear to be generation of a small cohort of knowledge producers and a large mass of knowledge consumers (along a continuum). In this paper, after elaboration of several mechanisms that appear to contribute to such undemocratic effects, some perspectives and practices are discussed that should promote: *inclusion*, rather than elitism, *diversity*, rather than conformity, *self-motivation*, rather than passivity, *comprehension*, rather than confusion, *awareness*, rather than naivety, *self-determination*, rather than regulation and *collaboration*, rather than isolation. At the same time, it is stressed that few of these perspectives and practices are likely to take effect in schools until the economic elite and their political supporters become aware of anti-democratic effects of school science and possible reforms that may lead to a more just science education.

INTRODUCTION

It is apparent that children are being used, effectively, as "raw material fashioned by structures into functions of production and sites of consumption in the capitalist system" (Weinstein, 2000, p. 96). The milieu in which teaching and learning occur is now overwhelmingly affected by feverish efforts on the part of governments to assist businesses in successfully competing in increasingly globalized economic markets. The discourse of *economic rationalism* is evident in curriculum policy documents like *A Nation at Risk* in the USA:

> Our *Nation* is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by *competitors* throughout the world. ... If an unfriendly power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of *war*. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral *educational disarmament* (NCEE, 1983, p. 5; emphases added).

Other jurisdictions have, dutifully, incorporated this ideology into their curricula. The government of Ontario, for example, seems overly beholden to commercial interests—rather than to the people they were elected to serve:

> The new Ontario curriculum establishes high, internationally *competitive* standards of education for secondary school students across the province. The curriculum has been designed with the goal of ensuring that graduates from Ontario secondary schools are well prepared to lead satisfying and *productive* lives as both citizens and individuals, and to *compete* successfully in a *global economy* and a rapidly changing world (MoET, 2000, p. 3; emphases added).

Since release of *A Nation at Risk*, "corporate elites and elected officials have orchestrated a massive propaganda campaign aimed at convincing the public that schools are, at once, the cause and the cure for their economic insecurity. In typical fashion, the media very obediently assisted in facilitating this fraud" (Gabbard, 2000a, p. xiii). "As declared 'allies of the state' schools work as an ideological apparatus to 'shape advantage' for those who are in the best position to push the levers of capitalist accumulation" (McLaren & Baltodano 2000, p. 47). This neo-conservative, neo-liberal campaign has been so successful that few can deny that a kind of 'corporatese' has been successfully infused into normal discourse in industrialized nations; including terms and phrases such as: *competition, individual responsibility, standardization, efficiency and accountability* (Anderson & Cavanagh, 1996; Beyer, 1998; Dobbin, 1998). Gabbard (2000a) suggests that *global economization* "subordinates all other forms of social interaction to economic logic and transforms non-material needs, such as education, into commodities" (p. xvii). Consequently, it is apparent "globalization in its contemporary forms is colonialism writ large, in that it is associated with the further and more complete spread of Western specific and especially Anglo-American specific language, economic practices, cultural forms and social relations" (Marginson, 1997, p. 23). To maximize profit, corporations need governments to develop curricula focusing on "the transmission of economically valuable skills and the grading and selection of learners for a hierarchy of economic roles" (Winter, 1998, p. 58). Corporations can benefit from "a school system that will utilize sophisticated performance measures and standards to sort students and to provide a relatively reliable supply of ... adaptable, flexible, loyal, mindful, expendable, 'trainable' workers for the twenty-first century" (Noble, 1998, p. 281). In other words, corporations can benefit from schools that function as 'bio-technologies'; that is, mechanisms of social engineering that mold children in ways conducive to production and consumption of goods and services.

Given the prominent role professional science and technology play in industrialized—and, more recently, in knowledge-based—societies, it follows that there must be significant ways in which school science assists in this social engineering. In this article, several mechanisms of corporate-friendly social engineering apparently at play in school science are used as a basis for describing changes to science education that may lead to more democratic forms of citizenship.

'BIO-TECHNOLOGICAL' EFFECTS OF SCHOOL SCIENCE

In her book, *The Real World of Technology*, Ursula Franklin (1999) contrasts characteristics of *prescriptive* and *holistic* technologies and their respective effects on people. With the former approach, each worker performs a separate task in a chain of events that is conceived and managed by central planners—all designed to efficiently generate large numbers of a desired product. Automobiles are built this way, with each worker repeating a separate task on an assembly line. Increasingly, it appears humans are 'engineered' this way, as well. Central planners—especially personnel in government, often with influences from business 'partners'—develop 'product specifications' (i.e., statements of expectations for student achievement), categorize them into useful groups (e.g., subject disciplines), make recommendations for implementation by workers (e.g., policy guidelines for teachers) and monitor efficiency of production (i.e., through curricular and instructional assessment and evaluation).

Using principles inherent to prescriptive technologies to educate humans generally is, however, unjust. Humans should not be treated like so many car models; thousands with identical styling, colour, engine capabilities, etc. Given humans' right to self-determination and diversity, it is essential that education be structured as a *holistic* technology. In this conception, each child is nurtured in ways meeting his/her needs, interests, perspectives and abilities—rather than being shaped towards certain 'product specifications' that meet needs and interests of those who control their education. "Any tasks that require caring, whether for people or for nature, any tasks that require immediate feedback and adjustment, are best done holistically" (Franklin, 1999, p. 17). Drawing on principles inherent to *situated cognition* (Lave & Wenger, 1991), *activity theory* (e.g., Engeström, 1996), *communities of practice* (Wenger, 2000) and *naturalistic epistemologies* of knowledge (Lincoln & Guba, 2000), for example, meaningful and just learning can be construed as something that occurs in a unique way for each individual, in each particular (usually social) learning context. Many learning contexts would be like a *Gestalt* experience, in which myriad situational variables interact to generate outcomes that are different from the collection of component variables. Central planners cannot (and should not) pre-determine every outcome in this sort of education. Instead, particular students and their peers, those that care for them, teachers and others in the local context interact in ways unique to their situation. It is this unpredictable uniqueness that is most empowering for students being educated.

It is apparent school science is in serious need of being transformed into a *holistic technology*. There is considerable evidence it is being used as a significant element in a prescriptive '(bio-)technology' (human engineering system) operating to generate societies conducive to maximizing corporate profit. Overall, the role of school science in this appear to be to generate citizens who can perform, i) a *production* function, capable of labouring to produce goods and services and ii) a *consumption* function, willing to enthusiastically consume products and services. Ways in which these twin functions of promotion of production and consumption may operate in school science are elaborated below, along with appeals for subverting these effects—so that school science may become more democratic.

The Production Function: Identifying and Educating Knowledge Producers

For maximizing profit, businesses need (amongst a variety of factors) an appropriate work force—one that can produce goods and services with mass appeal, but at a minimum cost. Increasingly, especially with the advent of the so-called *knowledge economy*, that can be achieved with a workforce composed of a few *symbolic analyzers* (i.e., those who can analyze and manipulate symbols, including words, numbers and visuals), such as scientists and engineers, and a larger mass of progressively less skilled workers who can effectively follow labour instructions from the symbolic analyzers (Gee *et al*., 1996; Lankshear, 2000). School science appears to be structured to generate a relatively small contingent of knowledge producers (i.e., symbolic analyzers) and large numbers of knowledge consumers. These are the *production* and *consumption* functions, respectively, of school science.

In order to identify knowledge workers (symbolic analyzers), school science operates like a complex *testing* environment. Official curricula, textbooks and traditional teaching practices tend to be overly geared towards identifying students with the potential to become scientists or engineers (Claxton, 1991) who may—as *symbolic analyzers*—help develop and manage mechanisms of production and consumption of goods and services for business and industry. Selection of these knowledge workers is generally accomplished through the emphasis in school science on rapid-fire teaching and learning of *abstractions*, such as laws and theories, often in the absence of practical applications. This makes school science a *survival of the fittest* experience. However, because those with an aptitude for abstract thinking tend to be rich in *cultural capital* (Bourdieu, 1983)—derived from experiences with abstract talk, encouragement to read and access to new technologies (Henry *et al*. 1999), for example—school science often is a survival of the (culturally) *richest*. Indeed, according to Lemke's (2001) discourse analyses of schooling in general, "curricula and teaching methods are ... most closely adapted to the needs of middle- and upper-middle-class, culturally North European-American, fluent speakers of prestige dialects of English" (p. 306). Overall, "one of the greatest determinants of academic success is parental income .... [T]he myth of equal opportunity therefore masks an ugly truth: the educational system is really a loaded social lottery, in which each student gets as many chances as his or her parents have dollars" (McLaren, 1994, pp. 220-221). Consequently, we appear to be dominated by a "democratic-capitalist social order in which commodity fetishism, the rule of the market, patriarchy, and White supremacy constrain, distort, and oppress the expression of many individuals" humanity and their ability to act democratically" (Beyer, 1998, p. 260). "Thousands of years of human development and progress are reduced to the pursuit of 'efficiency,' our collective will is declared meaningless compared to the values of the marketplace, and communitarian values are rejected in favour of the survival of the fittest. A thinly disguised barbarism now passes for, is in fact promoted as, a global human objective" (Dobbin, 1998, pp. 1-2). Regrettably, this elitist situation is not improving, as many jurisdictions are *raising* standards—i.e., setting the bar higher—with "challenging new curriculum" (MoET, 1998, p. 3). As a result, "[school science] is not terribly popular. It commands respect, but not affection" (Ogborn, 1996, p. 147).

The Consumption Function: Training Knowledge Consumers

As a result of this intense effort to identify and educate the relatively few students who may choose careers in science and engineering, many students are left relatively scientifically illiterate. Such illiteracy is good for business, however. It leaves people more likely to function as consumers of knowledge, rather than producers of it. As such, they may more likely: i) serve as compliant workers, willing to 'consume' (follow') labour instructions provided by knowledge workers (and, ultimately, financiers) and ii) 'consume' (e.g., purchase) goods and services produced by business and industry. There appear to be at least six mechanisms operating within school science that contribute to such consumerism:

1. Conformity via Standardization: Like business and industry, schools systems are organized to generate graduates that adhere to tight 'product specifications'; that is, to precise standards of achievement. Governments claim such uniformity in curriculum and instruction will guarantee all learners equal opportunities, regardless of their learning situation (AAAS, 1989, 1993; DfEE, 1999; MoET, 1999; NRC, 1996). Another perspective, however, is that standardization is leading to societal *conformity* (Elkind, 1997). For example, "around the world, ... science students are expected to construct scientific concepts meaningfully even when those concepts conflict with indigenous norms, values, beliefs, expectations, and conventional actions of students" life-worlds" (Aikenhead & Jegede, 1999, p. 270). It is apparent, "Eurocentric traditions have privileged certain facts and people, excluding whole races, classes, and segments of society from full participation in learning or living" (Gross, 1997, pp. 16-17). Along these lines, Lemke (2001, p. 301) provides a clear example of a cultural clash in school science:

   > To adopt an evolutionist view of human origins is not, for a creationist, just a matter of changing your mind about the facts, or about what constitutes an economical and rational explanation of the facts. It would mean changing a core element of your identity as a Bible-believing (fundamentalist) Christian. It would mean breaking an essential bond with your community (and with your god).

   Such societal conformity is good for business. The more people are alike, the more susceptible they may be to mass marketing (Galbraith, 1958), a major *consumption* function. That the English language is becoming more ubiquitous around the world, for example, can enable corporations to communicate with and influence larger markets (Lankshear, 2000). "If choice [e.g., amongst schools] combined with national standards results in uniformity of thinking [and speaking] in public schools, then democracy is dead" (Spring, 2000, p. 30).

2. Confusion via Intensification: While governments claim that standardized expectations (and accompanying testing/assessment) for student learning should improve student achievement, the converse frequently occurs. Often, being a student of school science is like trying to take a sip from a fire hose! It also has been likened to a ride on "an out-of-control roller coaster" (Millar 1996, p. 8). All too frequently, teachers feel compelled to 'cover' curriculum content (i.e., for learning *science*) so rapidly (intensely), and with few opportunities for application in personally meaningful contexts that many students are left confused or only capable of rote learning (Claxton, 1991; Jenkins, 2000). Millar (1996) claimed, for example, that most studies of students' (by the age 16) understandings of fundamental laws and principles of science—including the particle theory of matter, the model of the solar system, and ideas about animal and plant gas exchange—are either simplistic or quite different from those of scientists. Similar results are obtained for lay adults. According to a student in the UK, for example, "You just get to know what you're talking about and [teachers] change [the topic] ... you forget everything that you know ... in the end you do not know what you are doing" (Claxton, 1991, p. 24).

   This sort of illiteracy may be good for business because citizens would be less able to contribute to public decision making on matters pertaining to science and technology. Also, with poorer understandings of science concepts, they may be more inclined to have those supplied by others—including businesses, who control much of professional science and technology.

3. Passivity via Saturation: In addition to causing confusion, the rapid-fire transmission of *achievements* (e.g., laws and theories) of professional science can have a *pacifying* effect on students. They can be, in effect, lulled into habits of consumption. The "medium [of school science] is reinforcing the message ... that science education is about remembering the results of other's [professional scientists' and engineers'] research ('facts') rather than developing the ability to conduct one's own" (Claxton, 1991, p. 28). A steady diet of conclusions can stifle students' desire to ask questions, to critique claims, to criticize those who control knowledge and to develop their own conclusions. It may condition them into habits of passive consumption. This may be good for business, though, as such passivity can ensure workers follow labour instructions and that people think of themselves as consumers of products and services, rather than producers of them. Saturating people with consumer goods (or scientific and technological achievements) has, indeed, served as an excellent pacifying technique (Galbraith, 1958; Dobbin, 1998). Henry Ford, for example, suggested that approach for defeating the Bolsheviks:

> The way to a greater wealth is to use our new production techniques to create and distribute commodities to those capable of laboring to earn them. [Remember,] material poverty is the seedbed of seditious ideas. We will sterilize that seedbed with goods carefully designed to addict and render impotent the majority of citizens (cited in Fawcett, 1990, p. 72).

4. Dependence via Regulation: Student passivity is exacerbated in school science by the tendency for student decision-making to be *regulated*, thus limiting the extent to which they may think independently. Paradoxically, students rarely, if ever, *do* science in school science. In other words, texts or teachers invariably control decisions about areas of exploration, questions or problems to solve, methods of data collection, analysis and critique and decisions about conclusions from the investigations (Hodson, 1996; Lock, 1990). Even with constructivism-informed pedagogies, through which students might *believe* they are freely constructing knowledge, coercion often occurs. Students' thoughts and actions are 'attacked' in ways ensuring their conclusions match those of Western science, including by: i) maligning their pre-instructional conceptions, ii) engineering their empirical inquiries and iii) regulating their conclusions (Bencze, 2000a). This sort of mind and action control, where it occurs, is undemocratic. It is a sign students in schools are being *oppressed*. Indeed, such a situation

> in which some men [sic] prevent others from engaging in the process of inquiry, is one of **violence**. The means used are not important; to alienate men from their own decision-making is to change them into subjects (Freire, 1997, p. 73). … [A] dominator has no choice but to deny true *praxis* [reflective action] to the people, *deny them the right to say their own words and think their own thoughts* (Freire, 1997, p. 107, emphases added).

Having had many of the procedures in which they participate and conclusions about which they draw regulated by authorities, students may leave school without expertise for and confidence in various aspects of problem-posing, problem-solving and peer-persuasion phases of knowledge-building. This sort of education can "denaturalize thought and reason … to stop people from acting and participating … through generating the rules by which action and participation occur" (Popkewitz, 2000, p. 40). Students may remain dependent on those controlling professional knowledge-building which, currently, is largely in the hands of corporate interests.

5. Naïvety via Idealization: School science is—in various ways—like an 'infomercial' for professional science. Achievements of science (e.g., theories) are made to appear certain, methods of achieving those portrayed to be efficient and objective and the sciences are depicted as unproblematic in their relationships with fields of technology, societies and environments (Hodson, 1999; Solomon & Aikenhead, 1994). Among myths about professional science perpetuated through school science are that: i) observation provides direct and reliable access to secure knowledge, ii) science starts with observation, iii) science proceeds via induction, iv) experiments are decisive, v) science comprises discrete, generic processes, vi) scientific inquiry is a simple, algorithmic procedure, vii) science is a value-free activity, viii) science is an exclusively Western, post-Renaissance activity, ix) the so-called "scientific attitudes" (e.g., lack of bias) are essential to the effective practice of science, and x) scientists possess these attitudes (Hodson, 1999). Such naïve views about the nature of science can lead students to become uncritical consumers of products of science and technology.

Such scientific illiteracy must be eliminated. Sociological and historical studies of scientific practices suggest that hoarding of information, cultural variations in science practices, personal and group biases, plagiarism, and blind trust in data often are found in authentic scientific practices (e.g. Knorr-Cetina, 1995; Latour & Woolgar, 1986; Lynch, 1985; Traweek, 1988). While the sciences have contributed enormously in many positive ways in societies, they are not completely unproblematic. To suggest the sciences are nearly robotic (in terms of efficiency and objectivity), almost god-like (in the sense of being all-knowing) and entirely altruistic (with respect to effects on societies and environments) represents a huge disservice to students. With such naïve views about professional science, students would be *intellectually dependent* on authority figures (Munby, 1980), ill-prepared to make informed judgements about scientific products and practices. Indeed, because of increased advertizing in our society, students may be, contrary to official claims, "prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems" (AAAS, 1989, p. 13). "We are 'colonized' if our learning is limited to received knowledge. We are not fully literate unless we develop 'meta-knowledge' " (Gee *et al*., 1996, p. 137).

6. Disempowerment via Individualization: Finally, as part of the selection process that identifies and educates potential scientists and engineers, students are forced to *individualize* and compete amongst one another for assessment success in school science. While businesses value collaboration, to an extent, we increasingly live in an age in which "radical individualism" is promoted and "the social good is revealed in and through the actions of independent, self-motivated individuals—especially as they engage in economic exchanges" (Beyer, 1998, p. 250). "[P]ossessive individualism" is promoted; that is, "a set of skills, capabilities, and knowledge that promise an individual the possibility of successfully negotiating the hazards of a competitive and predatory culture" (Shapiro, 2000, p. 103).

> In such an environment, a student learns that when the boy seated next to her drops out of school, he is solely responsible for the decision. In the words of the Conference Board of Canada, he has 'apparently ignor[ed] the tremendous cost to himself and society.' What happens to him is of no concern to her. She is learning to blame the unemployed for their condition ... (Barlow and Robertson, 1994, p. 82).

At the same time, such a focus on individualized, competitive learning and assessment may promote consumerism—because isolated individuals may be more dependent on producers of goods and services than would be members of collaborative teams. Ideas, motivation and other factors in knowledge building are made *scarce*. "Economization insists on scarcity as the defining characteristic of the human condition" (Gabbard, 2000a, p. xx). Scarcity thus created in the minds and conditions of the public can, then, be filled by business and industry.

Such mind and motivational control is *undemocratic*. There appears to be a "decidedly undemocratic spirit that motivates reforms designed to keep the public ignorant and passive as opposed to enlightened and active" (Wood, 1998, p. 185). This generally stratifying and disempowering education appears to represent a major mechanism for maintaining the global economic *status quo*—that is, a modern-day feudal system in which a small fraction of the world's population controls the vast majority of Earth's wealth (Chomsky, 1993). Gaps between rich and poor are getting so great, indeed, some refer to existence of a "global economic apartheid" (McLaren & Baltodano, 2000, p. 56). Astonishingly, "what [may look] like the apex of humanism [may], in fact, [be] the pinnacle of human submission: children are educated to become precisely what society expects of them" (Ellul, 1954, p. 348). School systems need to ensure students of science have opportunities to develop realistic conceptions of the nature of science (as argued earlier) and *abilities* (and opportunities) to *create* knowledge using methods of science, in addition to learning products of professional science and technology (Hodson, 1998).

TOWARDS A MORE DEMOCRATIC SCHOOL SCIENCE

It is apparent that, like ancient 'Philosopher Kings' (Plato, c375 BC), a relatively small cohort of globally-connected economic elite govern the lives of the vast majority of humanity (Henry *et al*., 1999; Martin & Schumann, 1997). Economically, the top twenty percent (20%) of US society, as an example, controls ninety-four percent (94%) of total financial wealth, while most of the rest is controlled by the next quintile (Tozer, 2000, p. 152). Similarly, it is estimated that about eighty percent (80%) of working populations in the USA are "exploited and excluded" (Percucci & Wysong 1999, p. 100). Many of the rulers control large trans-national corporations and, through those, the rest of us (Dobbin, 1998). A key instrument of their control is public science education, which has the power to influence human thought and action when people are most impressionable (DeBoer, 2000). Under such control, the phrase 'public science education' is an oxymoron. Public schooling in science seems to be structured to serve needs and interests of private businesses and industries more than those to be educated. More importantly, for most students, school science is not an education at all but is, rather, a mechanism for making them subservient. As discussed above, an over-emphasis on identifying and educating the relatively few students who may choose careers in engineering and science tends to create—as a by-product—a large mass of students who are relatively scientifically illiterate. That most survivors of this intense selection process tend to be cultural rich also means that school science often is elitist. Only a few advantaged students in any school develop a reasonable level of scientific literacy. Of those, a small fraction will choose careers in engineering and science and, through those, help businesses and industries develop and manage mechanisms of production and consumption of goods and services. A large fraction of all students entering secondary schools will, generally, develop minimal scientific literacy. Indeed, it is apparent their 'education' will be, in effect, an apprenticeship for a life of consumerism. They will be 'consumers' in at least two senses; i.e., i) as faithful followers of labour instructions from central planners and ii) as enthusiastic consumers of goods and services of business and industry. Their preparation for this consumerism will have involved at least six mechanisms inherent to school science. Firstly, because governments have standardized what they are to learn, and—to a great extent—how they are to learn, they may become more alike. Businesses can more efficiently advertize and sell to a homogeneous market than to a diverse one. Secondly, by saturating students with volumes of scientific achievements (e.g., laws & theories), they can become habituated to consuming products, rather than producing them. Thirdly, because of the intensity with which teachers must 'cover' large volumes of scientific achievements, many students are left confused about laws and theories of nature and, consequently, more willing to leave scientific decisions to others. Fourthly, because products and practices of science are made to appear exceedingly ideal, students may be naïve about possible problems related to science—and, by association, business and industry. Fifthly, because teachers tend to control—for various reasons, many beyond their control—most learning decisions, students tend to become de-skilled in terms of abilities needed to solve scientific problems independently. Consequently, they may be more willing to let others solve problems for them. Lastly, because school science—and many other subjects—tends to force them to be assessed individually, students tend to miss out on benefits of collaboration, including abilities to solve problems independent from authorities.

Where a public service like science education is being used—consciously or otherwise—for such social engineering, it is clearly undemocratic. It must be subverted and made more *just*—as soon as possible. In short, based on the arguments above, school science needs to become more *inclusive*, rather than elitist, *pluralist*, rather than conformist, *self-motivating*, rather than pacifying, *comprehensible*, rather than confusing, *realistic* rather than idealistic, *self-determining*, rather than regulating and *collaborative*, rather than isolating.

> Everyone is potentially victimized when the separation between those with basic scientific knowledge and those without such knowledge grows too large. A small elite group with knowledge and political power (or controlled by such power) can manage the destiny of a larger, less knowledgeable and powerless society. If the decisions of the knowledgeable elite are 'good,' then everyone benefits. But, how can we be assured that the decisions will always be in the collective best interest? (Parke & Coble, 2000, p. 280).

Given this deplorable socio-economic situation, creation and maintenance of which school science appears to play a significant role, there is a desperate need to bring more democracy to schooling, in general, and science education, in particular. All students,

> regardless of gender or cultural background, [should] have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them (CMEC, 1997, p. xx).

Given the relatively mature state of science education research, along with research in fields such as psychology and sociology, there are many pedagogical perspectives and practices available to bring more democracy to school science. Several of these are described below, sorted in terms of Hodson's (1998) classification for learning outcomes in school science; that is, in terms of learning: i) *science* (i.e., achievements of science and technology, including laws and theories), ii) *about* science (e.g., learning about epistemological and ontological conceptions about science) and iii) to *do* science (i.e., to create scientific knowledge using appropriate selections of methods for particular contexts).

Towards Improvements in Learning <u>Science</u>

Many problems in school science could be solved by reducing—i.e., *consolidating*—expectations for student learning of achievements of science. While defining such essential scientific knowledge has been difficult, not settling on this is preventing educators from addressing other important aspects of scientific literacy—including learning *about* science and to *do* science. As argued above, as elsewhere quite often, with so many expectations in curricula for student learning of laws and theories of science, teachers often feel the need to 'cover' these so rapidly and with few opportunities for student application that students become habituated to consumption, confused about these concepts, and isolated from one another (because of competition for achievement in learning these concepts). This means that school science often represents a set of *instructions* about how to explain nature and how to bring about changes in it. At the same time, teachers are unable to provide adequate opportunities for students to learn about the nature of science, including its theory-based nature, possibility for human biases, and relationships amongst sciences, technologies, societies and environments. An excessive emphasis on expecting students to learn achievements of science also prevents them from developing expertise enabling *them* to create scientific achievements; that is, to develop knowledge about nature using methods of science. In short, as the American Association for the Advancement of Science (AAAS, 1989) has—officially—advocated for well over a decade, students should have opportunities to *do more with less*. It is high time this advice was heeded.

Through reduction in what students are expected to learn, students would be freed to apply fewer concepts and skills to important problem solving situations (Cajas, 1999; DeBoer, 2000; Fensham, 2000; Hodson, 1998; Jenkins, 2000; Longbottom & Butler, 1999). This would improve students' abilities to develop deeper conceptions of particular laws and theories. "Understanding, by its very nature, is related to action; just as information, by its very nature, is isolated from action" (Dewey, 1946, p. 49). Their learning of *science* would, thus, improve greatly.

While students from various sub-cultures need access to powerful Western scientific knowledge in order to participate in decision making on matters relating to science (e.g., regarding policies on genetically-modified foods), they do not, necessarily, have to change their fundamental *belief* systems. The concept of *border-crossing* into the sub-culture of Western science (and back to one's own sub-culture) has great potential to create more culturally accommodating curricula that allow people to develop *understandings* of scientific concepts without becoming committed to them:

> In the 21st century, the borders around school science need to be reshaped and reconstituted to encourage students classified as Other Smart Kids, 'I Don't Know' Students, or even Outsiders, to participate in collateral learning by helping them negotiate the cultural transitions into newly designed science programs, characterized by their inclusive curricula and culturally sensitive instruction (Aikenhead & Jegede, 1999, p. 284).

At the same time, culturally accommodating education must not be *one-directional*; that is, with minorities learning about the majority view, while the converse does not occur. Students in a democratic society deserve opportunities to develop an "egalitarian literacy" (Bencze, 2000a), literacy that acknowledges and respects ways of knowing and doing of diverse cultures, races, ethnic groups and both genders (Hodson & Dennick, 1994; Hynes, 1994; Rodriguez, 2001). All people of difference need opportunities to evolve—to adapt to new environments as conditions change. Since evolution depends on the degree of difference *within* a group, clearly it is likely wise for each group to *diversify*. From a community-of-practice (CoP) perspective, it may be unwise for groups to have closed borders; rather, they may need brokers (e.g., people participating in multiple CoP) and boundary objects (e.g., communications between CoP) (Wenger, 2000). This can provide for an intermingling of ideas and practices. In addition, besides such methods of sharing knowledge *already developed*, groups may need to promote diversity through knowledge *production*. In a science education context, that can translate into promoting opportunities for students to create knowledge using 'scientific' approaches—through, for example, student-controlled empirical science projects (Bencze, 1996, 2000a, 2000b, 2001; Gott & Duggan, 1995; Hodson, 1993; Roth, 1995). Because these encourage students (individually or in groups) to direct procedures and control conclusions (Lock, 1990), great breadth in perspectives about (e.g., theories) and changes to (e.g., inventions) natural phenomena may be developed.

Towards Improvements in Learning About Science

If students are to be properly and ethically educated, school science must be honest about limitations of and problems associated with professional science (Cunningham & Helms, 1998; DfEE, 1999; NRC, 1996).

> If we teach more rigorously about acids and bases, but do not tell students anything about the historical origins of these concepts or the economic impact of technologies based on them, is the scientific literacy we are producing really going to be useful to our students as citizens? The most sophisticated view of knowledge available to us today says that it is a falsification of the nature of science to teach concepts outside of their social, economic, historical, and technological contexts. Concepts taught in this way are relatively useless in life, however well they may seem to be understood on a test (Lemke, 2001, p. 300).

Students with better awareness of conceptions about science may be more fully equipped to function in participatory democracies (Wood, 1998) and, regarding matters of particular importance to them, prepared to become *citizen activists* (McGinn & Roth, 1999)—assuming leadership roles on important public issues relating to science.

Helping students develop awareness of more realistic conceptions about science, is however, a complex and problematic matter. To begin with, wide agreement about the nature of science does not exist (Rudolph, 2000). At the same time, students tend to have difficulty 'discovering' (i.e., through *induction*) particular conceptions about science through their experiences with scientific practices, like when engaged in science project work (Abd-El-Khalick & Lederman, 2000). Consequently, it is important for educators to provide students with a breadth of—sometimes conflicting—perspectives about science, such as those encompassing Loving's (1991) Scientific Theory Profile[1]. At the same time, as argued above about conceptual learning, it is difficult for learners to develop deep understandings about conceptions associated with science without having opportunities to test (i.e., through *deduction*) competing conceptions through experiences with realistic knowledge building activities. On the other hand, it would be impossible for educators to provide students with experiences with all possible cases of science in action against which students might judge propositions about science. Consequently, the most philosophically sound approaches to nature-of-science education may be those that provide inductive and deductive immersion experiences in as representative a collection of cases of science-in-action as possible (Bencze & Elshof, under review).

Towards Improvements in Learning to Do Science

To ensure schooling is not dominated by knowledge *consumption*, students need to develop attitudes and abilities (and be provided with conditions) enabling them to *construct their own conceptions of nature*. Curricula in democracies should include

> not only what adults think is important, but also the questions and concerns that young people have about themselves and their world. [They invite] young people to *shed the passive role of knowledge consumers* and assume the active role of 'meaning makers'. [They recognize] that people acquire knowledge by both studying external sources and engaging in complex activities that require them to *construct their own knowledge* (Beane & Apple 1995: 15-16; emphases added).

In the context of school science, this can be accomplished by encouraging students to conduct science projects largely under their control, often dealing with topics of concern to them (Bencze, 2000b; Gott & Duggan, 1995; Lock, 1990; Roth, 1995). With project work, more learning would be like a *Gestalt* experience (Wertheimer, 1959)—with unique sets of learning outcomes arising from each particular context in which myriad situational variables interact. Among contexts in which such idiosyncratic knowledge building could occur would be science projects directed by teams of

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[1] Loving's (1991) Scientific Theory Profile is composed of a grid with two intersecting axes. The epistemological axis is a continuum extending from Rationalism through Naturalism, intersected at right angles by an ontological spectrum from Realism through Antirealism.

students. Students might, for example, investigate effects of pH changes on mineral retention in soil or changes in room lighting patterns on humans' mood, or they might attempt to engineer biodegradable forms of packaging. With each particular group of students tackling such projects, questions they ask, problems they pose, methods they develop, conclusions they draw and forms of communication of conclusions they conjure would be unique to that set of students, in their particular circumstances for knowledge development. It would be an "individualizing pedagogy, which aims to help students cultivate a discourse through which they can deliberate their interpellations and eventually construct a discourse unique to each of them, which will, as it continually mutates, constitute their ideology(ies)" (Weinstein, 2000, p. 100). Through engagement in common activities over extended periods of time, groups of students could—in principle—become *communities of practice* (Wenger, 2000), having developed shared discourse practices, tools, rules, beliefs, identities, tacit knowledge, domains of interest, etc. (Lave & Wenger, 1991). Such cohesion would be empowering for groups, making them less subject to systematic controls, such as universally applied curriculum standards and assessment practices. Rather than being oppressed by dictates from central planners, members of communities of practice are empowered through their freedom and ability to create outcomes unique to their situations. Others cannot easily control their knowledge and knowing because "the primary source of value creation lies in *informal* processes, such as conversations, brainstorming, and pursuing ideas" (Wenger, 2000, p. 244; emphasis added).

Without such opportunities to do science in social-historical contexts, students would not have had a science education. Moreover, education in science would continue to be about following instructions from others on how to explain nature (i.e., through scientific theories) and how to bring about changes to nature (i.e., through technological innovations). More particularly, because of structures inherent to industrialized societies, school science would be primarily about a transfer of instructions about how to think and act from the world's economic elite to the masses of workers and consumers. Gestalt experiences in school science can undermine this transfer of instructions. With this view, "curriculum could be something determined after the fact of education, like a curriculum vitae" (Davis & Samara, 2000, p. 174).

An excellent Gestalt-type learning experience for school science is *technological design*. Technology education, in general, and technological design, in particular, has traditionally been avoided in science education. Indeed, a major factor contributing to the selection role that school science plays is its domination, effectively, of technology education. Paradoxically, school science (and not technology education) selects students for admission to post-secondary programmes in both engineering and science. This difference in status appears to be due to the prestige science enjoys, as compared to technology, because of its association with *abstract* thinking—which has long been associated with the elite (McCulloch *et al*., 1985), and which has been used as a basis for promotion of science within the school curriculum by academic scientists (Fensham, 1993). Technology, meanwhile, often is stigmatized as only appropriate for "less able, concrete thinkers" (Fensham & Gardner, 1994, p. 168) and often is misleadingly portrayed as "the routine, tedious and menial application of the seminal products of pure science" (Layton, 1988, p. 369).

An over-emphasis on abstract, *de-contextualized* scientific knowledge in schools is highly disempowering. It has a great *depersonalizing* effect, suggesting that the most important knowledge is that which can be applied across all contexts, regardless of factors such as the nature of the people involved. Accordingly, there is a need to contextualize school science, to make it more relevant to individual needs, interests, perspectives and abilities. One approach to this is to infuse more *technology* education into science education (Cajas, 1999; DeBoer, 2000; Fensham & Harlen, 1999; Jenkins, 2000; Layton, 1993; Millar, 1996; Longbottom & Butler, 1999). Technological thinking is highly *situated*, involving unpredictable interactions amongst myriad variables unique to each context, including the people involved in the design and the people for whom the design is intended (Bucciarelli, 1986). Promotion of such unique situations could help to subvert the discriminatory effects of the emphasis on abstractions that has characterized school science. A combined science and technology programme also makes *epistemological* sense. Generally, the two fields are more alike than many people might think (Bencze, 2001; Roth, 2001), although there is a paradox about this. On the one hand, science resembles 'technology' because, from a constructivism perspective, science invents useful ideas about nature. On the other hand, technology resembles 'science,' in the sense that it can characterize and explain the nature of natural phenomena—assuming that human inventions are part of nature (because humans are part of nature).

While some jurisdictions have, indeed, made provision for integrated science and technology programmes (e.g., MoET, 1998), curriculum frameworks for them are still rare. Fundamental to such frameworks, however, likely would be *constructivist* learning principles. Because these acknowledge and celebrate diversity amongst learners and, as well, use those as a basis for learning, constructivism-informed curricular approaches are inherently contextual. They view learning as highly *situational* (Lave & Wenger, 1991), involving simultaneous consideration of myriad contextual variables—including characteristics unique to particular learners. This makes them, as well, highly *inclusive*—with learners having considerable choice with respect to all problem-posing, problem-solving and peer-persuasion (Johnson & Stewart, 1990) aspects of knowledge development. Among pedagogical approaches grounded in constructivism are problem-based learning (PBL), in which 'real-life' issues or problems are used as a motivator and context for learning (Hmelo & Evensen, 2000). In a blended science and technology programme, a powerful variant of PBL is issues-based STSE (Science, Technology, Society and Environment) education (Solomon & Aikenhead, 1994), in which learning often occurs in the context of attempts to take actions relevant to a societal and/or environmental problem associated with science and technology. Indeed, given most students will not likely assume careers in science or engineering, it is likely more important they gain experiences and expertise enabling them to become citizen activists regarding issues of importance to them (McGinn & Roth, 1999). In these and other approaches, where control of learning has been ceded—to a great extent—to students (e.g., Bencze, 2000b), education is less about serving interests of controllers of education and more about serving those being educated.

Finally, although science (and technology) project work has had official curricular assent (e.g., DfEE, 1999; NRC, 1996), it has not, generally, been well implemented (Jenkins, 1995). As described earlier, teachers tend to be too pre-occupied with ensuring students develop conceptions of laws and theories of Western science. However, the problem also is that teachers are trapped in a vicious cycle; that is, because they have not, generally, conducted science projects under their control, they lack expertise to help students do such projects (e.g., Olson & Loucks-Horsley, 2000). Consequently, teacher education approaches that mentor student teachers in science project work and corresponding pedagogical perspectives and practices, some of which have enjoyed successes (e.g., Bencze & Bowen, 2003), need development.

Need for Political-Economic Awareness and Action

Pedagogical perspectives and practices described above could, in principle, help all students to gain sufficient scientific and technological literacy enabling them to live well-adjusted lives in societies that are greatly affected by professional science and technology. Graduates would have well developed conceptions of laws and theories about nature, realistic conceptions of the nature of science and would be able to conduct scientific investigations in meaningful contexts. Unfortunately, for most schools, very few of the recommendations for school science above work well. Most teachers are overwhelmed by demands to 'cover' learning expectations relating to achievements of science and technology. They perceive there to be few opportunities for: enabling students to express their pre-instructional conceptions (for constructivism-informed approaches), providing students with laws and theories other than those developed by Western science and technology, encouraging students to ask their own questions, explore the history, philosophy and sociology of science and technology, develop their own inquiries and socially negotiate (with peers) their own conclusions or organize curriculum around social and/or environmental issues in an STSE approach. To a great extent, many of these perspectives and practices are not promoted in schools because teachers lack experience with them. There is a kind of 'vicious cycle' at play; i.e., teachers of science de-emphasize these perspectives and practices because they were de-emphasized when teachers were students. Efforts to promote these perspectives and practices in teacher education often fail due to lack of support for them in schools, the environment most highly prized by student-teachers. Ultimately, as argued earlier, many of the perspectives and practices described above are not incorporated into schooling because of the excessively prescriptive and demanding nature of government curricula. A focus on improving teaching methods, etc. obscures the fact that curriculum is highly pre-determined and not subject to inspection or reconsideration (Davis & Samara, 2000). Ironically, teachers feel powerless against these mandates while, at the same time, mandating that their students attempt to achieve them. When teachers considered at what grade level to promote student controlled science projects, they chose grades (9-10) at which government curriculum guideline outcome statements were most *vague* (Bencze, 1995, p. 245). Teachers are, in effect, forced to exhibit an 'authoritarian personality'; that is, a tendency to oppress those below them in a hierarchy because they (teachers) are being oppressed by those above them. Systems of accountability depend on those with an authoritarian personality: "[T]o maintain the privileges of his or her status as an ambassador of authority, the delegate [of authority from superiors] wants to be judged as effective in fulfilling his or her function" (Gabbard, 2000b, p. 54). It is as John Dewey said so long ago (1944):

> The vice of externally imposed ends has deep roots. Teachers receive them from superior authorities; these authorities accept them from what is current in the community. The teachers impose them upon children. As a first consequence, the intelligence of the teacher is not free; it is confined to receiving the aims laid down from above. Too rarely is the individual teacher so free from the dictation of authoritative supervisor, textbook on methods, prescribed course of study, etc., that he can let his mind come to close quarters with the pupil's mind and the subject matter. This distrust of the teacher's experience is then reflected in lack of confidence in the responses of pupils. The latter receive their aims through a double or treble external imposition, and are constantly confused by the conflict between aims which are natural to their own experience at the time and those in which they are taught to acquiesce. Until the democratic criterion of the intrinsic significance of every growing experience is recognized, we shall be intellectually confused by the demand for adaptation to external aims (p. 109).

As argued in this paper, the "superior authorities" (in the Dewey quote above) who control curriculum and instruction in recent years are, primarily, financiers of large businesses and politicians who are accountable to these financiers. Therefore, as a first step towards promoting perspectives and practices that should bring more democracy to school science, pressures on politicians and business leaders must be exerted with great vigour. The problem is not curricular or pedagogical; it is *socio-economic*. Societies need to be made aware that "problems in learning may not reside in some deficiency in the student or in the student's background[, for example,] but in the interaction between a class-based school culture and the class-conditioned cultures from which students come" (Tozer, 2000, p. 158). Use of schools, in general, and school science, in particular, to maintain and enhance socio-economic stratification must end. "Public schools ... should not function to strengthen the state [including the economic elite]; they should strengthen the power of individuals to defend themselves from the state, to define and pursue their own interests" (Gabbard, 2000b, p. 60).

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