Anti-capitalist/Pro-communitarian Science & Technology Education

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Responses
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Abstract
Many of us live in a hyper-economized world, in which personal identities and routine practices are significantly oriented towards production and consumption of for-profit goods and services. Extreme consumerism appears to be strongly associated with many personal, social and environmental problems. It is apparent that professional science and science education help facilitate this problematic hyper-economization. Briefly, science education tends to emphasize generation of knowledge producers, including engineers, scientists and other symbolic analyzers — who, in turn, develop and manage mechanisms of production of goods and services. At the same time, fields of professional science (e.g., via data-mining and marketing) and science education (e.g., via guided discovery inquiries) orient citizens towards habits of unquestioning and enthusiastic consumption of goods and services. Central to this system of problematic for-profit hyper-consumerism appear to be epistemological and ethical considerations. Science, for example, often is seen — largely misleadingly — as a very systematic and decontextualized process generating highly effective and unproblematic products/services that can contribute greatly to individuals’ wellbeing. In this paper, we counter these epistemological and ideological stances through argumentative support — partly through summaries of two educational case studies (Science and the City and STEPWISE) — for communitarianism. Under this philosophy, knowledge is seen as historically and temporally complex, perhaps leading us to a communalist (if not altruistic) ethical position with regards to the wellbeing of individuals, societies and environments. Ramifications of these positions for science education may include: Equity, Diversity, Holism, Breadth, Depth, Empowerment, Self-determination, Enlightenment, and Responsibility.

Introduction
Humanity is facing many significant personal, social and environmental challenges — including increasing discrepancies between rich and poor, excessive dependences on technologies, and potentially catastrophic environmental degradation and consequent species losses. Although there are likely many potentially valid explanations for these problems, there is considerable support for the contention that much culpability should be borne by those driving extreme, ‘unbridled,’ capitalism — which has taken us to the point that production and consumption of for-profit goods and services (and their brands) supplants most other bases for life decisions. Associated with this zeitgeist1 is cost externalization, that is, the ethical principle that guides people to maximize profit, as much as possible, by ensuring that costs — including those

1 Zeitgeist refers to the ‘spirit of an age’ within a society; including its intellectual, cultural, ethical and political climate, ambiance and morals.
associated with personal, social and environmental degradation — are borne by others. It is, in short, an ethos of perceived or real rights-to-benefits without responsibilities.

Apparently complicit in the zeitgeist described above are fields of professional science and science education. Fields of professional science often serve as mechanisms for production, marketing and distribution of goods and services on behalf of business and industry, while the primary source of professional scientists is science education. Additionally, it is apparent that science education generates various classes of lower-skilled workers and, perhaps, crucially, a societal mind-set geared towards unquestioning and enthusiastic production and consumption of for-profit goods and services.

A key to breaking the aforementioned problematic sequence involving science education, fields of professional science, business and industry, for-profit goods and services and their consumption, and personal, social and environmental degradation appears to be a weakening of extreme acquisitiveness. In this paper, after a critical review of repercussions of the hegemony of out-of-control capitalism, we elaborate a general framework for science education that might at least moderate societal acquisitiveness — and, indeed, balance it with a communitarian epistemology.

Hyper-economization

Although capitalism, an economic system in which private wealth increases through economic exchanges as currency earnings surpass costs (e.g., for production and distribution), has existed for centuries, it has apparently come to dominate the zeitgeist of many societies. Gabbard (2000b) suggests, for example, that people have been increasingly affected by 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). Under an ethic of economization, anything, anywhere, can — potentially — be traded for profit.

A key element of economization is economic liberalism, a view that societies must take various steps to reduce impediments to market-based decisions about the nature of production and consumption of goods and services and, related to that, profit. This is a view dating at least to the time of Adam Smith’s (1776) treatise, An Inquiry into the Nature and Causes of the Wealth of Nations, in which he argued that societies would grow and prosper if individuals were left (free from government intervention) to pursue their own economic self-interests. More recently, after a period of intensive government social spending following World War II and the Great Depression, this ideology has been renewed in the form of neoliberalism (McMurtry, 1999). Under neoliberalism, governments have tended to: reduce taxation and, related to that, spending on social programs (e.g., health and education), place more emphasis on individual responsibility rather than the public good; reduce regulations on business activities, such as transnational trade and environmental and labour standards; and, privatize some government services (e.g., forms of transportation) — all in the name of liberation of businesses to generate profits, often assuming that some business profit will ‘trickle down’ to lower classes in societies. In this ethic, responsibility to others is a passive, rather than a pro-active, phenomenon.

Neoliberalism appears to be a very pervasive ideology. Indeed, there are suggestions that it has penetrated the sub-conscious of large segments of societies. In describing it, Larner (2000) suggests that, although overt reductions — such as relaxed regulations — in government intervention in markets may occur, there still may be societal governance favouring neoliberalism:

[...]the 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

2 In this paper, the term science encompasses the term technology — since, to a great extent, fields of science and technology are co-dependent or, to a degree, comparable (Gardner, 1999; Roth, 2001).
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).

Neoliberal governmentality, as discussed by Foucault (1991), is a form of governance in which the will to function along neoliberal lines infiltrates people’s sub-conscious, leading them to believe that they are acting independently. However, because of persistent messages promoting such virtues as individual responsibility and competition, standardization, privatization, and commodification, many of their thoughts and actions may be strongly influenced by agents of neoliberalism — thus dominating their societal zeitgeists (e.g., Bowers & Apffel-Marglin, 2005; Gabbard, 2000a; McMurtry, 1999).

Global economization does not, necessarily, benefit all the people of the globe. It appears, instead, to be a project — perhaps subconsciously — of the global elite. People in power worldwide often take steps to ensure 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 traditional elite (Carter, 2005; Gabbard, 2000a).

Economization & School Science

In order to maintain and, indeed, augment the process of economization — and associated neoliberal and neoconservative ideological perspectives — economic elite may benefit if succeeding generations of children are enculturated along economic lines. 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, 1997, p. 19). Given the importance of science and technology to for-profit production and consumption (involving significant marketing) of goods and services, a major contributor to such social engineering appears to be school science. Despite references to ensuring all students develop ‘scientific literacy,’ there are indications in curriculum policy documents and guidelines that governments’ main priority is to prepare students for work and participation in economic transactions — so that ‘countries’ (particularly in terms of their businesses) can compete successfully in local and global markets. For example, in the National Science Education Standards (NSES) document (NRC, 1996), the authors state that one of the purposes of science education is to “increase economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers” (NRC, 1996, p. 13). The Canadian standards document similarly advises that “[t]he emergence of a highly competitive and integrated international economy, rapid technological innovation, and a growing knowledge base will continue to have a profound impact on our lives” (CMEC, 1997, p. 5). 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.

Especially in the context of so-called knowledge economies/societies, companies can benefit from schooling that generates a small group of knowledge producers. In contrast to earlier economies, which tended to be based on production and consumption of physical products, knowledge economies increasingly focus on knowledge in the form of ideas and concepts for production and marketing (including in terms of branding) of products for repeated cycles of consumption (Lash, 2002). In knowledge-based ‘economics,’ work is being polarized within a new work order, in which a dichotomy exists between workers capable of providing symbolic analytic services versus those who can provide routine production and in-person services (Gee et al., 1996). Symbolic analytic services include abilities to analyze and manipulate symbols, including words, concepts, numbers and graphics — and these tend to be possessed by relatively
small numbers of people (Lankshear, 2000). Knowledge workers include: scientists, engineers, accountants, lawyers, management consultants, investment bankers, authors, editors, art directors, video and film producers, etc. (Reich, 1991) — members of which are said to comprise a “managerial class” (Apple, 2001, p. 30).

Although there may be many ways to interpret effects of hyper-economization on science education, it is apparent that education in science — as in other economically important subjects — often appears to be a highly individualized competition for access to scarce cultural capital (i.e., literacy in science and technology) (Bourdieu, 1983). A relatively small fraction of students tend to be ‘successful’ (e.g., in terms of advancing to later grades of study and developing realistic, functional and long-lasting conceptions) in school science (e.g., Chinn & Malhotra, 2002; Claxton, 1991; Eisenhart et al., 1996; Parke & Coble, 2000). Advanced students ‘survive’ school science, in a sense, through their abilities to process large amounts of abstract, decontextualized knowledge (e.g., as laws, theories and functions of inventions) that often are rapidly-transmitted to them in school science (Claxton, 1991). Among the more common strategies in school science that, in effect, sorts students according to their ability to think and work in the abstract is the typical empirical inquiry ‘lab.’ Through interactions with phenomena, students are expected to ‘discover’ — albeit with teacher intervention — important abstractions. Students in grade three are expected, for example to “[i]dentify, 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). Apparently, it is those students rich in cultural capital who are largely able to succeed in this environment and, if they choose, may assume careers, particularly in knowledge economies, as knowledge producers, largely working as symbolic analyzers (refer above). 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). Such students will become members of middle-upper classes, receiving considerable expendable income. McLaren and Baltodano (2000) suggest that such exclusivity in schooling is contributing to what they believe to be a state of “global economic apartheid” (p. 56). For most students, school science amounts to an intensive ‘test’ of their potential to serve as knowledge producers — rather than an equal opportunity to gain a broad, deep, enabling and critical literacy in science and technology. Education that sorts students according to their existing cultural capital, rather than attempting to ensure equity of such ‘riches,’ is, clearly, undemocratic. It seems to have contributed to the well-documented severe and increasing worldwide differences between rich and poor (e.g., McLaren & Baltodano, 2000).

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).

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3 Apparently, an emphasis on abstract, decontextualized knowledge largely makes science education more suitable for selection of knowledge workers than technology education, which tends to emphasize knowledge in context. To ensure science education takes precedence over technology education, technology often is stigmatized as only appropriate for “less able, concrete thinkers” (Fensham & Gardner, 1994, p. 168). Science, meanwhile, has long enjoyed high status associated with abstract thinking (McCulloch et al., 1985), status often perpetuated by academic scientists (Fensham, 1993). To help its case, school science often creates an “illusion of indispensability” (Bencze, 1995, p. 22-24) for professional science. Topics are sequenced from abstract to concrete, for example, thus misleadingly portraying technology “as the routine, tedious and menial application of the seminal products of pure science” (Layton, 1988, p. 369).
School science that mainly focuses on educating the relatively small number of potential knowledge producers may be contributing to dramatic and growing differences between rich and poor noticed throughout the world. 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. 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.

In its intense pursuit of potential knowledge producers, school science systems often appear to compromise most other students’ literacy (cultural capital) in science and technology (Désautels et al., 2002). Without such literacy, it is difficult for students to assume careers as knowledge producers and, consequently, may best be prepared to become knowledge consumers — in terms, for example, of a willingness to comply with labour instructions and purchase goods and services (Parke & Coble, 2000). Indeed, there are suggestions that economic elite seem to benefit from — and, perhaps, promote — “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). To accomplish this, school science appears to function, to a great extent, as a veritable apprenticeship for consumership. Mechanisms in school science (and some other subject areas) that may contribute to students’ tendency to become passive consumers of knowledge include, as elaborated and justified elsewhere (Bencze, 2001): Compartamentalization; Science is taught separately from other subjects and, in individual subjects like science, units of study often are disconnected from each other. Such reductionism prevents students from understanding more complex associations among, for example, fields of science and technology and societies and environments — many of which may be problematic and, if citizens were aware of them, they may be more critical of processes and products of science and technology; Standardization: Instructional outcomes are standardized, thus promoting homogenization among students. Mass marketing becomes easier when citizens are more alike; Intensification: Instruction tends to be so rapid that rote learning tends to dominate and, eventually, students are left confused about what they were to have learned or may simply forget such ‘learning.’ Such lack of literacy limits citizens’ abilities to participate in personal and public decision-making relating to science and technology; Idealization: School science often is like an ‘infomercial’ for professional science, misleadingly suggesting to students that all processes and products of science and technology are very appropriate, efficient and benign with respect to possible personal, social and environmental problems. Associated with this view, fields of professional science are seen as isolated from fields of technology and from societies and environments — purportedly adhering to certain norms of proper practice, leaving fields of technology and society to determine how to use knowledge they develop (Rudolph, 2005). Citizens educated in this way may be less likely to critique or challenge processes and products of science and technology and/or people who control them. This appears to be necessary, however, in that — in the context of business-science partnerships, for example — scientists and engineers often have compromised the integrity of their work (e.g., in terms of topic choice, methods, dissemination and recommended uses of its products) in order to maximize profits while minimizing costs (e.g., Angell, 2004; Krimsky, 2003; Ziman, 2000); Regulation: Students’ decision making relating to, for example, topic choice, problem solving
methods, and dissemination approaches often is regulated by teachers and/or textbooks. Students tend not to develop skills and attitudes necessary for independent problem solving and, thus, may be dependent on those (e.g., companies) having such expertise; Saturation: School science tends to give students the impression that professional science has solved most relevant problems and, thus, there is little need for citizens to question them and/or generate new ideas; and Isolation: Particularly in terms of testing, students often must work independently; thus, being deprived of opportunities to benefit from collaborative decision making, which can enable individuals to, effectively, achieve more than they might achieve independently.

School science’s orientation towards consumerism, apparently, along with mass marketing and other influences may account for the tendency for citizens in ‘developed’ nations to excessively consume products and services — to the degree that sovereignty over their thoughts and actions may be threatened and, perhaps more obviously, biotic and abiotic environments are likely to be rapidly degraded (e.g., through soil, air and water pollution and consequent species loss) (e.g., Angell, 2004; Bakan, 2003; Barber, 2007; Gabbard, 2000a; McLaren, 2000; McMurtry, 1999, 2002). Examples of environmental degradation, which now may be worse, from a decade ago included:

- 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 km² 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).

Overall, the contribution of school science to societies and environments, therefore, seems highly problematic. Although professionals, such as scientists, engineers, lawyers, etc., are generated for societies, it is apparent that the overwhelming effect of school science is to orient (or re-orient) children towards egoism. Students have been encouraged to desire and compete for scarce cultural capital and, in doing so, suppress concerns for others’ exclusion from it. Dobbin (2000), for example, finds this barbaric:

[O]ur 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 (pp. 1-2).

Envisioning Communitarian School Science

Suggesting that school science is barbaric and analogous to a ruthless ‘animal-world’ survival-of-the-fittest, as found in Darwin’s (1871/2004) writing, may seem appropriate — given its competitive and unequal distribution of ‘wealth’ (cultural capital) and its consequent disempowerment of the masses and environmental compromises. However, further reading of Darwin’s works suggests that he did not recommend a ‘dog-eat-dog’ mentality for human progress but, rather, urged adoption of a more ‘civil’ form of evolution; that is, one that promotes caring, love, moral evolution, and education as the prime driver for human evolution (Loye, 2004). In this conception of knowledge and learning, each of us finds our niche, partly guided by ways in which we can contribute to sustainable evolution. This is comparable to a
**communitarian** epistemology; that is, that individuals are socially (historically and temporarily) constituted and, consequently, albeit not necessarily for altruistic reasons, need to act responsibly towards each other and their cultural and social capital (e.g., Code, 1987, 2006; Eiglad & Bookchin, 2007; Lehrer, 2001). In this view, knowledge carries with it consequences, commitments and responsibilities. Communitarianism is related to the philosophical and ethical concept of epistemic responsibility. Lorraine Code (1987), for example, laments the position that moral issues of ‘character’ are integral aspects of epistemic evaluation. Her text concludes by offering the moral conditions for knowing well (intellectual virtue) as an expansion of the literature in epistemology. In her more recent work, *Ecological Thinking* (Code, 2006), she notes that “… ecological thinking is about imagining, crafting, articulating, endeavoring to enact principles of ideal cohabitation” (p. 24). This is neither a new nor a startling stance. Such a position features in familiar, often implicit, aspects of knowledge as the basis of action in daily life, and also is the foundation of many professional and legalistic practices embodied within, for example, the ‘Hippocratic Oath’ taken by medical students around the world. The subject of science and social responsibility also has been the focus of extensive, often heated, debates ever since the Enlightenment. Given this and a contemporary era increasingly defined by social and ecological uncertainty, it is not surprising that ‘social responsibility’ has once again returned as a central preoccupation. In the 2008 America Association for the Advancement of Science (AAAS) presidential address, to select one example, Professor John Holdren catalogued the social, ecological and economic dilemmas of the age and emphasized the ‘responsibilities’ of scientists and technologists to participate in improving relevant conditions.

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**Figure 1: The STEPWISE Curricular & Instructional Framework.**

The teacher helps students develop more realistic conceptions about the nature of science & technology (NoST) and about relationships among fields of science & technology and societal environments (WISE). Each activity is intended to reduce or eliminate WISE problems, such as use of toxic chemicals in toys, foods, organisms, plastic bottles, etc. Activities include: evaluating educating others, changing your own practices, lobbying, new products, etc. and small steps to prevent or eliminate harmful substances—such as pollutants, chemicals, and pesticides. Some more positive aspects include their science & technology have developed many useful surgical techniques and instruments. However, whereas more STEPWISE (WISE) problems, students should be made aware of them and encouraged to try to reduce or eliminate them. A unique feature of STEPWISE is that, through Student Projects, students generate data that may motivate and inform their Wise Activism.
Given the prominent role played by school science in perpetuating the hyper-economized and problematic zeitgeist described above, it seems essential that principles of communitarianism be applied to science education in elementary and secondary schools. We have, for the last five years, been involved in separate, but co-informed, projects that we believe have placed communitarianism (and epistemic responsibility) at their core. Science and the City is described elsewhere (Alsop & Ibrahim, 2008), but involved an intergenerational group of researchers: 36 elementary students (grades 6, 7 & 8) working with their teachers, 6 university-based researchers, parents and community members. The goal was to come together, learn science and technology together, and use this knowledge to provide meaningful experiences that make a difference to the lives of friends, families, communities and environments that surround the school. The collective experience allowed students, teachers and learners to foster imagination, responsibility, collaboration, learning and action. A similar project, on which we are currently working, is ‘STEPWISE’4 (Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments) (Bencze et al., 2008). This project is based on the curricular and pedagogical framework illustrated in Figure 1. STEPWISE orients most learning outcomes in science and technology education towards ‘WISE Activism,’ which is/are action(s) people might take to overcome problems for the ‘wellbeing of individuals, societies and environments’ (WISE) associated with fields of science and technology and their products and services. There are many forms of ‘WISE Activism.’ It may first involve changes to one’s personal life — and then such activism as: educating others (e.g., via posters, websites, school announcements), lobbying ‘power-brokers’ to make official changes (e.g., letter-writing to members of government, business, etc.), developing services that can improve WISE (e.g., a better recycling method, safer recreational & exercise equipment, etc.) and, perhaps, disrupting WISE Problem situations (e.g., with municipal approval, disrupting automobile traffic by clogging the roads with bicyclists). An emphasis on such activism appears necessary, given the severity of the various personal, social and environmental problems — many of which are described above — that appear to be associated with (science and science education based) hyper-economization.

There are many possible teaching and learning approaches based on STEPWISE. In principle, teachers might begin instruction with any element in the framework. Based on constructivist learning theory, however, all instruction should begin by giving students an opportunity to ‘express’ (through talk, drawing, modelling, etc.) their conceptions and/or skills about which the teacher intends to teach. They might, for instance, start

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**Figure 2: A STEPWISE Unit Plan Outline.**

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4 For a fuller description of STEPWISE, refer to: http://www.stepwiser.ca.
by asking students such questions as: ‘What are some of the most important things you’ve learned in school science?’ and ‘To what use(s) can you put the knowledge and skills you learn in school science?’ You might, then, tell them stories about actions that members of activist groups have taken to address what they perceive to be WISE Problems. Providing students with such stories can motivate them to learn more about the subject matter of the unit to be addressed.

One scenario for implementation of the STEPWISE framework is provided in Figure 2 for a unit in basic chemistry, *Chemical Reactions and Their Practical Applications* (MoE, 2008, pp. 88-89). Although it is, clearly, only one of many possible ways to implement STEPWISE, the approach in Figure 2 is based on some important principles of teaching and learning — as discussed below for another topic (cell metabolism):

1. **Clarification of Subject Matter:** At or near the beginning of the unit, teachers organize activities that encourage students to first express (e.g., in a ‘placemat’ activity) and then learn (e.g., with teacher direction) the basic meaning of the major topics in the unit (e.g., the meaning of cell metabolism). Students might also be asked, ‘What do you hope to learn in this unit?’ and ‘Once you have learned some important things in this unit, what could/should you do with this learning?’ Student responses to such questions could be stored and then compared to their responses to similar questions at the end of the unit (or a course).

2. **Motivation via WISE Problem Education:** To motivate students to learn the unit material and, more importantly, to orient their learning towards WISE Activism, teachers should organize some lessons (or parts of them) to make students aware of various WISE Problems and corresponding WISE actions that people have conducted to address such problems. Students should be encouraged to share WISE Problems and Activism about which they were already aware. Teaching strategies for these sorts of sensitization lessons might include: brief class discussions; student completion of a survey, followed by a class discussion; a field trip to a WISE Problem site (e.g., landfill or homeless shelter); student review of news media, followed by a report; teacher’s infusion of WISE Problem/Solution examples into other conversations; student internet/library search, followed by a report; hearing from a guest speaker, followed by class discussion; and, students’ interaction with a text-based or multimedia case method. A very good example of a multimedia case documentary on which to base a metabolism case method is *Fast Food Nation*. The point of these lessons is to illustrate for students that topics they are about to learn may help them to address WISE Problems relevant to those topics.

3. **Integrate STSE-NoST Education with Products-Skills Education Throughout the Unit:** The balance of the unit, as seen in Figure 2, should alternate among Products and Skills Education (finishing in Students’ Projects and WISE Activism). As often as possible, such Products and Skills Education should be linked to STSE and NoST Education (indicated in Figure 2 by the arrows passing through STSE & NoST Education). Doing so, should give students motivation for learning products and skills. Although there are many positive aspects of STSE and NoST Education that should be shared with students, it also will be important for teachers to emphasize some STSE and NoST Problems (collectively known as ‘WISE Problems’). For example, in a unit on cell metabolism (e.g., cellular respiration), the teacher could help students to realize that learning about metabolism could help them with nutritional problems, such as in the case of the poor nutritional value of manufactured and fast ‘foods.’ Similarly, when helping students to develop skills for conducting correlational studies, the teacher could guide students through a study of students’ gender-based choices of foods and/or beverages from the school cafeteria.

4. **Students’ Projects:** A defining feature of STEPWISE is the student-directed, open-ended science inquiry project. Through their own experiments and studies, students may generate findings that inform and

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5 This pedagogical framework was developed in the context of an action research project involving several teachers of science who were collaborating on STEPWISE implementation (http://www.stepwiser.ca).
6 http://www.youtube.com/watch?v=NLIMAycqZF8
motivate them to take WISE action(s). Students become motivated to take actions because they have ownership of the inquiries that indicated the severity and nature of the WISE Problems they were investigating. This motivation may be greater than from STSE-NoST Education alone. Because the projects are to be student-led, the topics students investigate should, perhaps, be left to them. If the teacher has earlier emphasized WISE Problems, the students may independently choose to focus their inquiries on WISE Problems. But, sometimes — perhaps early in a course — the teacher may want to provide students with a list of possible inquiry projects. For example, in a unit on cell metabolism, one group of students might conduct an experiment to test effects of increasing concentrations of food colouring on yeast cell metabolism. Results may indicate that certain concentrations of food colouring limit yeast fermentation. This result may motivate students to take WISE actions to address such harmful effects.

5. **WISE Activism**: Again, ideally, students should be given a choice about which WISE Problems to address with their action(s). The teacher should provide some ‘parameters’ for completing this assignment — such as: i) produce ‘ready-to-use’ materials (e.g., letter to government), ii) produce at least two forms of action (letter and poster), iii) include in the actions (e.g., letters and posters) about 500 words of text (and graphics) that indicate the STSE and/or NoST behind the problem to be addressed and a possible solution, and iv) rationale (e.g., 500 words) for the action(s) that provides some information about Products, STSE and/or NoST, and results of their own inquiry. One student group might, for instance, place posters in the school cafeteria and short messages in daily PA announcements that promote healthier eating. In a separate document, they would justify their recommendations for better eating.

The annotations in Figure 1 provide brief explanations of the various elements of STEPWISE. However, it is important to recognize principles that underlie the framework\(^7\), including:

**Equity**

STEPWISE aims to ensure that all students develop their maximum potential literacy in science and technology. A key element of this position is to ensure that their education is as contextualized as possible — in contrast to the decontextualization common to school science. Instead of sorting students along a gradient associated with their pre-instructional cultural and social capital, including their abilities to think and act in the abstract, we encourage educators to provide students with opportunities to be engaged in teaching and learning environments that acknowledge the idiosyncratic, situated (contextualized) nature of learning. For example, infusing more technology education into school science may be appropriate (e.g., Fensham & Harlen, 1999), given the complex, situational nature of decision making in technology design. Although 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 situated (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, 2003), 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

\(^7\) *STEPWISE and Science and the City* share these principles.
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).

Diversity

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; 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.

Holism

Associated with the contextualization that may promote equity and diversity is the concept of holism; that is, the idea that the properties of a system (e.g., physical, biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by its component parts alone. Instead, the system as a whole determines in an important way how the parts behave. Aristotle (c350BC) was among the first to suggest this, with his claim that ‘the whole is different from (perhaps greater than) the sum of its parts.’ This applies to STEPWISE, in that each element of the framework may be affected by and affect each other
element in it. As teachers conduct lessons in Products Education, for example, they may inadvertently communicate messages to students about STSE-NoST (Hodson, 2008). Alternatively, the teacher might plan for this, attempting to be explicit about particular claims about science as laws, theories, etc. are being taught (Abd-El-Khalick & Lederman, 2000). On the other hand, teachers’ approaches and students’ learning often depend on their respective positions about STSE-NoST (Bencze et al., 2006; Tsai, 2002).

A holistic approach, such as that in STEPWISE, resists — by definition — its antithesis, *reductionism*, which would sanction educators to emphasize teaching and — especially — assessment and evaluation of *inscriptions* (e.g., drawings of cells, chemical algorithms, and transcriptions of student conversations) which, some would argue, are unavoidably amenable to reification (e.g., Wenger, 1998). Reification associated with inscriptions is, in turn, associated with power and control — and, in educational contexts, enables certain educational stakeholders to control students’ thoughts and actions in ways not necessarily to their benefit (Roth & McGinn, 1998). By encouraging more spontaneous and situated decision-making, STEPWISE tends towards ceding of learning control to students.

*Breadth*

There is a great deal of disagreement and, indeed, controversy, surrounding the sort of science education that is best for students. Much appears to depend on the nature of ‘stakeholders’ — such as politicians, members of the business community, government officials, parents, students, etc. — who might contribute to and/or benefit from their association with science education. Although agreement is lacking about the nature of literacy that might be best for students, the elements in the STEPWISE framework are based on the *broad* categories* for learning in science and technology education* promoted by Hodson (2003):

*• Learning Science and Technology [Products Education]: acquiring and developing conceptual and theoretical knowledge in science and technology, and gaining familiarity with a range of technologies.*

*• Learning About Science and Technology [NoST/STSE Education]: developing an understanding of the nature and methods of science and technology, an awareness of the complex interactions among science, technology, society and environment, and a sensitivity to the personal, social and ethical implications of particular technologies.*

*• Doing Science and Technology [Skills Education & Students’ Projects]: engaging in and developing expertise in science inquiry and problem solving; developing confidence and competence in tackling a wide range of ‘real world’ technological tasks.*

*• Engaging in Sociopolitical Action [WISE Activism]: acquiring the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern (p. 658).*

Many curricula in the world (e.g., CMEC, 1997; DfEE, 1999; NRC 1996) make provision for school systems to encourage students to develop literacy (and inquiry and/or design project findings) encompassing the elements around the periphery of the STEPWISE framework. Such a broad definition of literacy is intended to provide students with opportunities for enhancing their personal lives and to serve as contributing members of societies greatly integrating fields of science and technology. If education were limited to the kinds of instructional outcomes indicated around the periphery of the framework in Figure 1, however, it might still promote *possessive individualism* — with each student primarily focused on enriching his/her own knowledge, expertise, etc. As noted above, possessive individualism is highly associated with

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8 It should be noted, as Hodson (2003) suggests, that learning in any one domain may be dependent upon and affect learning in one or more other domains. This is indicated in Figure 1 by the double arrows. As an example, Abd-El-Khalick and Lederman (2000) have noted that, while students are conducting projects (‘Students’ Projects’), they may implicitly develop — to some extent — conceptions ‘about science and technology’ (part of ‘STSE Education’). Therefore, it is important to note that STEPWISE is a dynamic system, with learning in various domains affecting and being affected by other domains.
the profit motive — 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 1) in ways that would promote wellbeing for other people, societies and living and non-living environments.

**Depth**

Ensuring students have opportunities to develop deeper understandings of scientific concepts must be a priority for educators. However, 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). Such an epistemology is reflected in knowledge duality theory. According to Wenger (1998), for example, deep learning is more likely when learners directly participate in development and use of representations of phenomena. Learning depth occurs, perhaps, due to students’ sense of ownership in the inductive (Participation → Reification) and deductive (Reification → Participation) phases of this dialectical relationship (refer to Figure 3). 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.

**Empowerment**

Rather than being veritably convinced that knowledge production, dissemination, etc. belong to powerful others and are largely efficient and complete, as described above, 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 (under “Enlightenment”) — can be helpful along these lines. 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 (e.g., laws & theories) of professional science and technology, thus giving students more opportunities to learn about science and technology and to develop expertise — e.g., through “Skills Education” — 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).

Given the apparently natural differences among people (e.g., genetically), it seems clear that not everyone can be ‘rich’ in social and cultural capital to the same extent. This should not in our view, however, mean that such differences should be valued differently. One way to overcome such differences is to prioritize collaborate group learning, etc. In this vein, it is crucial for school systems to 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 such entities as:
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).

**Self-determination**

Given the consumerist orientation of science education, as argued above, 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). 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. “[T]eachers 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 and confidence to help students conduct 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).

**Enlightenment**

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 practices common in the sciences, 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\(^9\). 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). 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.

**Responsibility**

Finally, as argued extensively above, education needs to be conceived of as an opportunity for students to develop cultural, social and other forms of capital (e.g., as literacy in science and technology) so that they might improve their own lives but, crucially, so that they might spend their ‘wealth’ on improving the wellbeing of other individuals and on societies and environments. This is, of course, the essence of WISE Activism — the central organizer for STEPWISE.

Overall, *Science and the City* and *STEPWISE* emphasize a socialised, situated approach to pedagogy in which knowledge is generated through collaborative inquiry in a particular context. Such contexts are selected because of their propensity to generate student-focused explorations routed in the knower’s ‘externalised’ responsibility to family, friends and local environments and communities. An axiomatic feature of this pedagogy is that knowing-well and acting-well become constitutive features of science education.

**Concluding Remarks**

Given the severity of the many personal, social and environmental problems that appear to be associated with science, science education and, more particularly, with a hyper-economized societal zeitgeist, it seems clear that radical changes are needed. Based on the arguments above, it is apparent that we generally need to shift humans’ orientation away from a social ‘Darwinist’ ideological perspective towards one based more communitarian epistemological perspectives. As in STEPWISE, students might come to see their education not just as a source of their own wellbeing but, also, as a resource for contributing to the wellbeing of individuals, societies and environments. Although teachers may successfully implement manifestations of the above frameworks, readers also might consider that no such framework can be free from bias and, therefore, it will be important for them to engage in revolutionary conscientization (enlightenment/awareness) and praxis (critical reflective practice) (McLaren, 2000).

**Bibliography**


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\(^9\) 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.


