‘Spending’ Cultural Capital on People and the Planet: Theory & Practice.

A presentation at the international conference,
The National Value of Science Education: New Insights and Shared Challenges,
sponsored by The Wellcome Trust, UK, and the National Science Foundation, USA,
National Science Learning Centre, York, UK, September 17-18, 2007.

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ABSTRACT

An overriding/whelming consideration for educators in many parts of the world is the phenomenon of *global economization* — a process “that subordinates all … forms of social interaction to economic logic and transforms nonmaterial needs, such as education, into commodities” (Gabbard, 2000b, xvii). Many argue that this phenomenon is pathological, significantly contributing to personal struggles, social injustices and environmental degradation (McMurtry, 1999). Given the prominence of fields of professional science and technology in this process, school science systems often appear to be indirect contributors to individual, social and environmental problems relating to global economization. Carter (2005) suggests, for example, that *neo-conservatism* and *neo-liberalism* — which she claims govern global economization — underlie school science. In this paper, after further analysis of possible contributions of school science to economic globalization and related problems for individuals, societies and environments, 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 *collectivism*, rather than *individualism*. A key element of these transformations are theoretical frameworks that relate Wenger’s (1998) conceptions of *knowledge duality* (i.e., a reification-participation dialectic) and Foucault’s (1991) conceptions of *governmentality* (i.e., governing through influences on self-governing).

September 2007

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INTRODUCTION

Science education often functions, perhaps paradoxically, as a 'technology.' In other words, like many machines, it takes in raw materials (i.e., children) and frequently attempts to mold them into forms (i.e., people with particular conceptions, skills, attitudes, etc.) that may serve purposes deemed important by controllers of the technology. Unfortunately, the machine, the controllers of the machine, or both need(s) repair. Although its appears to continue to be successful, more or less, at generating its main products, its 'waste-products' seem to be increasingly problematic.

Problems associated with science education appear to stem from its overwhelming pre-occupation with selection and education of a relatively small number of potential knowledge producers (e.g. scientists, technologists, engineers and mathematicians) who may assist businesses and governments to accumulate wealth in an increasingly competitive and globalized marketplace. Adversely affected — to varying degrees — by this selection process is the 'science' (including technology, etc.) literacy of most other students. A not, necessarily, anticipated benefit for businesses and governments of such illiteracy, however, is that these students may function as knowledge *consumers* — generally amenable to accepting, without much question, labour instructions from the knowledge producers and, as well, purchasing, without much question, for-profit products and services of business and industry that were generated with the assistance of knowledge producers.

Underlying this role for science education is the business ethic of *competitive individualism*. Students must, in essence, compete for the limited supply of 'cultural capital' — in this case, in the form of science literacy. It appears to be a preferential competition, however, as students already rich in cultural capital tend to be the main survivors. In this sense, the process is a 'survival of the *richest*' — generally ensuring that class structures will be maintained or, perhaps, augmented. What seems to survive, however, is an ethic of competitive individualism. Students seem to learn from science education, as from other economically important subjects, that their survival will always depend on their abilities — or lack thereof — to compete in an increasingly 'Darwinian' world. While this ethic appears to benefit a few advantaged citizens, particularly in the short-term, it also appears to engender many problems for individuals, societies and environments.

In this article, after an elaboration of problematic connections among science, science education and the globalized economic system, some possibilities are explored for a science (and technology) education promoting wellbeing for individuals, societies and environments.

SCIENCE, SCIENCE EDUCATION AND GLOBAL COMPETITIVENESS

A Milieu of Global Economization

According to several educationalists, philosophers, cultural critics, and others (e.g., Bakan, 2003; Cavanagh & Manders, 2004; Derber, 2003; Dobbin, 1998; Gabbard, 2000a; Klein, 2000; McLaren, 2000; McMurtry, 1999, 2002), there has been, over approximately the last half century, unprecedented human orientation towards global *economization*; that is, a process that "subordinates all … forms of social interaction to economic logic and transforms nonmaterial needs, such as education, into commodities" (Gabbard, 2000b, xvii). It is, according to Derber (2003), "a system of economic integration (1) driven more than any prior global order by the priorities of profit, (2) managed politically largely by the United States and an allied set of new global institutions such as the WTO, and (3) legitimated culturally by the values of consumerism" (p. 15). This is a *neo-liberal* agenda; that is, an orientation towards maximizing production and consumption of goods and services — through the services of the world's workers — in ways that minimize costs (e.g., through progressively reduced wages, benefits, and environmental protections, etc.), maximize prices in order to maximize profits (Carter, 2005; Gabbard, 2000a).

Global economization is not, necessarily, a priority for all the people of the globe. It appears, instead, to be a project — at least, subconsciously — of the global *elite*. People in power worldwide often take steps to ensure that their continued power status and this, often, appears to translate into efforts to preserve traditional social interactions and stratification. This is said to be the neo-*conservative* agenda of globalization; that is, an orientation towards conserving (and augmenting) global social-economic stratification, which implies — among other things — that wealth will continue to be funneled towards the already-wealthy (Carter, 2005; Gabbard, 2000a).

The power of the global economic elite has long been great, but has been remarkably enhanced since July 1994 when the dominant members of the Allied Forces, including the USA, the UK and France, along with major corporate leaders, bankers and economists, met at Bretton Woods, New Hampshire, to deal with the devastation of the war and prevent another Great Depression (Cavanagh & Manders, 2004). These were monumental meetings, effectively beginning the process that is shifting power from the 'local' — e.g., municipal, provincial/state and national — to the global level of influence. Out of these meetings came the World Bank (WB) and the International Monetary Fund (IMF) and, later, the World Trade Organization (WTO). Sometimes known as 'The Unholy Trinity' (Cavanagh & Manders, 2004), these institutions now have considerable power over national governments, requiring them to, in effect, arrange economic conditions throughout the world to suite the interests of international financiers, the global currency market and transnational corporations. They are

'unholy' in the sense that, rather than being accountable to all citizens, these entities are beholding only to the world's economic elite. Through their powers, the veritable 'world government' of the IMF, WB and WTO work to promote neo-liberal economics by, for example, promoting:

- hypergrowth and unrestricted exploitation of environmental resources and new markets to fuel that growth
- privatization and commodification of public services and of remaining aspects of the global and community commons [e.g., water]
- global cultural and economic homogenization and intense promotion of consumerism
- integration and conversion of national economies, including some that were largely self-reliant, to environmentally and socially harmful export-oriented production
- corporate deregulation and unrestricted movement of capital across borders
- dramatically increased corporate concentration [creation of oligopolies; small groups of colluding companies]
- dismantling of public health, social, and environmental programs already in place
- replacement of traditional powers of democratic nation-states and local communities by global corporate bureaucracies (Cavanagh & Mander, 2004, p. 34).

Associated with global neo-liberalism and neo-conservatism are some significant worldwide personal, social and environmental problems (e.g., Bakan, 2003; Cavanagh & Manders, 2004; Derber, 2003; Dobbin, 1998; Gabbard, 2000a; Klein, 2000; McLaren, 2000; McMurtry, 1999, 2002). There is, for starters, staggering local and global environmental degradation. To name a few problems:

- about 100 acres of the Earth's rainforests are cut every day by private companies
- about 200 species are lost per day from habitat destruction
- 80 countries (with 40%) of the world's population have water shortages
- 26 billion tons of soil are lost each year from 50% of the Earth's arable land
- more than 60,000 km^2 of land in over 100 countries becomes desert each year, hastened by global warming — which, in turn, has been hastened by a 16-fold increase in industrial effluents in the last 30 years
- coastal ecosystems are being degraded by run-offs of industrial pesticides and fertilizers
- oceans are being depleted of fish by deep-sea trawling; the take of fish has quadrupled in the last 40 years
- loss of stratospheric ozone is causing hundreds of thousands of cancers each year, loss of amphibian species' capacity to reproduce and loss of ocean phytoplankton (McMurtry, 1999, p. 83).

While earth's environments are being degraded, it is apparent that progressively fewer people are living in relative comfort; as wealth appears to be funneled towards small fractions of the world's population. Concentration of wealth in the hands of a very few is, indeed, staggering. The approximately four hundred and fifty billionaires in the world have, for example, wealth equivalent to that of half of the world's six billion people. The top three shareholders of Microsoft Corporation controlled more wealth than the entire population of Africa in 2000, and the three richest people in the world have combined wealth exceeding that of the Gross Domestic Product (GDP) of the forty-eight poorest countries (Derber, 2003, p. 47). Meanwhile, the average daily income of these three billion people (approximately) is about three dollars per day, about thirty percent of the world's population is unemployed, most new jobs are low-paying, insecure and part-time, about a quarter of the world's population is starving, about a third of the world's children are undernourished, and the number is rapidly increasing, and poor countries of the South pay about one-half billion dollars per day in compounded interest rates to rich banks (McMurtry, 1999, p. 83). This is, clearly, staggering social degradation while an increasingly small cadre of economic elite dramatically increase their wealth and wellbeing.

Although proponents of global economization claim that their intense focus on transnational production and consumption will eventually lead to economic prosperity for all, claiming that a "rising tide will lift all boats" (Cavanagh & Mander, 2004, p. 44), it is increasingly clear that "it lifts only yachts" (Cavanagh & Mander, 2004, p. 49). To the extent that this is happening, it is highly problematic — or worse, *pathological*. Indeed, in *The Cancer Stage of Capitalism*, McMurtry (1999) suggests that many of the economic elite have, in a sense, mutated to become 'foreign invaders' doing great damage to the 'body' of Earth's living and non-living systems, despite being 'disguised' as one of us (like metastasizing cells). This would be a highly oppressive situation, as advised by Freire (1997): "For the [oppressor], to be is to have, almost always at the expense of those who have nothing" (p. 46). Along similar lines, Bakan (2003), suggests that such greed at the expense of others is a sign that the perpetrators have psychopathic tendencies, caring little for others while enriching themselves.

Global Economization and Science

In order to maintain and, moreover, magnify their wealth and wellbeing, the global economic elite need the services of professional science and technology — which can provide the means for generation and marketing of for-profit goods and services. However, prior to about 1950, the culture (or 'ethos') of science, particularly in academic (e.g., university-based) settings was not, apparently, congruent with ideologies and practices in business and industry. Although there may be various ways to analyze an ethos of science, the norms of practice proposed by Robert Merton (1942, 1973) seem very convenient and, although few people believe that all scientists adhered to them at all times, they "are particularly useful because they stress the sociological features that academic scientists consider to be peculiar to their profession" (Ziman, 2000, p. 55). Up

until about the middle of the last century, academic science was largely characterized by Merton's Norms of practice, which included: i) Communalism: As a collective activity, scientists should share ideas, methods, findings, etc. with other scientists in their communities, ii) Universalism: All scientists, regardless of such differences as age, career status, gender, race and cultural background, can participate equally in science — including through generation and publication of findings, iii) Disinterestedness: All scientists, along with those who support them, are expected to operate in unbiased, objective ways, iv) Originality: Scientists are expected to contribute novel ideas, methods and results to the literature; not merely copying the work of others, and v) Skepticism: The scientific community is continually expected to critically scrutinize their own and colleagues' work with respect to its scientific merit, level of universalism, disinterestedness, and originality ('CUDOS') (Ziman, 2000, pp. 57-82). Together, these norms represented an ideal 'ethos' for professional scientists; a mind-set that was to govern their knowledge building and dissemination practices (Merton, 1973).

Apparently, the ethos of science as defined above has radically changed in approximately the last fifty years. In short, academic science seems to have evolved into a 'post-academic' science, taking on a cultural character similar to that of *industrial* science; that is, science that is practised in for-profit businesses (Ziman, 2000, p. 67-82). Gibbons and co-workers (1994) described a similar phenomenon, naming the phases 'mode 1' (academic) and 'mode 2' (post-academic). There are various possible factors giving rise to this shift. Soon after the Second World War, there were some significant changes both within and surrounding academic science. As described in the last section, this was a period of increasing *global economization*. This apparently placed increased pressure on professional scientists to organize their work towards for-profit *applications* of scientific ideas. At the same time, however, many fields of science have matured (entering a stage of 'finalization'; Ziman, 2000, p. 73), which often has meant that they require expensive equipment, materials and contexts for research. These changes have, in turn, led to *collectivization*, in which large — often trans-disciplinary — teams of professionals must collaborate in order to achieve demanding project goals. However, limits to which public benefactors can support such large-scale research have been increasingly met, which has opened the door to increased *private* funding. Indeed, "the development of much closer relationships between academia and industry is one of the major features of the transition from academic to post-academic science" (Ziman, 2000, p. 172). Consequently, there has been a much greater emphasis on *utility*; a situation in which researchers are asked to explain how their work will generate technological products that people in society "consider beneficial and profitable" (Ziman, 2000, p. 73). "[A] norm of utility is being injected into every joint of the research culture. Discoveries are evaluated *commercially* before they have been validated scientifically …" (Ziman, 2000, p. 74; emphasis added). "In effect, post-academic science is under pressure to give more obvious value for money. … [It] … is being pressed into the service of the nation as the driving force in a national R&D system, a wealth-creating *technoscientific* motor for the whole economy" (Ziman, 2000, p. 73; emphasis added). "Metaphors of 'discovery,' 'forging frontiers,' and 'working at the cutting edge' are giving way to an idea of science as 'wealth creating,' and 'life enhancing,' 'competitive,' 'market oriented,' and 'entrepreneurial' " (Cohen *et al*., 2001, p. 145). It "is clearly an activity where socio-economic activity is the final authority" (Ziman, 2000, p. 174).

In order to accomplish the corporate goal of expediency, the *integrity* of investigators' work is sometimes compromised. There are threats, for example, to Merton's (1967) Norms, including *Communalism* (e.g., Purposes, methods, data and results often are exclusively-held by Contract Research Organizations (CROs) {Davidoff *et al*., 2001}), *Universalism* (e.g., Conflicts-of-interest in regulatory agencies privileges certain investigators' claims {Angell, 2004}), *Disinterestedness* (e.g., Provision of 'finders fees' often biases drug trials {Morin *et al*., 2002}), *Originality* (e.g., Most 'new' drugs are, in fact, minor variations of existing ones and most drug trials pit 'new' ones against placebos (rather than existing drugs) {Angell, 2004}) and *Skepticism* (e.g., Large proportions of refereed journal articles dealing with drug trials are 'ghost written' {Bodenheimer, 2000}). With regards to skepticism, the profit motive has significant negative repercussions for the reliability and validity of knowledge claims in pharmaceutical sciences. A convenient way to evaluate such effects is through use of the idea of 'concepts of evidence' (Gott & Duggan, 1996; Gott *et al*., 2003), which are concepts, processes, strategies that scientists tend to use in theory-data negotiations. For example, drug companies — often through CROs employed by them — frequently use small sample sizes, younger, healthier [less susceptible to negative side-effects] subjects, lower doses than to be prescribed, and short test periods in drug trials to maximize probability of drug approval (Angell, 2004; Bodenheimer, 2000). Also, it is not uncommon for companies to use various tactics to prevent release of data not supportive of their products (Psaty *et al*., 2004). Finally, areas of research and development often are affected by the profit motive including, for example, companies' avoidance of research into causes and cures for tropical diseases because people needing the medications often lack the financial means to obtain them (Angell, 2004).

Global Economization and Science Education

Although the world's economic elite have at their disposal the powers of the IMF, WB and WTO as agents of global economization, it is apparent that their influence is not restricted to overt legal (e.g., through trade agreements) pressures on governments and their citizens. Rather, it seems that there may be an insidious covert mechanism at work known as *neo-liberal governmentality* (Foucault, 1991). According to Larner (2000), for instance,

> *[t]he most influential post-structuralist theorisation of neo-liberalism is that associated with the neo-Foucauldian literature on governmentality. This literature makes a useful distinction between government and governance, and*

> *argues that while neo-liberalism may mean less government, it does not follow that there is less governance. While on one hand neo-liberalism problematises the state and is concerned to specify its limits through the invocation of individual choice, on the other hand it involves forms of governance that encourage both institutions and individuals to conform to the norms of the market. .. (p. 12).*

This is a form of governance in which the will to function along neo-liberal lines is instilled into the sub-conscious of the world's peoples, who may believe that they are acting independently — but, because of the predominance of ethics of individual competition, standardization, externalization of costs (e.g., expecting others to pay for their wastes), commodification, etc. among them, many of their thoughts and actions may be strongly influenced by members of the economic elite or their agents.

Among entities apparently influenced by neo-liberal governmentality, education is a particular important one for economic elite. Education is an excellent medium for perpetuating neo-liberal ideals. Indeed, it has been claimed that "… the major purpose of education is to make the world safe for global capitalism" (McLaren, 2000, p. 196) and that "education …has become a primary medium of globalization, and an incubator of its agents" (Marginson, 1999, p. 19). A sign of this influence was, indeed, evident in the USA and elsewhere as early as the mid-1980s. In *A Nation at Risk*, a policy document released by the National Commission on Excellence in Education (NCEE, 1983), it was stated that:

> *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).*

Such economic rationalism has now spread to curricula in many jurisdictions worldwide, including to those in Ontario, for example:

> *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).*

Authors of such documents seem quite comfortable recommending, in effect, that jurisdictions use children as "human capital" (Apple, 2001, p. 38) in their global economic conflicts. "As declared 'allies of the state' schools [that is, school systems, including government, text publishers, and school district administrators] 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). Guided by this economic ethic, corporations 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).

Given the importance of science and technology to industrial production and consumption (involving significant marketing) (Gabbard, 2000a), a major contributor to such social engineering is school science. Overall, although it is somewhat simplistic to view it this way, it is apparent that school science generates:

1) a small cohort of potential knowledge *producers* — such as engineers, scientists, lawyers, accountants and business managers — who may assist socio-economic elite by developing and managing mechanisms of production and consumption of goods and services; and,
2) many knowledge *consumers* — who, to varying degrees, are likely to faithfully follow labour instructions and enthusiastically and unquestioningly purchase commodities (Bencze, 2001a; Parke & Coble, 2000).

Although evidence for conscious planning for such overall outcomes is elusive, these two broad effects of school science appear to provide two main services to global economic elite; that is, a *production function* and *consumption function*, respectively. Each of these functions is elaborated below.

The Production Function of School Science

For maximizing profit, businesses need an appropriate work force — that is, one that can regularly generate new goods and services with mass appeal, but at a minimum cost. Increasingly, especially in the so-called *knowledge economy*, that can be achieved using relatively few *symbolic analyzers* — that is, professional workers who can analyze and manipulate symbols, including words, concepts, numbers and graphics, such as scientists and engineers and other members of a "managerial class" (Apple, 2001, p. 30). For its contribution to generation of knowledge builders, school science focuses on identifying and educating those few students who may pursue careers in engineering and science. In a sense, this makes school science more like a complex *testing* environment than one enabling each child to become enlightened and empowered. To survive school science, students must have a propensity for quick and efficient *abstract thinking* — for rapidly comprehending many laws and theories, often in the absence of practical applications (MoET, 1999, p. 13). Among the more common strategies that, in effect, sorts students according to their ability to think and work in the abstract is the typical empirical inquiry 'lab.' While students are engaged in experiences with phenomena, they often are expected to 'discover'

particular abstractions through these activities. The Ontario curriculum for elementary school science and technology is, for example, quite direct in its promotion of them:

> *Teachers will provide as many hands-on activities as possible since the inquiry and design skills emphasized in this curriculum must be taught and learned through experiences with concrete materials. The activities provided should allow students to discover and learn fundamental concepts through investigation, exploration, observation, and experimentation ... (MoET, 1998, p. 6; emphasis added).*

A typical discovery practical activity in this curriculum expects young students to 'discover' some important abstractions:

> *[Students in grade three must:] Identify, through observation, different forms of energy and suggest how they might be used to provide power to devices and to create movement (e.g., the release of energy from a tightly-wound rubber band or spring would create movement in a wind-up toy) (MoET, 1998, p. 57).*

Students in the third grade (and, likely, in some later grades) would, likely, have considerable difficulty 'discovering' such abstractions as forms of energy — like potential and kinetic states — without *already* having conceptions of these in their heads (Hodson, 1996). Indeed, few students have such abilities, as indicated by the persistently low fraction of societies that achieve a reasonable level of scientific literacy. This is problematic by itself, but even more so when one considers *which* students tend to possess abilities enabling them to 'discover' such abstractions; that is, those who are rich in *cultural capital* (Bourdieu, 1983) — derived, for example, from experiences with abstract talk, encouragement to read and access to new technologies (Delpit, 1988; Henry *et al*., 1999). While economic wealth is not the only factor contributing to cultural capital,

> *[o]ne 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).*

Where this occurs, schooling is elitist; it is, in a sense, a 'survival of the *richest*.' Nevertheless, influences from business and industry have, apparently, encouraged school systems to set increasingly higher 'standards' of achievement, with regular 'surveillance' (assessment) to ensure teacher compliance. For many students, schooling is now a difficult and challenging experience, rather than one that addresses their particular needs, interests, abilities and perspectives.

> *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).*

Such elitist tendencies of school science may be contributing to the dramatic and growing differences between rich and poor described above. Indeed, the problem is so severe that some suggest we are in a state of "global economic apartheid" (McLaren & Baltodano, 2000, p. 56). While the complexities of wealth accumulation and power politics preclude a firm connection between characteristics of school science and such stark socio-economic stratification, its overall exclusionary tendencies suggest an association. This, in turn, points to the need for dramatic school science reform in ways that would help lead to more socio-economic equity.

> *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).*

The Consumption Function of School Science

In its intense pursuit of potential scientists and engineers, school science often appears to compromise most other students' access to appropriate scientific and technological literacy. This, in turn, may jeopardize these students' opportunities to effectively and appropriately participate in societies greatly affected by professional science and technology. Indeed, it is apparent that several characteristics of school science appear to contribute to the *consumer* ethic that is so critical to success of the global economic project that is a significant contributor to social and environmental problems discussed above. Some suggest that generation of consumers is a major benefit of education in a market-oriented milieu, in which there appears to be

> *a many-sided corporate plan to convert public and higher education to its permanent and guaranteed profitable-exploitation, with the unstated terminus ad quem of this process the reproduction of all present and future students as [enthusiastic and unquestioning] consumers and employees whose desires for commodities and willingness to compete for corporate functions are imprinted reliably into neuronal processes from the moment they enter school to their graduation (McMurtry, 2003, p. 7).*

There appear to be at least six characteristics of school science (and some other subject areas) that may contribute to students' tendency to become passive consumers of knowledge — in terms, for example, of a willingness to comply with labour instructions and purchase goods and services. Each of these is discussed below, with some examples from school science curricula and practice:

- Standardization: As with other economically important subjects (e.g., mathematics, business studies, etc.), governments have highly standardized and kept under tight surveillance (e.g., through testing) expectations for student achievement in science. Governments claim such uniformity in curriculum and instruction will guarantee all learners equal opportunities, regardless of their learning situation (e.g., MoET, 1999). Although equal opportunity is, no doubt, good, a negative side-effect of such standardization may be societal conformity. For example, Aikenhead and Jegede (1999) state that "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" (p. 270). Such societal conformity may be tolerated, nevertheless, because it can be good for business (Apple, 2001). The more people are alike, the more susceptible they may be to mass marketing (Galbraith, 1958).
- Misrepresentation: Marketing is extremely important for business — particularly in a knowledge-based economy. Many businesses now spend far more on branding and advertising than on research and production (Bakan, 2003; Klein, 2000). From this perspective, therefore, it can be very helpful for business if professional science and technology — and, by extension, business and industry, which largely control science and technology — are positively portrayed in school science. Indeed, it is apparent that school science is, in various ways, like an 'infomercial' for professional science and technology. 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, and societies and environments. Among 'myths' — albeit from a social constructivist perspective — about professional science perpetuated through school science are, for example, that: science starts with observation, experiments are decisive, scientific inquiry is a simple, algorithmic procedure, science is value-free, science is an exclusively Western, post-Renaissance activity, and the so-called "scientific attitudes" (e.g., lack of bias) are essential to the effective practice of science (Hodson, 1999). Sociological and historical studies of scientific practices suggest, however, that hoarding of information, cultural variations in science practices, personal and group biases, plagiarism, and blind trust in data sometimes are found in authentic scientific practices (e.g. Knorr-Cetina, 1995). 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) would be a huge disservice to students. With such naïve views about professional science, students would be *intellectually dependent* on authority figures (Munby, 1980) and ill-prepared to make informed judgements about scientific products and practices. Indeed, because of increased advertising 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).
- Saturation: While there is little consensus on the meaning of 'scientific literacy' that is so frequently advocated in curriculum policy documents, three broad categories involve, respectively, learning: i) *science* (e.g., laws & theories), ii) *about* science (e.g., that science is theory-based) and iii) to *do* science (i.e., expertise in scientific practices) (Hodson, 1998). Teachers tend to emphasize, however, learning *science* at the expense of learning in the two other domains. 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. In other words, it can condition them into habits of passive consumption. Indeed, the desire to consume products and services increasingly motivates work — through nearly ubiquitous, and often subliminal, operant conditioning inherent to advertizing (McMurtry, 1999, p. 153). This may be good for business, however, as such passivity can ensure workers follow labour instructions and that people think of themselves primarily as consumers of products and services. Saturating people with consumer goods (or scientific and technological achievements) has, indeed, served as an excellent pacifying technique (Dobbin, 1998). Similarly, in knowledge-based economies, workers must be amenable to passively receive and follow discrete sequences of labour instructions that have been determined by the aforementioned symbolic analyzers.
- Intensification: Often, being a student of school science is like trying to take a sip from a fire hose! All too frequently, teachers feel compelled to 'cover' curriculum content (i.e., for learning *science*) so rapidly, and with few opportunities for application in personally meaningful contexts that many students are left confused or only capable of rote learning (which often is forgotten after tests) (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). Such illiteracy may, however, be good for business. Citizens would be less able to contribute to public decision-making on matters pertaining to professional science. Also, with poorer understandings of science concepts, they may be more inclined to have those supplied by others — including by businesses, who control much of professional science.
- Regulation: Paradoxically, students rarely, if ever, have opportunities to *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 investigations (Hodson, 1996). Even with constructivism-informed pedagogical approaches, 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*. Nevertheless, such coercion is good for business — which can capitalize on a citizenry lacking skills and confidence for developing conceptions of (e.g., theories) and appropriate changes to (e.g., inventions) natural phenomena. They are more likely to serve as compliant workers and enthusiastic consumers of products and services.

- Isolation: Finally, as part of the selection process that identifies and educates potential scientists and engineers, students are forced to individualize and compete 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). 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). A sense of scarcity is, thus, created in the minds of the public — which can, then, be filled by business and industry.

School science systems that are contributing to such pathological local/global economization must, therefore, be reformed in ways that ensure the ongoing wellbeing of (all) individuals, societies and environments.

S.T.E.P.W.I.S.E.

Preamble

Given the apparent overt (e.g., via supranational organizations like the World Trade Organization) and covert (i.e., via neo-liberal governmentality) influence that members of the global economic elite seem to have over most people in the world and, perhaps highly associated with that, dramatic and increasing personal, social and environmental degradation that is occurring, radical action appears to be necessary in order to promote wellbeing for all individuals, societies and environments. Peter McLaren (2000), a major proponent of radical social and educational change, recommends that we employ Paulo Freire's (and, more *implicitly*, Che Guevara's) principles of *conscientization* and *praxis*. Each of these is discussed below with regards to school science reform in ways that might contribute to the wellbeing of all individuals, societies and environments.

Conscientization

McLaren (2000) suggests, in the spirit of the work of Freire and Guevera, that little will improve regarding adverse effects of global economization on individuals, societies and environments without significant *conscientization*. This is consciousness-raising process, in which individuals learn to perceive social, political and economic contradictions and to take actions against oppressive elements of reality (Freire, 1997). Although this may seem straightforward, identifying oppressors is not, necessarily, easy. Often, those who limit the wellbeing of fellow humans and/or the environment are unaware of their own oppressive character. Similarly, the oppressed often are not aware that they are oppressed, they do not recognize their oppressors and, moreover, they tend to identify with and/or want to emulate their oppressors (Freire, 1997). "Only as they discover themselves to be 'hosts' of the oppressor [or oppressors] can they contribute to the midwifery of their liberating pedagogy (Freire, 1997, p. 30). "Liberation is thus a childbirth, and a painful one" (Freire, 1997, p. 31). Given this uncertainty of identification of oppressor and oppressed, along with the idea that oppressor and oppressed do not recognize their own oppressor-oppressed relationships, it is likely prudent and appropriate to attempt to promote conscientization amongst all potential stakeholders related to school science. This would include, among others, students, parents, teachers, school administrators, government officials, business leaders and — in light of the discussion above — members of the IMF, WB and WTO, whose role in promoting global economization appears to be so strong.

Although many 'stakeholders' may dispute various claims made above, they may be worth sharing with them, given the significant refereed literature base in support of the claims. Accordingly, it may be helpful to enlighten 'stakeholders' (such as those listed above) about possible adverse effects of 'pathological' global economization on individuals, societies and environments — including, for the purposes of this paper, the 'production' and 'consumption' functions of school science outlined above.

Pointing out such many and varied contradictions will not be enough to liberate the oppressed and their oppressors, however. They also need to gain access to possible solutions — and, possibly, rationale for them — to problems relating to pathological global economization. In broad societal terms, Charles Derber (2003, p. 143) recommends, in *People Before Profit*, some radical changes; that is,

- Create accountable world government(s), perhaps through revisions to the policies of the United Nations and decommissioning the IMF, WB and WTO;
- Re-construct national democracies, such as by reforming election spending legislation in ways that prevent the rich from overly influencing government;
- Democratize global corporations, including through spitting larger ones into smaller, more manageable entities and by re-writing legislation so that board members are accountable to workers, the environment and to other stakeholders, as well as to shareholders;
- Resurrect local communities, but with global citizenship; and,
- Create collective security.

These are complex recommendations, largely beyond the scope of this paper; but, they seem logical based on the current role of many members of the global economic elite described above.

Well within the scope of this paper are some recommendations for reform of school science in ways that might promote wellbeing for all individuals, societies and environments. Based on the analysis of possible adverse effects of pathological global economization on school science, along with calls for inclusion of sociopolitical *action* within the context of school science (e.g., Hodson, 2003; Pedretti, 2003), the framework for curriculum development in science and technology education given in figure 1 was developed. Generally, the framework recommends that science and technology education include the elements around the periphery of the model in figure 1 — which are traditionally part of science curricula in various jurisdictions (e.g., DfEE, 1999; NRC, 1996). Briefly, students should learn 'science' ('learning conclusions'), 'about science' ('learning characteristics'), and to 'do science' ('developing skills' & 'creating knowledge') (Hodson, 1998). However, if education were limited to these kinds of instructional outcomes, science and technology education would largely promote *individualism* — as each student would have opportunities to enrich their knowledge, expertise, etc. As noted above, individualism is a central element of the neo-liberal/conservative ideology — training each student to compete for limited resources (e.g., knowledge, skills, etc., and marks), training that would, supposedly, enable them to "*compete* successfully in a *global economy* and a rapidly changing world" (MoET, 2000, p. 3; emphases added). To overcome this ideology, the framework in figure 1 also includes opportunities — in the context of their schooling — for students to take socio-political action ("WISE Activism") to address individual, social and environmental problems. Taking such action would benefit from education regarding the more traditional elements around the periphery of the framework in figure 1, as indicated by the arrows pointing WISE Activism. At the same time, however, WISE Activism could help students to further develop expertise for the peripheral elements in figure 1, as indicated by the arrows pointing towards them from WISE Activism. In this way, the framework in figure 1 represents a dynamic system, in which its elements are dialectically related in ways unique to each teaching and learning situation. By including WISE activism in the system, however, such an education also would be more *altruistic* — encouraging learners to both develop and use their expertise (e.g., those elements around the periphery in figure

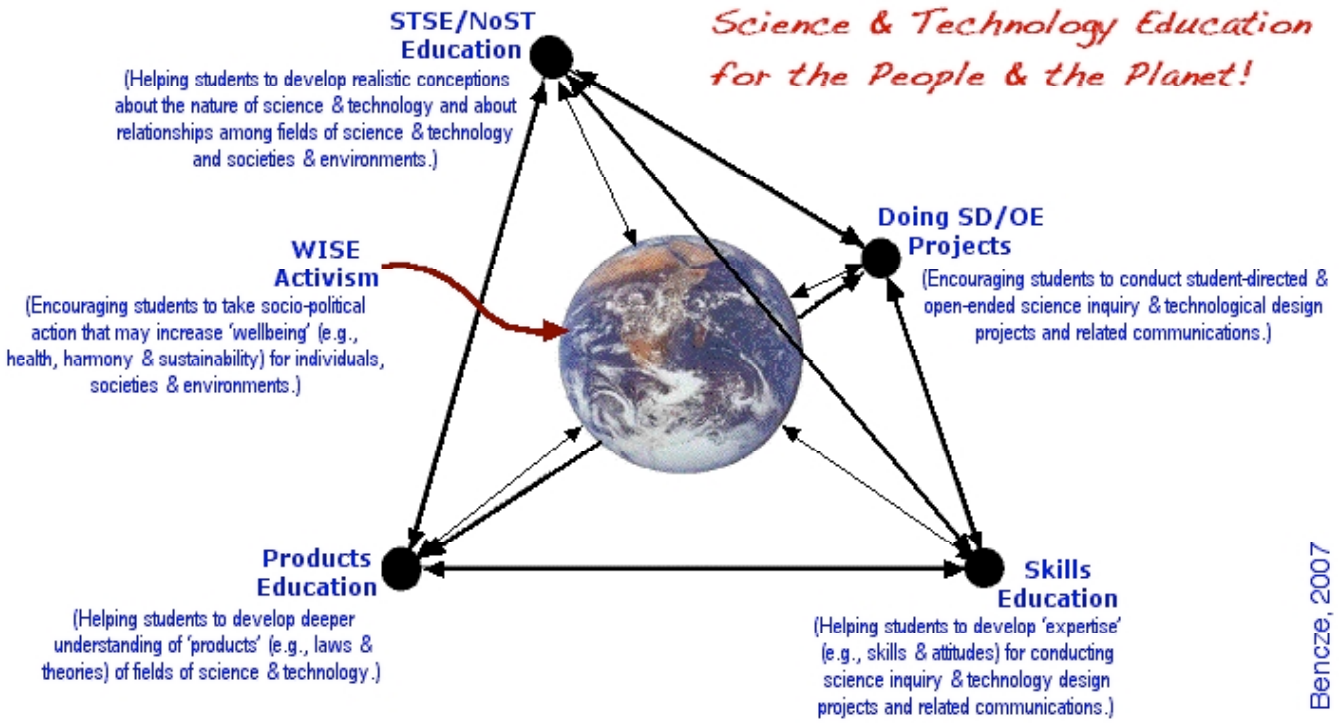

Figure 1: A Framework for 'Altruistic' Science & Technology Education.

1) in ways that would promote wellbeing for other people, societies and living and non-living environments. Such an education would, in principle, contribute greatly to efforts at combating pathological global economization. For example, as indicated by the research-informed arguments given in figure 2, the framework may contribute in significant ways towards overcoming the mechanisms, as described above, that appear to be manifestations of pathological global economization in school science.

Overcoming Elitism: To encourage a broader spectrum of student engagement in science learning, students need more opportunities to be engaged in teaching and learning environments that acknowledge the idiosyncratic, situated nature of learning. For example, infusing more *technology* education into school science may be appropriate (e.g., Bencze, 2001b; Fensham & Harlen, 1999), given the complex, situational nature of technological decision making. While frameworks for integrated technology and science education programmes are still being developed, *constructivist* learning principles may play a major role. Because they 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 about many aspects of knowledge development — including *problem-posing*, *problem-solving* and *peer persuasion* aspects (Johnson & Stewart, 1990). 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 (Pedretti, 1996), in which learning often occurs in the context of attempts to take actions relevant to a societal and/or environmental problem associated with professional science. 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 (such as corporations) and more about serving those being educated. While bringing about such more contextualized, inclusive education is essential for the democratization of school science, achieving such a major change is likely to be difficult. High status has long been associated with abstract, decontextualized thinking (McCulloch *et al.*, 1985) and this has regularly been used as a basis for prioritization of science, as compared to technology, in the curriculum (Fensham, 1993). At the same time, technology has been 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). Nevertheless, for reasons such as those cited above, opportunities for more contextualized, inclusive experiences like those offered by technology education need to be vigorously pursued. Although some jurisdictions have, indeed, made provision for integrating technology education into school science programmes (e.g., MoET, 1998), frameworks for their pedagogical integration are still being developed (e.g., Cajas, 2001). The STEPWISE framework, which promotes integration of science and technology education, and idiosyncratic and contextual problem solving (i.e., *Creating Knowledge* and *WISE Activism*), may serve as a basis for such development.

Overcoming Standardization: Students should have opportunities to develop diverse forms of literacy. 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. They allow people to develop *understandings* of scientific concepts without becoming committed to them (Aikenhead & Jegede, 1999). At the same time, culturally accommodating education need not be *one-directional*; that is, having minorities learn about the majority view without encouraging the converse. 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 (e.g., Hodson & Dennick, 1994). 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 science projects (Bencze, 1996, 2000a, 2000b, 2001b; Gott & Duggan, 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. They are particularly effective if participants have had opportunities to develop a breadth of conceptions (e.g., laws & theories) about contexts they may explore more independently. A pluralist education of this sort is part of the STEPWISE framework, particularly where teacher input is involved (e.g., Learning Conclusions).

Overcoming Misrepresentation: School science must be honest about limitations of and problems associated with professional science and technology (Cunningham & Helms, 1998; DfEE, 1999). Helping students to develop awareness of more realistic conceptions about science is, however, a complex and problematic matter. To begin with, students tend to have difficulty 'discovering' (i.e., through *induction*) particular conceptions about science through experiences with scientific practices, such as when engaged in science project work (Abd-El-Khalick & Lederman, 2000). Consequently, it is important for educators to explicitly provide students with particular conceptions about science that they might not, otherwise, discover through experience. Knowing which perspectives to provide, however, creates yet another problem. There are many, often conflicting, positions about the nature of science (Rudolph, 2000). Accordingly, it is necessary to explicitly represent a diversity of views, such as those

encompassing Loving's (1991) Scientific Theory Profile (which depicts spectra of views regarding the nature of knowledge building and the truth value of knowledge). At the same time, as argued above about conceptual learning, for learners to develop deep understandings about conceptions associated with science, they must have opportunities to test (i.e., through *deduction*) competing conceptions through experiences with realistic knowledge building activities. However, that, too, can be difficult — given the diversity of knowledge building contexts in science that exist. Perhaps one of the most philosophically sound and pragmatic approaches to nature-of-science education is to provide inductive and deductive immersion experiences in as representative a collection of cases of science-in-action as possible. Such an approach is elaborated elsewhere (Bencze & Elshof, 2004). This is represented in the STEPWISE framework in terms of *Learning Characteristics*, followed by *Knowledge Creation*. 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 public science-related issues that are important to them.

Overcoming Saturation: Students need opportunities to become more active, self-motivated learners. To begin with, they need to realize that knowledge and knowledge building in science are uncertain, sometimes biased and frequently limited by technological innovations. Work done with them to help them gain more realistic conceptions of the nature of science — as described above — can be helpful along these lines, and this is built into the STEPWISE framework, particularly in terms of *Learning Characteristics*. However, at the same time, students need to gain the sense that knowledge building in science is an incomplete project, that there is still room for them to become active in this regard. This can be partly accomplished by reducing expectations for learning about products/conclusions (e.g., laws & theories) of professional science and technology, thus giving students more opportunities to learn about science and technology and to develop expertise for creating knowledge using methods of science and technology. Students would be freed to *do more with less* (AAAS, 1989); that is, to apply fewer concepts and skills to important problem solving situations (e.g., Jenkins, 2000).

Overcoming Intensification: Ensuring students have opportunities to develop deeper understandings of scientific concepts must be a priority for educators. However, as argued above, that would likely imply a *rationalization* of curricula; that is, reducing and re-organizing curriculum expectations to what stakeholders consider absolutely essential knowledge. This would leave time for learners to apply each of these knowledge entities in problem solving situations having meaning for them which, in turn, would contribute to development of deeper understanding. "Understanding, by its very nature, is related to action; just as information, by its very nature, is isolated from action" (Dewey, 1946, p. 49). There are many well-developed application activities from which teachers could choose, if time was more available for them to use them. Again, problem-based learning approaches (e.g., Hmelo & Evensen, 2000) would be excellent choices. Such activities are, again, particularly evident in the *Knowledge Creation* and *WISE Activism* components of STEPWISE.

Overcoming Regulation: Educators need to provide students with opportunities to *self-determine* their thoughts and actions. 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). Once again, the STEPWISE framework provides for this through its the *Knowledge Creation* and *WISE Activism* components. Through such projects, students negotiate aims, methods, conclusions, etc. By so doing, they are engaging in 'Gestalt' educational experiences, in which learners construct unique sets of meanings from amongst a 'background' of myriad interacting variables — including physiological, psychological, social, and environmental considerations (Winn & Snyder, 1996). It is a holistic sort of 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). For teachers, such experiences imply arranging learning environments, rather than engaging in instruction-assessment cycles. "[Teachers] cannot teach another person directly; [they] can only facilitate his [sic] learning" (Rogers, 1965, p. 389). When they do so, they acknowledge that "[the norm of free inquiry is the very basis of authentic education …" (McMurtry, 2003, p. 10). With this view, "curriculum could be something determined after the fact of education, like a curriculum vitae" (Davis & Samara, 2000, p. 174). While science project work has had official curricular assent (e.g., DfEE, 1999) and many individual successes (e.g., Bencze, 2000b; Gott & Duggan, 1995), it has not, generally, been well implemented. As described earlier, teachers tend to be too pre-occupied with ensuring students develop understandings of conclusions (e.g., laws & theories) developed by 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 the expertise to help students do such projects (e.g., Olson & Loucks-Horsley, 2000). Consequently, teacher education approaches are needed that mentor student teachers in science project work and corresponding pedagogical perspectives and practices, although there have been some successes (e.g., Bencze & Bowen, 2003; Windschitl, 2003).

Overcoming Isolation: It is crucial school systems give groups of students opportunities to form *communities of practice* (Wenger, 2000). Through engagement in common activities over extended periods of time, participants can come to develop and share (for example) discourse practices, tools, rules, beliefs, identities, tacit knowledge, domains of interest, etc. Such cohesion is empowering for groups, making them less subject to systematic controls, such as universal 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). Of particular importance along these lines would be that such situated and personalized problem solving has a strong *social* and community-based character, one that accommodates the concept of *distributed expertise* — which is said to be a critical to problem solving that aims to emulate real-world contexts and promote and ethic of lifelong learning (Roth & Barton, 2004). Although all components of STEPWISE encourage this, it may be particularly evident the *Knowledge Creation* and *WISE Activism* components.

Figure 2: Arguments in Support of STEPWISE.

Praxis

Although the framework for STEPWISE education in figure 1 may contribute in positive ways towards overcoming effects of pathological global economization in school science, there can be no "predefined utopia or blueprint for a new society" (McLaren, 2000, p. 192). Every teaching and learning situation is unique, for example, dependent on myriad, often interacting, contextual variables — frequently involving the nature of the teacher, students, politicians, administrators, school structure and resource, parents, etc. (Barnett & Hodson, 2001). Again, in the spirit of the work of Freire and Guevera, McLaren, 2000) recommends that conscientization must be accompanied by praxis for all 'stakeholders.' Although the word 'praxis' has various meanings, it refers here to dialectical, critically-reflective, self-directed, action in particular, although unpredictable, contexts. Particularly because of the idiosyncratic and contextual nature of praxis, it is a process that "… affirms men and women as beings in the process of becoming — as unfinished, uncompleted beings in and with a likewise unfinished reality" (Freire, 1997, p. 65). Without this, education would, to a degree, be indoctrinating — and neo-liberal governmentality likely would continue to function.

All educational stakeholders need to be encouraged to become engaged in praxis. The framework in figure 1 (defended in figure 2) involves praxis in at least two of the five elements; that is, "Doing SD/OE Projects" and "WISE Activism." For most other 'stakeholders,' praxis could, in essence, take the form of *emancipatory action research* (Carr & Kemmis, 1986). 'Action research' is any systematic effort to learn about one's own practice by attempting — through repeated attempts — to improve it. It is 'emancipatory' when those carrying out the actions under study have most or all control of those actions (Habermas, 1972). According to *knowledge duality* theory (e.g., Wenger, 1998), this sort of problem solving should be personally meaningful — in the sense that there would be close, dialectical, associations between personal *participation* in the world and *representations* of it. This is, in essence, the opposite of neo-liberal governmentality (Foucault, 1991), in which economic elite covertly infuse neo-liberal principles into the minds of otherwise independently thinking and acting persons.

Actively promoting emancipatory action research is, by definition, potentially problematic, however. In the process of 'leading' or 'recommending' praxis and/or a particular form of it, coercion is still possible or, even, likely. "Someone's tradition, someone's construction of what is important to know and how it should be used, is always incorporated into our planned curriculum, often in hidden ways" (Beane & Apple, 1995, p. 15). There may, moreover, be a dilemma for those wanting to promote praxis in the case of individuals who are not familiar with praxis or action research. Contributing to this dilemma, moreover, is Kuhn's (1970) idea that fundamental (revolutionary) changes in thought are unlikely to occur without the availability of alternatives (e.g., as provided by praxis facilitators). To address this and other dilemmas associated with promotion of praxis and/or emancipatory action research, many educators recommend, like Lewin (1946), that participants begin the process with critical self-reflection regarding their perspectives and practices. "A politics of liberation must always begin with the perspective, desires, and dreams of those individuals and groups who have been oppressed by the larger ideological, economic, and political forces of a society or a historical moment" (Lincoln & Denzin, 2000, p. 1048). If any agent avoids critical self-reflection, the system would have a less emancipatory character. In the event that educators feel the need to 'facilitate' stakeholders' topics, methods or conclusions of praxis, it may be helpful to promote *collateral learning* (learning new ideas, but not, necessarily, abandoning your own) (e.g., Aikenhead & Jegede, 1999), instead of *conceptual change* (being expected to replace your ideas with 'better' ones) (e.g., Hewson *et al*., 1998). Finally, and perhaps crucially, facilitators need to remove themselves from practitioners' decisions about the merits of different perspectives and practice by encouraging them to independently solve problems and create knowledge. Again, the STEPWISE framework (figures 1-2) promotes this through student-directed, open-ended science inquiry and/or technological design projects and through WISE activism. A recommended by Freire (1997), it would only be in such scenarios that participants would be free to direct their own liberation.

CONCLUDING REMARKS

Given the seriousness of problems facing individuals, societies and environments, along with the probability that many of these problems can be attributed to the immense power of global economization that appears to be facilitated — at least in part — by the character of school science systems that favour selection and education of potential scientists and engineers, revolutionary pedagogical perspectives and practices are needed for promotion of wellbeing for the people and the planet. In this paper, a series of recommendations for reforming school science and global economic systems have been provided. While these may have merit, oppressor-oppressed relationships will continue unless these recommendations are problematized and used as the basis for critical reflective practice (praxis) by school science stakeholders.

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