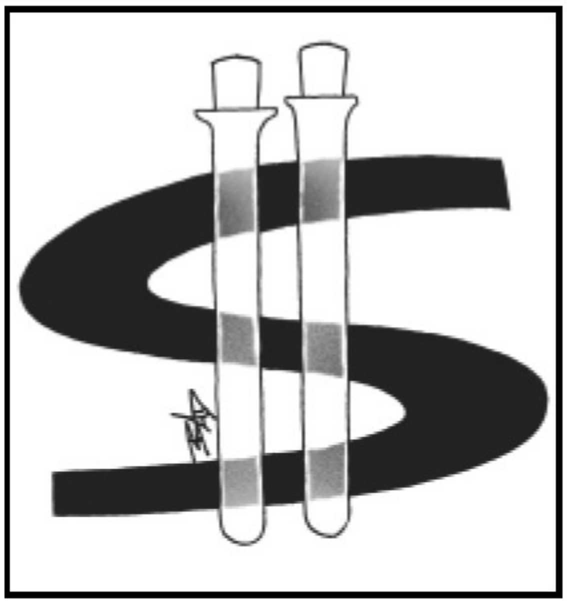
For-Profit Science & Science Education



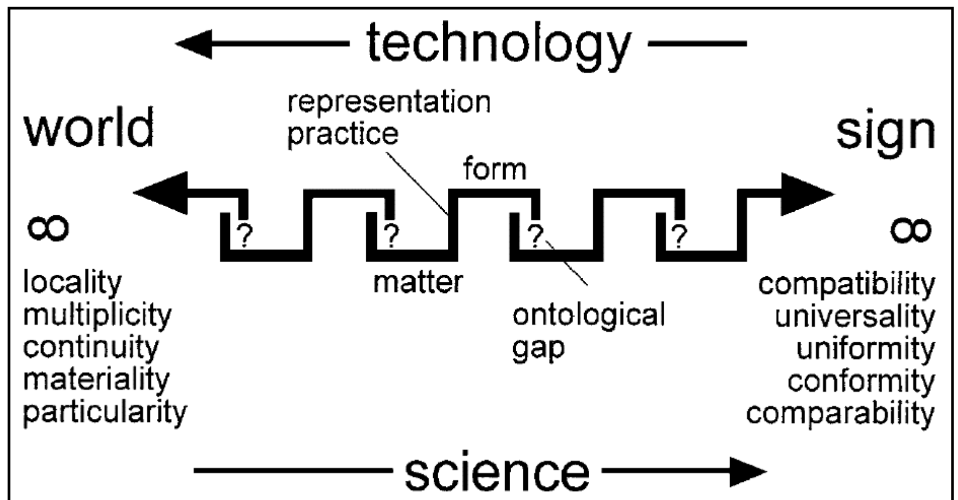
A Position Paper by
J. L. Bencze, 2008

UNIVERSITY OF TORONTO
OISE | ONTARIO INSTITUTE FOR STUDIES IN EDUCATION

INTRODUCTION

School science has the role, to some extent, of representing fields of professional science[1] for students and, through them, the larger society. To help ensure this, many governments have included learning goals relating to the nature of science in their curriculum policy documents and guidelines. In support of these goals, educational researchers, teachers, and others have helped develop teaching and learning strategies that may help students to develop realistic conceptions about fields of science. An aspect of professional science that has had relatively little attention, however, pertains to effects of the profit motive on practices and products in the sciences.

[1] Classically, 'science' has been considered an activity aimed at documenting, explaining, and predicting about phenomena of the world, while technology is aimed at bringing into existence phenomena that do not naturally exist (Schauble *et al*., 1991). Relationships between science and technology are complicated. Gardner (1991) suggested that, historically, there have been at least four relationships between fields of science and technology; that is, i) science precedes, and is necessary for, technology; ii) science and technology are independent of each other; iii) technology precedes, and is necessary for, science; and, iv) technology and science are co-dependent. There is much debate about such differences and relationships, however. From the field of semiotic (the study of signs and symbols), it is possible to conceive of these fields as similar, if not identical. As shown in Figure 1, below, 'science' in a classical sense can be thought of as that activity that generates 'signs' (representations, such as drawings of cells) from phenomena of the 'world' (e.g., cells), while technology involves bringing phenomena into the world based on various signs (Roth, 2001). However, due to the dialectic relationship between 'Sign' and 'World,' it is apparent that each affects the other and is affected by the other. Therefore, it is difficult to distinguish between them and, indeed, 'they' may actually 'be' something intermediate between the 'two.'



Roth, W.-M. (2001). Learning science through technological design. Journal of Research in Science Teaching, 38(7), 768-790.

Figure 1: 'Science' vs. 'Technology.'

Studies of science indicate that there are some significant compromises to the integrity of scientific work associated with the profit motive and, in democratic societies, it seems clear that students - as future citizens living in a world strongly influenced by practices and products of science - should be informed about the existence of such indiscretions. Accordingly, after a review of portrayals of science in school science, this review article focuses attention on the nature of profit-influenced science and corresponding implications for science education.

NATURE OF SCIENCE IN SCHOOL SCIENCE

"[H]elping students develop adequate conceptions of nature of science (NOS) and scientific inquiry has been a perennial objective in science education … Indeed this objective has been agreed upon by most scientists and science educators for approximately 100 years …" (Lederman, 2006, p. 302). Students might learn, for example, that topic choice often is influenced by powerful people, there is no one standard inquiry method, and that many inquiry decisions (e.g., data-collection and interpretation) are theory-dependent. Such an education can benefit students in many ways. Driver, Leach, Millar and Scott (1996), for example, provide five arguments for providing students with an education in the nature of science, including for: making sense of everyday phenomena (*Utilitarian* argument); participating in public discussions and debates on matters relating to science and technology (*Democratic* argument); appreciating science as one part of culture(s) (*Cultural* argument); gaining insights into sets of moral perspectives (*Moral* argument); and, assisting in their learning of 'products' (such as laws and theories) of science and technology (*Science Learning* argument).

Despite the long-term motivation and efforts, it is apparent that NOS education has not been as successful as many would hope it to be in many school contexts. Lederman (2006), for example, laments that, "[d]espite numerous attempts, including the major curricular reform efforts of the 1960's, to improve students' views of the scientific endeavor, students have consistently been shown to possess inadequate understandings of several aspects of NOS and scientific inquiry…" (p. 302). Similarly, Bell (2006) claims that "[n]early five decades of assessments have consistently shown that students do not develop adequate conceptions of the tentative nature of science from their educational experiences" (p. 436). There appear to be many aspects of the nature of science that educators feel could be learned more successfully by students. Hodson (1998) has suggested, for example, that school science promotes at least ten 'myths' about professional science, including: *science comprises discrete, generic processes*; *scientific inquiry is a simple, algorithmic procedure*; and, *science is a value-free activity*.

There appear to be various factors that may explain why science education systems (e.g., involving governments, business leaders, scientists, school system administrators, etc.) have struggled with NOS education goals. Although there have been many efforts to support teachers, it is apparent that many of them continue to hold views that are largely incongruent with history, philosophy and sociology of science (Abd-El-Khalick & Lederman, 2000). This may explain, at least partly, why prominent educators like Crawford (2007) claim that most teachers in the USA are having difficulty "creating classroom environments that are inquiry-based [which, in the USA and elsewhere is associated with NoST Education], and that support their students in developing informed views of scientific inquiry and the nature of science" (p. 613). "Further exacerbating this problem," according to Bell (2006), is that "… textbooks and other curricular materials [are] rife with explicit references to misconceptions about the nature of scientific enterprise" (p. 437). Perhaps partly for such reasons, science education systems tend to emphasize instruction in products of science and technology - often compromising students' education about the nature of science. Bell (2006), for example, states: "In the typical classroom, instruction has focused almost exclusively on the well-established products of science and cookbook approaches to laboratory exercises, using authoritarian teaching modes" (p. 430). These sorts of activities appear to be attributing to students' difficulties in developing realistic conceptions about science. Regarding common guided 'lab.' activities used in school science, for example, Chinn and Malhotra (2002) concluded that the epistemology of many of them were "… *antithetical* to the epistemology of *authentic* science" (p. 175, emphasis added).

An influential source limiting the extent to which science education systems depict professional science in realistic ways appears to be communities of professional scientists - particularly 'academic scientists' (such as those working in universities), who seem to have worked to ensure their fields are portrayed in ways that might encourage students to study in the sciences (Fensham, 1993). Scientists, like members of any profession, likely prefer to have their work perceived as being appropriate, efficient and effective. Scientists frequently have, apparently, promoted such views in the context of portraying science as isolated from fields of technology/engineering and, more broadly, from societies. Guston (2000), for example, concluded that the scientific community has acted over the years to ensure that it has autonomy from public scrutiny. It prefers to have the freedom to investigate topics of interest and, if applications may arise from those interests, all the better. It does not want to be considered open to public/private scrutiny or influence (Rudolph, 2005). With reference to the framework in Figure 2, scientists seem to often prefer to acknowledge the Internal Sociology of Science - involving, for example, social negotiation of knowledge among scientists in a field - but not the External Sociology of Science, in which fields of science are thought to interact with fields of technology/engineering and with societies and their interest groups.

To promote the idea that fields of science can and should act independently from fields of technology and from societies, the scientific community often portrays itself as adhering to a set of principles that are purportedly capable of ensuring the integrity of their work (e.g., in terms of appropriateness, efficiency and effectiveness). One such set of principles is

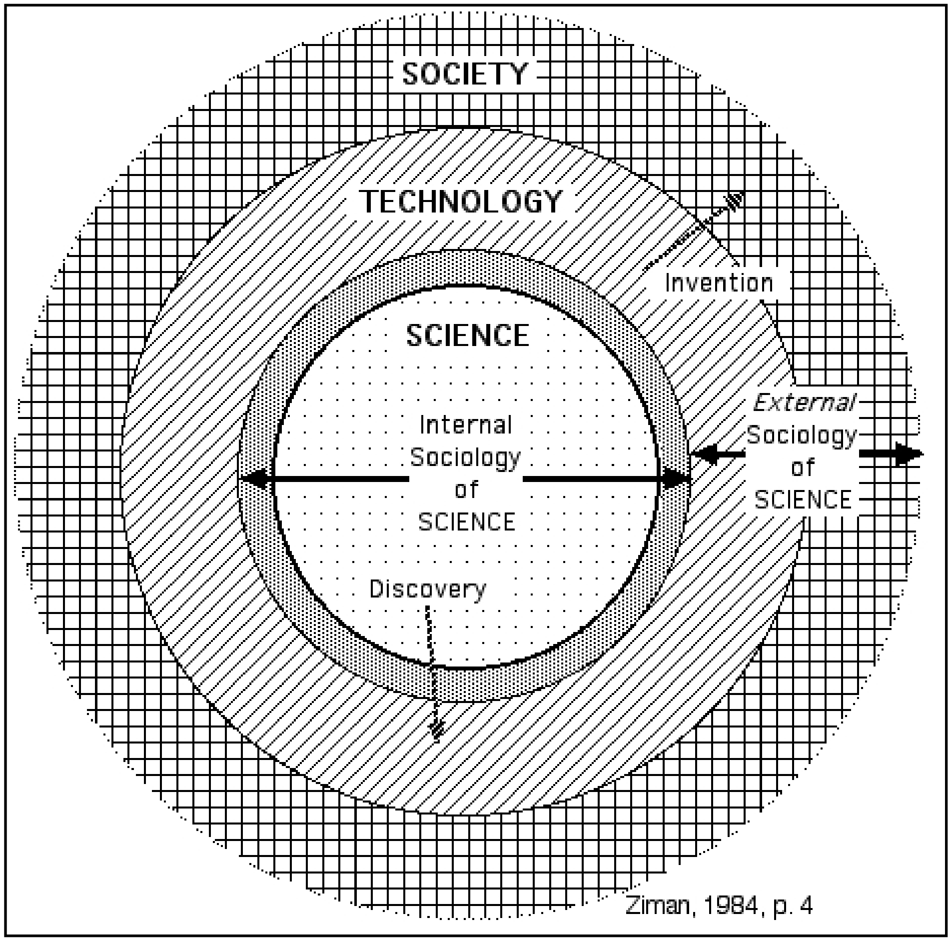


Figure 2: 'Internal' vs. 'External' Sociology of Science.

Merton's Norms (or institutional imperatives) for the sciences (Merton, 1942, 1973). Briefly, he recommended that practitioners within fields of science should try to adhere to the following principles: 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 (Ziman, 2000, pp. 57-82).

It is, perhaps, important to note that Merton's Norms were, largely, a set of presciptions for, rather than descriptions of, the sciences. He developed them not so much, apparently, out of studies of typical scientists in action as in response to largely unethical practices by scientists influenced by the Nazi regime (Kellogg, 2006). He was aware that some scientists do compromise his norms. He recognized, for example, that scientists generally had a vested interest (contravening disinterestedness) in results of their work and would withhold them (contravening communalism) until they could be published. He also recognized some contravention of the norm of universalism, such as in the case of prominent scientists finding it easier to have publications accepted, funding applications approved, etc. - a phenomenon he called the Matthew Effect (Merton, 1988). He also felt that "communism [communalism] of the scientific ethos is incompatible with the definition of technology as 'private property' in a capitalist economy" (Merton, 1986, p. 612). Nevertheless, to ward off extreme abuses of science, such as in the case of Nazi science, he felt that it was necessary for scientists to vigorously adhere to and promote his normative principles. In setting these principles, he also was, apparently, influenced by Polanyi's (1941-3) suggestion that science needs to function like a free market - a self-regulating system free from outside influences (Martin, 1999). Additionally, it is thought that Merton, as a very religious person, was greatly influenced by Weber's (1904-5) treatise, *The Protestant Ethic and the Spirit of Capitalism* - which promoted persistent and honest work (Turner, 2007).

Merton's (1942, 1973) prescriptions for science have gained credence over the years. There are suggestions that many scientists believe (and strongly claim) that they adhere closely to Merton's Norms. Ziman (2000), for instance, advises that the norms "are particularly useful because they stress the sociological features that academic scientists consider to be peculiar to their profession" (Ziman, 2000, p. 55). Some of this belief appears to emanate from government policy documents. After World War II, according to Kellogg (2007), the US government released a major policy document for the funding of research in the sciences that "supports a conception of basic science that is Mertonian in all of its essentials" (p. 8). The influence of Merton's prescriptions for behaviour in the sciences also is evident in government curriculum policy documents and guidelines. In Science for All Americans (AAAS, 1989), for example, it is apparent that the authors view science as being internally regulated:

> The direction of scientific research is affected by informal influences within the culture of science itself, such as prevailing opinion on what questions are most interesting or what methods of investigation are most likely to be fruitful. Elaborate processes involving scientists themselves have been developed to decide which research proposals receive funding, and committees of scientists regularly review progress in various disciplines to recommend general priorities for funding (p. xx).

Congruent with such isolationist portrayals, it is common for governments to depict fields of science as distinct from fields of technology/engineering. In the National Science Education Standards (NRC, 1996), for example, the authors state that it is important for students to understand that "science and technology are pursued for different purposes … [and science is described as an activity] … driven by the desire to understand the natural world … [with the direction of inquiry largely guided by curiosity, while seldom being influenced by societal desires. Technology, meanwhile, is explicitly linked to societal concerns, being oriented towards the] … need to solve human problems" (NRC, 1996, p. 192).

An isolationist view of science, such as belief in strict adherence to Merton's (1942, 1973) norms, is problematic from several perspectives. From historical and philosophical perspectives, for example, science and technology often interact and, indeed, have much in common (Roth, 2001). Kitcher (2001) has gone so far as to suggest that "the complex intertwining of the epistemic and the practical and the mixed motivations of actual researchers [in science and technology] . . . make[s] the application of any simple distinction . . . impossible" (p. 90). Apart from such historical and philosophical issues, however, it is, perhaps, more problematic that an isolationist view of science is limiting citizens' education with regards to various power relations involving fields of science and technology and societies. For example, Allchin (2004) cites issues of power surrounding the science of craniology in the 19th century:

> The goal was explicit for many: to justify (or perhaps understand) the natural intellectual inferiority of women and non-European races. Yet the practice seemed to follow standard norms of 'good' science. For example, craniology was a quantitative science par excellence, with 600 instruments and, according to one researcher, over 5000 requisite measurements of the skull. When evidence did not fit their theories, scientists revised them, shifting from raw cranial size to more subtle measures of body weight ratios or facial angles. But they did not question the enterprise itself, nor see its potential for bias (p. 938).

Similarly, regarding fields of technology, citizens might learn that "different people are situated differently and possess unequal degrees of power as well as unequal levels of awareness" (Winner, 1986, pp. 28-29). Without such an education, however, citizens may be at a distinct disadvantage in terms of their participation in democratic decision-making on matters involving science and technology (Winner, 1995). About this, Rudolph (2005), for example, states:

> When complex technical issues of national importance come up for public debate-issues related to transportation policy, energy development, or communications technology-the likelihood is that the public, seeing the problem as primarily "scientific" and possessing all the characteristics of science in the abstract, might be inclined to defer to the experts. The result is that a small, nonrepresentative group of individuals will make decisions that significantly influence how the majority of citizens will live and relate to one another in the world. … This state of affairs, I would argue, is one that does not bode well for the collective well-being of our increasingly technological society (p. 808).

An aspect of the nature of science that has not had extensive attention in education pertains to effects of economic forces on professional science and technology (Carter, 2008). Such effects appear to have significant implications for the traditional isolationist view of professional science often promulgated in school sciences. Hurd (2002), for example, said: "A reinvention of science education calls for a recognition of the many changes in the social and economic character[is]tics, ethos, practice, and culture of science" (p. 5). This is a contested terrain, but studies about science suggest that there are some significant problems regarding the integrity of science in some science-business partnerships. Accordingly, in addition to learning about some of the more philosophical ideas about science, such as that observation may always be theory-laden, students should become familiar with such sociological issues as those stemming from business-science relations.

PROFESSIONAL SCIENCE AND GLOBAL ECONOMIZATION

Global Economization

Any analysis of science must take into account the milieu in which it functions. As argued above, science cannot be considered a closed system with scientists independently making such decisions as topic choice, inquiry methods, conclusions or the extent and nature of dissemination. In many countries of the world, a significant factor in general decision making is a deeply-entrenched economic ethos (Weber, 1904-05); that is, a set of assumptions that promote significant human focus on for-profit trade in goods and services. This has been, and continues to be, a major driving force in human life. In recent years, many analysts (e.g., Bakan, 2003; Carter, 2008; McMurtry, 1999; Wood, 2005) discuss this ethos in terms 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). 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 allow market mechanisms to freely (independently) determine the nature of for-profit production and consumption of goods and services. 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 the devastating effects of the Second World War, this ideology has become known as *neoliberalism* (McMurtry, 1999). Under neoliberalism, governments have tended to: reduce taxation and, related to that, spending on social programmes (e.g., health and education), place more emphasis on individual responsibility rather than the public good; reduce regulations on business activities, such as environmental and labor standards; and, privatize some government services (e.g., forms of transportation) - all in the name of liberation of businesses to make a profit, often under the assumption that some business profit will 'trickle down' to lower classes in societies.

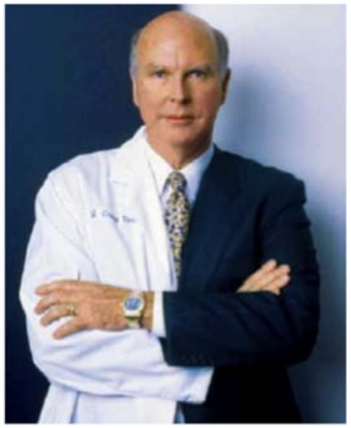
Neoliberalism appears to be a very pervasive ideology. Indeed, there are suggestions that it has penetrated the sub-conscious of large segments of societies. In describing it, Larner (2000) suggests that, although overt mechanisms of government regulation may be reduced, neoliberalim may still promote societal governance:

> [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).

Neoliberal *governmentality*, as discussed by Foucault (1991), is a form of governance in which the will to function along neoliberal lines is instilled into the sub-conscious of the world's peoples, many of whom may believe that they are acting independently but, 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. Decades ago, in *One-Dimensional Man*, Marcuse (1964), suggested that mass media may assist in infusing messages into the subconscious of members of society, in a process comparable to governmentality: “The political needs of society become individual needs and aspirations, their satisfaction promotes business and the commonweal, and the whole appears to be the very embodiment of Reason” (p. xli).

University-Business-Government Partnerships

Among entities in societies that appear to have been affected by economic liberalism is traditional academic science, where it exists. This sort of science, which often is situated in universities, is said to operate in relative isolation from fields of technology and the larger society, but aims to generate knowledge about nature that may (or may not) be of use to the common good of societies (Ziman, 2000). Gibbons, Limognes, Nowotny, Schwartzman, Scott and Trow, M. (1994) referred to such autonomous science, in which scientists have significant freedom to make such decisions as topic choice, inquiry methods and extent and nature of dissemination, as *Mode 1 Research*. This is a view of science that, as described above, seems to be supported by many scientists, members of the public and members of school science systems. Gibbons *et al*. (1994) recognized a different form of science, however, which they referred to as *Mode 2 Research* - and Ziman (2000) later called *post-academic* science. This second conception of research is, generally, said to involve significant associations among fields of science and technology and the larger society. Physical signs of the existence of Mode 2 Research in universities include: “science and technology parks, centres of excellence, and other university-based research innovators and incubators …” (Dzisah, 2007, p. 127). Frequently, they involve partnerships between fields of science and technology (and other departments) in universities, along with government (representing the larger society) and, as well, private enterprise. Etzkowitz and colleagues (e.g., Etzkowitz, 2003; Etzkowitz & Leydesdorff, 2000) describe such partnerships as the Triple Helix of University-Industry-Government relations. These partnerships are portrayed as contributing to the national good, as well as to private profit, particularly in terms of their orientation towards efficient and effective production of goods and services and, through that, assistance in a nation's international economic competitiveness. The existence of such partnerships is not, necessarily, new. Pestre (2003), for example, suggests that “knowledge has always mattered tremendously to states and to economic elites [perhaps partly represented by business]; that most knowledge producers have always been attentive to the interests of those elites; and that science has always directly contributed to, and has been a major resource for, changes in social ideologies” (p. 250).



University-Industry-Government partnerships are considered by many to have various benefits. As Etzkowitz and Leydesdorff (2000) say, “[although] the driving force of the interactions can be specified as the expectation of profits [for private firms, 'profit'] … may mean different things to the various actors involved” (p. 118). They suggest, for example, that universities can gain freedom from government regulation and that businesses can become more academic, such as through promotion of training and knowledge dissemination. Similarly, Dzisah (2007) and Ziman (2000) point out that, particularly for fields of research and development that is heavily-reliant on expensive technologies and other resources, the private sector can support universities in an era of declining government financial support. Such collaborations have, indeed, generated technologies considered by many to be beneficial, such as hip replacement surgery (Weinstein, 2007). A closer association between abstract knowledge production and technological applications (e.g., via Triple Helix relationships) also appears to make philosophical sense. In terms of Wenger's (1998) *knowledge duality theory*, for example, deep understanding (a traditional goal of science) is promoted through close dialectic associations between participation in the world (knowledge use) and representation(s) (e.g., laws and theories) of it. Supporters of Triple Helix relations can be seen to accommodate (consciously or otherwise) this concept suggesting, in terms of knowledge management theory, that "knowledge use/application cannot be separated from production" (Hellström & Raman, 2001, p. 145). In more practical terms, Mode 2 Research is said to have the advantage of shortening the time between discovery and production of useful products for societies (Etzkowitz & Leydesdorff, 2000).

Science for Private Interests

The idea of the existence of Mode 2 Research represents a significant challenge to the common view that science largely functions in isolation of fields of technology and the broader society and, in doing so, is a self-governing entity - strictly adhering, for example, to Merton's (1942, 1973) institutional imperatives. There is, therefore, a need to raise the awareness level of the nature of Mode 2 Research. In doing so, it is apparent that an aspect of such an education should be reference to possibly problematic characteristics of business-science relationships - in addition to references to the various benefits, as outlined above. A particular concern for many is that such partnerships indicate a reduction in contributions of science to the public good in favour of servitude to private economic interests. Nowotny, Scott and Gibbons (2003), for example, insist that " [k]nowledge is now regarded not as a public good, but rather as 'intellectual property', which is produced, accumulated, and traded like other goods and services in the Knowledge Society" (p. 185). In effect, there is the feeling that a public resource, academic science, has been turned over to private hands - a process of *privatization*, which is said to be a common element of the neoliberal agenda (e.g., Gabbard, 2000a). Associated with neoliberalism are corporations, and many analysts have significant concerns about corporate ethical leanings. Various analysts (e.g., Bakan, 2003; Gabbard, 2000a) stress that a key problem with corporations seems to be that their board members have the fiduciary obligation (in law) to orient all decisions towards maximization of profits for shareholders, regardless of side-effects of their actions. Along these lines, Bourdieu (1998) suggests that supporters of the neoliberal agenda - including many members of corporations - generally work to dismantle collective structures (e.g., public education and environmental regulations), since they are viewed as a threat to generation of maximum private profit.

There may be many ways to analyze effects of business associations with fields of science, but information from research literature bases seemed to apply to each of Johnson and Stewart's (1990) three broad - but not, necessarily, mutually-exclusive - categories relating to knowledge development in the sciences; that is: *Problem-setting* (e.g., topic choice), *Problem-solving* (e.g., inquiry methods), and *Peer-persuasion* (e.g., dissemination and argumentation). Throughout this analysis, references are made to ways in which science conducted in association with businesses indicate that Merton's (1973) institutional imperatives are not realistic - and, in so doing, provide convincing evidence for the existence of Mode 2 Research (alongside Mode 1 forms).

Problem-setting

There is considerable evidence that topic choice in science and technology often serves private interests over those that might benefit the larger society and, related to that, that science may not be as isolated from technology and society as is sometimes implied in schools. Broadly, when private interests are at stake, it seems that certain research and development (R&D) topics are either promoted or suppressed. Axelrod (2000), a practising scientist, said, for example, that "private and public funding agencies increasingly seek to reshape the purpose of research to define curiosity-based scholarship right out of the equation. If the results of our labours are not judged market-worthy, they are deemed to be of minor importance" (p. 201). Similarly, Carter (2008) said that the: "entrepreneurial ethos has extended the enterprise form to the institutions and processes of science, largely privileging the production of commercialised commodities over other concerns" (p. 618). A consequence of such choices may be that areas of R&D are restricted to those that companies feel are likely to efficiently - in terms of cost-benefit analyses - generate positive results, including profits (Ziman, 2000). It is much more expensive to support research for its own sake, research that may or may not have practical applications. "With the emergence of a Knowledge Society, knowledge 'products', many of which are derived from university research, are increasingly valued, not in terms of their long-term potential, but in terms of immediate market return" (Nowotny *et al*., 2003, pp. 182-183). In short, expediency may overrule originality, one of Merton's norms. This sort of thinking has, apparently, minimized the development of radical new approaches in the computing industry in the last few years, for example (Goldstein & Hira, 2004). A similar phenomenon exists in the pharmaceutical industry. Most (about 86% in 1998) new drugs are not new but are, rather, minor variations (called, 'me-too' drugs) of existing chemicals. In the USA, this is possible because government regulations allow additional patent protection for what is, essentially, the same molecular formula and because companies are only required to test a 'new' (likely with minor variations) drug against a placebo - a situation in which the new drug need only be better than doing nothing at all (Angell, 2004). Meanwhile, " [t]o create an impression of a robust body of research, … firms have promoted multiple publication of slender research results, sometimes shuffling the sequence of the researchers' names to disguise the repetition" (Greenberg, 2003).

Originality also can be contravened, in sense, by suppressing possible areas of research. There are instances, for example, where research in an area is deemed unprofitable due to lack of market potential. In this regard, drug companies have been known to ignore research possibilities that might lead to medications for tropical diseases (e.g., malaria, sleeping sickness or schistosomiasis) or discontinue research relating to rare illnesses (antivenoms for poisonous snakebites) because the market size is too small (Angell, 2004). In a different, but related, vein, it also is apparent that industries whose products (e.g., tobacco, asbestos and pharmaceutics) may harm individuals and/or environments have exerted considerable pressure to block the conduct of potentially incriminating research (Glantz, Slade, Bero, Hanauer & Barnes, 1996). Similarly, with pressure from the military and arms manufacturers, governments often have been inhibited from sponsoring research into non-violent forms of defense (Martin, 1992). To restrict research, business and universities have had support from government, particularly in terms of patent legislation. In the USA, for example, the Patents and Trademarks Amendments Act (Bayh-Dole Act, named after the sponsoring Senators) allowed universities and businesses to patent outcomes of government-funded research (Angell, 2004; Dunford, 1987; Weinstein, 2007). Such arrangements are known as technology transfer agreements, in which intellectual property is, effectively, transferred from the public sector (i.e., universities, sponsored by government) to private businesses. Biotechnology companies have, for example, been attempting to patent life forms and DNA sequences as a way of preventing others from engaging in related research and development (Martin, 1999).

Often associated with for-profit science and technology is the business principle of cost externalization; that is, efforts to ensure that as many costs are borne by individuals and groups other than the company. In the food industry, for example, companies promote and use research aimed at creating food additives, such as tastes, odours, and textures - the point that much of what we eat are "counterfeit foods" (McMurtry, 1999, p. 168).

Problem-solving

Once research topics are chosen, it is apparent that private interests can then influence knowledge-building processes (e.g., experimentation). Such influences can indicate that Merton's Norms are not, necessarily, followed during science inquiries. In terms of universalism, for example, it is apparent that individuals' participation in research can be limited, to various degrees. A good example of this appears to pertain to the availability of tools, instruments, etc. for the conduct of research in particular fields. For example, restrictive material transfer agreements and software licensing strategies sometimes restrict access to essential software tools (such as those related to supercomputing that can analyze things like folds in a protein) that scientists use to conduct their research (e.g., in the area of genomics, where companies are creating bioinformatic tools to assist in research and analysis of genome related data). Most scientific software is proprietary, and beyond the reach of many poorer parts of the scientific community - much of which resides in disadvantaged countries (Triggle, 2005).

Skepticism is another norm that may be compromised in the context of private funding. Indeed, Ziman (2000) suggests that a "norm of utility is being injected into every joint of the research culture. Discoveries are evaluated commercially before they have been validated scientifically …" (p. 74; emphasis added), and that business-sponsored research "is clearly an activity where socio-economic activity is the final authority" (p. 174). The pharmaceutical industry, for example, often employs Contract Research Organizations to conduct and/or facilitate conduct of clinical trials of the effectiveness of medications (Mirowski & Van Horn, 2005). These companies frequently promote use of small sample sizes, younger, healthier (less susceptible to negative side-effects) subjects, lower doses than those to be prescribed, higher doses of the new drug tested against lower doses of the old drug (for which the patent period had expired), ineffective drug delivery techniques for tests of older drugs that companies want off the market, and short test periods in drug trials to maximize probability of drug approval (Angell, 2004; Bodenheimer, 2000). Through such techniques, it is apparent that the overall purpose of the research is to generate results that might reflect favourably on the relevant technology (e.g., medication) and associated company (Cho, Shohara, Schissel & Rennie, 2000). For example, in a survey of seventy articles regarding the efficacy of a particular medication (calcium channel blockers), researchers found that ninety-six percent of the authors whose papers supported the drug had financial ties to the companies producing the drug, while only thirty-seven percent of the authors who were critical of the drug had such ties (Angell, 2004, p. 107). Similar situations have been documented for research in the tobacco industry. In an effort to indicate the safety of secondhand smoke, for example, a company apparently studied smoking and health relationships in workplaces providing designated smoking areas - thus giving the appearance of overall risk reduction (Barnes, Hammond & Glantz, 2006). Such lack of integrity can lead to some significant social and environmental problems. It is felt, for instance, that many patients are put at risk when prescribed medications that have not undergone rigorous testing or if potential clinical trial participants are not informed (in consent forms) of a drug's potential risks (Weinstein, 2007).

Peer Persuasion

Issues of research integrity associated with business-science partnerships also seem to influence processes of dissemination of findings. Such issues appear to cast significant doubt on the norms of communalism and skepticism that often are claimed to be associated with the sciences. The amount of communal sharing of evidence and claims, for example, often is less than some might imagine. Some of the more well-known cases of suppression of results have been reported for the pharmaceutical, tobacco and biochemical industries. Researchers under contract with drug companies have, for example, been prevented - until a public outcry - from publishing negative results of drug trials, including research on hypothyroidism (Krimsky, 2003) and thalassemia major (Bodenheimer, 2000). Similarly, tobacco companies have been known to consistently deny knowing about adverse effects of tar and nicotine in their products (Glantz *et al*., 1996), and manufacturers of pesticides have withheld research results that indicated toxic effects of their products (Hileman, 1998). In a related matter, it is apparent that, despite large inputs of public money into national defense research and development, governments have kept legislators and members of the general public in the dark about much of this work - often in the name of national security (Relyea, 1994; Weiner, 1990).

If companies have difficulties preventing release of incriminating results, however, some have been known to act in various ways to discredit the findings. In such cases, the norm of skepticism may be cast in doubt. Organizations can, for example, bury negative data within reports with mostly positive data, they can fail to discuss negative data in reports, and/or they can misrepresent negative data through various methods of display and organization (Martin, 1999). Failing that, or in tandem with such techniques, companies also have used various approaches to discredit researchers associated with incriminating findings. "Some of the methods used to attack dissenting scholars include ostracism, petty harassment, withdrawal of research grants, blocking of appointments or promotions, punitive transfers, reprimands, demotions, spreading of rumors, dismissal, and blacklisting" (Martin, 1999, pp. 346-347). In an apparent attempt to give the appearance of their integrity, however, some companies have resorted to hiring (for significant fees) reputable scientists to publish papers discrediting colleagues' work (Bodenheimer, 2000; Rosenstock & Lee, 2002). In the pharmaceutical industry, for example, private firms sometimes have been paid in the range of $12,000 to write a favorable article and then an academic scientist is paid about $1,000 for agreeing to have his/her name affixed to the article (Angell, 2004, pp. 158-159).

Given the various cases reported above about the nature of knowledge building and dissemination in the sciences, it seems clear that it is unrealistic to assume that all research is disinterested. Indeed, Ziman (2000) suggests that "[w]hat cannot be denied is that the academic norm of disinterestedness no longer operates" (p. 174) - if it ever did. Although it is likely that certain interests have always been - and probably will continue to be - part of the human condition (Habermas, 1972), business-science partnerships appear to provide clear evidence of this for science education. Similarly, Kleinman and Valla (2001) suggest that, "while the increasing commercialization of scientific research is often aimed at enhancing the legitimacy of academic organizations, it may have almost the opposite effect, actually undermining the long-established myth of scientific purity and disinterestedness" (p. 454).

SUMMARY AND CONCLUSIONS

People associated with research and development in universities, hospitals, and elsewhere appear to be aware of potentially adverse effects of business-science interactions. Bok (2003) reports, for example, that an editor of a prestigious medical journal is concerned that business-influenced research could be transforming the journal into "an advertisement mechanism rather than a vehicle for the distribution of sound medical science" (p. 74). Similarly, Pachter, Fox, Zimbardo and Antonuccio (2007), reporting on results of work of the Task Force on External Funding for the American Psychological Association, expressed concern that "a broad range of industries, including tobacco …, lead …, food …, real estate development …, and pharmaceuticals …, have used similar and often hidden strategies to influence a range of sciences, and educational organizations whose primary goal is to promote marketing, influence regulations, or advance other industry interests …" (p. 1006). Likewise, Pearce (2007), an epidemiologist, suggests that a significant "culprit … in the recent 'decline' in epidemiology …[is] … the increasing role of corporate influences" (p. 714), citing such issues as: "prominent epidemiologists regularly accept[ing] funding from industry either to conduct research, or more commonly to criticize research conducted by their colleagues, … [often involving] … episodes of industry cover-up or denial of deadly hazards, as in the Johns-Manville asbestos episode, the attempts to suppress the occupational hazards of brown lung disease, the protracted defence and promotion of cigarettes by the tobacco industry', and many other examples from the fields of pharmacoepidemiology and occupational and environmental epidemiology" (p. 715). From such awareness can come significant action to address problems perceived by such communities. Dzisah (2007), speaking for academic scientists in universities, recommended, for instance, that universities may not need to reject private funds, but should only accept such money in the form of grants - which he suggests will give scientists more control over their work.

Such awareness, and intent to act, appears to be needed in science education. Issues pertaining to business-science relationships do not appear to have been given significant priority in school science (Carter, 2008). Where business is mentioned, it is frequently discussed in terms of the perceived need to use science education as a means for preparing societies for global economic competition. The US National Science Education Standards document (NRC, 1996) states, for instance: "One of the purposes of science education is to "increase [students'] economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers" (p.13). Meanwhile, it is apparent that, in most science classrooms,

> recognition of the relationship between scientific work and capital is often reduced to simplistic assertions about the dependence of society on science, or vice versa. Except for participants in science fairs (who may have to purchase their own materials), students are usually fully isolated from the economics of the scientific work in which they engage; hence, it should not be surprising if their conceptions of science are

uninformed by financial concerns (Carlsen, 1998, p. 54).

Instead, it seems that professional science tends to be portrayed as logical, predictable, highly efficient and generally isolated from fields of technology and societies. Related to this, it is apparent that field of science and the people who work in them often are portrayed as adhering to Merton's (1942, 1973) institutional imperatives. Hodson (1998), for instance, concluded that school science tends to promote stereotypical attitudes not unlike Merton's Norms:

> It is commonly asserted that particular personal characteristics and attitudes are essential for the successful pursuit of science, and that scientists themselves all possess a particular cluster of attitudes and attributes, including superior intelligence, objectivity, rationality, open-mindedness, willingness to suspend judgement, intellectual integrity and communality. It is alleged that it is these 'scientific attitudes' that ensure that (i) all knowledge claims are treated sceptically until their validity can be judged according to the weight of evidence, (ii) all evidence is carefully considered before decisions are made, and (iii) the idiosyncratic prejudices of individual scientists do not intrude into the decision making (p. 205).

Despite the persistence and wide-spread nature of such views, it seems clear that science education needs to be reformed in ways that provide students with more realistic conceptions about the nature of science - including about various ways outlined above that economic liberalism seems to be affecting problem-setting, problem-solving, and peer persuasion in various fields of science and technology. As Allchin (2004) stated, "[t]he image of science typically promoted in science education-as pure and isolated from culture-… needs substantial transformation" (p. 939). It is apparent, for instance, that, like fields of technology often are portrayed, students need to realize that science is not an island in society but, rather, greatly integrated into it - often in ways that are influenced by economic interests. Carlsen (1998) seems to state this well: "Intellectual property issues, of course, are increasingly leaking into the most basic sciences, like mathematics and molecular biology creating incentives for secrecy that are rarely discussed in classrooms. The idea that secrecy and ownership are problems of technology, rather than science, is sociologically untenable" (p. 53). Such an education may require significant subject integration (Rudolph, 2005), given how fields of science and technology interrelate with each other and with societies and environments. Along these lines, various models of STSE education (e.g., Sadler, Barab & Scott, 2007; Walker & Zeidler, 2007) seem appropriate. As Hodson (2003) and others (e.g., Buxton, 2006; Pedretti, 2003) suggest, however, such an education would not be complete without helping students to prepare for and take sociopolitical action to address perceived STSE issues - including those pertaining to effects of economic liberalism on knowledge production and dissemination in the sciences. Such an activist education needs to accommodate many of most curriculum components (including student-led knowledge generation), due to the complexity of many challenges faced by individuals, societies and environments (Bencze & Alsop, *in press*).

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CONTACT INFORMATION

Dr. John Lawrence Bencze, Associate Professor
Department of Curriculum, Teaching, and Learning
OISE, University of Toronto
252 Bloor Street West
TORONTO, ON M5S 1V6 CANADA

Phone: 416 978 0079
Fax: 416 926 4744
Email: lbencze@oise.utoronto.ca
WebSite: http://www.lbencze.ca