



## **Science & Technology Education for Personal, Social & Environmental Wellbeing: Challenging Capitalists' Consumerist Strategies**

**Educação em Ciência e Tecnologia para o bem estar pessoal, social e ambiental: desafiando as estratégias consumistas capitalistas**

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### *Abstract*

There are many lenses through which we can examine science and science education. Drawing from a critical political perspective, this paper argues that school science and fields of professional science and technology are cooperatively-enmeshed in a global economic system prioritizing enrichment of few capitalists while compromising the wellbeing of many individuals, societies and environments. Under neoliberalism, for example, governments and extra-national organizations like the World Trade Organization promote strategic (non-)intervention in markets (regarding, for example, resource extraction, manufacturing, transportation and advertising) aimed at maximizing private profit, facilitated in part through externalization of personal, social and environmental costs. A major feature of this

apparent system appears to be emphasis on creation of elastic and enthusiastic consumer desires — particularly among those with few needs — that may repeatedly occlude profitable compromises associated with commodities. Cycles of utopian identities mask dystopian realities. Images of community, sexuality and power, for instance, may distract 'smart' phone users from environmental hazards of toxins (e.g., lead, bromine, chlorine, mercury and cadmium) within; and, as well, social justice concerns for workers in associated mining and manufacturing. Such consumerism, with its emphasis on cycles of acceptance of chameleon-like Trojan Horses, seems to be partly facilitated by school science. Fields of science are, for example, portrayed as overly systematic, unbiased and unproblematic while, often, their professional practices may be compromised through capitalist partnerships and influences — alliances that often appear to contribute to many socio-scientific issues. At the same time, learners may become alienated from opportunities to self-determine agents of being important to them and their communities. Drawing on concepts associated with liberatory pedagogy, a case study of a radical science teacher whose promotion of student-led, research-informed, actions to address critical socio-scientific issues seem to counter tendencies towards consumerism and associated potential personal, social and environmental problems are discussed.

**Keywords:** socioscientific issues; neoliberalism; consumerism; student-directedness; activism.

### *Resumo*

Existem muitas lentes através das quais podemos examinar a ciência e a educação em ciências. A partir de uma perspectiva política-crítica, este artigo argumenta que a ciência escolar e os campos da ciência e tecnologia profissional são cooperativamente emaranhados em um sistema econômico global que prioriza o enriquecimento de poucos capitalistas enquanto comprometem o bem-estar de muitos indivíduos, sociedades e ambientes. Sob o neoliberalismo, por exemplo, governos e organizações extra-nacionais, como a Organização Mundial do Comércio, promovem (ou não) intervenções estratégicas nos mercados (considerando, por exemplo, a extração de recursos, fabricação, transporte e publicidade), visando a maximização do lucro privado, facilitado em parte pela externalização dos custos pessoais, sociais e ambientais. A maior característica desse sistema aparente parece ser ênfase na criação de desejos de consumo elásticos e entusiasmados - especialmente entre aqueles com poucas necessidades - que podem repetidamente obstruir compromissos rentáveis associados com mercadorias. Ciclos de identidades utópicas mascaram realidades distópicas. Imagens da comunidade, sexualidade e poder, por exemplo, podem afastar os usuários de "smartphones" dos riscos ambientais das toxinas presentes neles (por exemplo, chumbo, bromo, cloro, mercúrio e cádmio); bem como das preocupações de justiça social para os trabalhadores associados à mineração e produção. Esse consumismo, com sua ênfase em ciclos de aceitação de cavalo de troia tipo camaleão, parece ser, em parte, facilitado pela ciência escolar. Os campos da ciência são, por exemplo, retratados como excessivamente sistemáticos, imparciais e sem problemas, enquanto suas práticas profissionais podem ser frequentemente comprometidas com parcerias e influências capitalistas - alianças que muitas vezes parecem contribuir para muitas questões sócio-científicas. Ao mesmo tempo, os alunos podem se tornar alienados das oportunidades de se auto-determinarem agentes importantes para eles e suas comunidades. Com base em conceitos associados à pedagogia libertadora, é discutido um estudo de caso de um radical professor de ciências cuja promoção da liderança estudantil, da pesquisa com ensino e ações

para tratar de questões sócio-científicas críticas, parecem contrariar tendências face o consumismo e os potencialmente problemas pessoais, sociais e ambientais associados.

**Palavras-chave:** *questões sociocientíficas; neoliberalismo; consumismo; direcionamento do aluno; ativismo.*

## Introduction

A fundamental characteristic of all life forms is a need to consume. Humans must, for example, extract nutrients and energy from environments in order to grow and prosper. It is apparent, however, that humanity's rates of consumption of matter and energy have dramatically increased in recent decades. Although controversial, many suggest that our increasing appetite for raw materials and finished products and services is posing significant threats to the wellbeing of individuals, societies and environments. Arguably the most significant of such threats are associated with dramatic increases in average global temperatures, but people also are concerned about such potential consumerism-related problems as health threats linked to manufactured foods, habitat destruction resulting from ever-expanding resource acquisition and, ultimately, species losses relating to a range of environmental changes.

Although reasons for such consumption-associated problems are, undoubtedly, complex, a significant factor appears to be the current state of capitalist economic systems — which, while generating many benefits, seem to be strongly orchestrating societies towards profit-generation largely fed by consumerism. Given that fields of science and technology play key roles in supporting capitalist production and consumption, a possible site of action for addressing consumption-oriented problems is school science — which assists in educating future scientists and engineers, along with other members of societies.

Accordingly, after a review of scholarship pertaining to capitalist economic systems and their current emphases on consumerism, suggestions for school science reform that may contribute to a better world are discussed — with particular attention to the work of a teacher (co-author here) who has been encouraging and enabling students to self-direct research-informed actions to address potential personal, social and environmental problems associated with fields of science and technology.

## Capitalist Networks of Influence

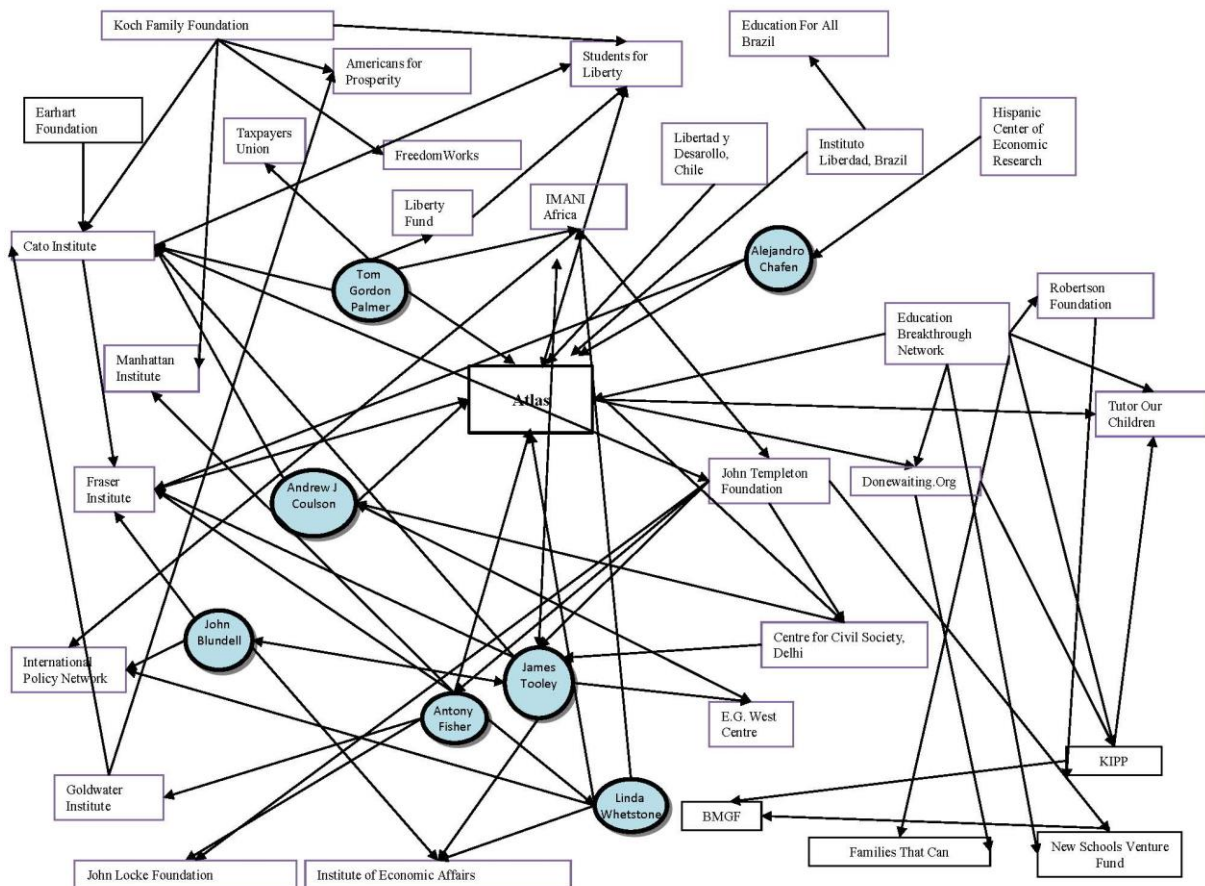


Figure 1: A Portion of the GCN, An 'Atlas' Network.

Although *capitalism* has existed for centuries, it seems to have come to dominate — perhaps in problematic ways — the *zeitgeist* of many societies. Many researchers suggest that it has become particularly influential and resilient in about the last four decades, with the advent of *neoliberalism* (MCMURTRY, 2013). Although economic self-interests are still prioritized, neoliberal capitalism is now more *globalized* (e.g., diffuse), *strategic* (e.g., with government intervention, at times) and, crucially, largely *subliminal* (e.g., semiotic). Its strength seems to derive particularly from its comprehensive network of cooperating 'actants' (materials, like people and diamonds, and semiotic messages, like 'I am cool') (LATOURE, 2005). In some ways, this global capitalist network (GCN) resembles a giant, three-dimensional, spider web that encompasses nation states and infiltrates into them. In his book, *Global Education Inc.*, Ball (2012) describes various networks linking actants aligned to support neoliberalism. As indicated in Figure 1, for example, 'think tanks,' like the *Atlas Economic Research Foundation*, are tied to such diverse actants as: *John Blundell*, *Koch Family Foundations*, *Education for All Brazil* and *Families that Can*. Key actants in this network are so-called *supra-national* organizations, like the World Trade Organization (WTO), World Bank (WB), Organisation for Economic Co-operation and Development (OECD) and International Monetary Fund (IMF). Like transnational corporations, while having offices and factories, etc. in individual countries, their operations are not tied to any one nation state. Rather, they function extra-nationally to serve global capitalists (HARVEY, 2010; MCMURTRY, 2013).

Although capitalism can and has sometimes used military actions to impose its will, a major mechanism of influence appears to be much more subtle — what Foucault (1991), for

instance, called neoliberal *governmentality*. Through various mechanisms (e.g., using actants like television, films, internet-based gaming), individuals are convinced to subconsciously accommodate and enact a range of neoliberal principles — such as: *excellence, efficiency, standardization, competition, privatization, individual responsibility* and *commodification* — while believing that they are self-governing. Sometimes, overt mechanisms, such as surveillance cameras assist in governmentality. Like the panopticon prison noted by Foucault (1977), however, citizens may subconsciously self-regulate their thoughts and actions in ways congruent with controllers' perspectives, even though people are not always monitoring the cameras (DENNIS, 2008). In some ways, we can think of processes of governmentality as forms of *education*. Indeed, many pro-capitalist actants appear to have such a function. In addition to others noted above, actants with significant educational purposes include 'transnational advocacy groups,' 'philanthrocapitalists' and pro-capitalist schools and universities, all spreading free-market ideology worldwide (BALL, 2012). Fundamental to their roles in 'post-industrial' capitalism is educational generation of pro-capitalist subjects that may construct/perform identities supportive of capitalists' agendas (BALL, 2000; HARDT & NEGRI, 2009; MCMURTRY, 2013).

### Pro-capitalist Fields of Technoscience

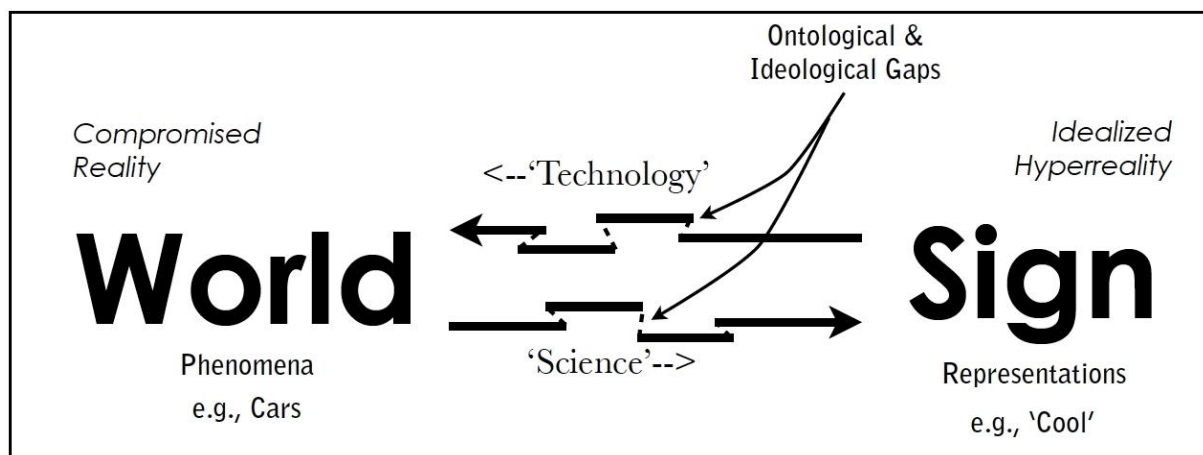


Figure 2: Neoliberalism-influenced Technoscience.

Among actants subjectified to support capitalism, fields of science and technology appear to be particularly essential. Many of their products essentially supply capitalists with instruments of wealth accumulation, including: electronics communication systems, biotechnologies, agricultural technologies, energy production and distribution systems and various forms of transportation. In addition to the many physical commodities generated by capitalists with assistance from fields of science and technology are, apparently, *semiotic* actants. This focus appears to be evident through capitalists' extensive promotion of consumer *desires* over commodity needs (BARBER, 2007; BAUDRILLARD, 1998; USHER, 2010). This priority can be understood using the schematic in Figure 2, which depicts theoretical relationships between 'science' and 'technology.' From one perspective, these two broad fields may be considered opposites — with 'science' generally involving World → Sign translations, while 'technology' converts Signs into new entities of the World. However, if we assume these opposite processes co-affect each other, then they may be considered one *dualistic* entity, perhaps called *technoscience*. Capitalists have, apparently, made considerable uses of this dialectic for profit-making. On the one hand, there has been

increasing focus during the neoliberal period on production of commodities ('World') as compared to science knowledge ('Signs'), as capitalists sought more immediate profits from investments in fields of science and technology. This effect was particularly-magnified when governments legalized business-science financial arrangements in university contexts (KRIMSKY, 2003; ZIMAN, 2000). A chemist might, for instance, not just determine physical and/or chemical characteristics of various compounds, but also may produce practical applications for development of commercially viable products — such as plastics, cosmetics or pharmaceuticals. Moreover, largely due to advancements in fields of technoscience, communication technologies, transportation infrastructure, energy availability, etc., companies have relatively high production capacities. However, rather than making goods and services available to most of the world's population, many of whom have desperate needs, many companies have elected to focus on increasing desires for cycles of consumption by the relatively few people in the world who can afford to pay prices that may maximize private wealth (e.g., BARBER, 2007; BAUDRILLARD, 1998; MCMURTRY, 2013; USHER, 2010). Regarding the schematic in Figure 2, promotion of consumer desires not only occurs through production of numerous innovative goods and services ('World') but, as well, innovative 'representations' ('Signs') of them. Indeed, the focus often seems to be largely on production of idealized *mis*-representations that may appear to represent commodities. This can be understood in terms of the 'ontological' and 'ideological gaps' in Figure 2. From an *antirealist* ontological perspective, Signs can never fully represent the World because, with successive translations (e.g., flower → photograph of flower → drawing of flower), there may be inconsistencies in how one entity (e.g., photograph) can be represented by a translated entity (e.g., drawing). These inconsistencies are called 'ontological gaps.' This seems to be a fundamental shortcoming of all human efforts to know and influence the world. However, according to Baudrillard (1998), manufacturers — e.g., through design of packaging and with the help of advertizing companies — may *purposefully* mis-represent commodities; indeed, to idealize them, as indicated in Figure 2, to such a degree that there may be very little connection between the phenomenon/commodity (World) and representations (Signs) of it. He said that such (mis-)representations create a *hyperreal* experience for people; that is, consumers may perceive the symbolic world more real than the material one. Since processes of misrepresentation are purposeful, we refer to them as 'ideological gaps' (Figure 2). Freed from bonds of connections to phenomena, signs are relatively easy to manipulate (LATOURE, 1987). Marketers can, therefore, often create innovative new images to attach to commodities — encouraging consumers to discard older (often relatively new) products in favour of ones with the latest brand identities (BARBER, 2007), as consumers perceive 'older' commodities to be obsolescent (LEONARD, 2010). Baudrillard (1998) suggested that many people, as consumers, are living their lives in a manufactured virtual world (which he called a *simulacrum*) that, essentially, serves those controlling such imagery (e.g., financiers).

People purchasing commodities with idealized hyperreal images associated with them may be consuming veritable *Trojan horses* — subterfuges perpetrated by veritable 'con artists' (e.g., marketers). In encouraging people/consumers to focus on idealized hyperreal images (e.g., 'classy'), consumers may be distracted from noticing problematic details associated with their purchases. There are, apparently, many potential compromises associated with production, distribution and disposal of for-profit commodities. Schlosser (2001) and Kincheloe (2010) documented, for example, how many fast foods and beverages contain harmful substances, such as excessive sugars, fats (and trans-fats), salts, food colourings and

preservatives that have been linked to diseases such as diabetes, heart disease and cancer. Various other health problems are linked to products like: genetically-modified foods, etc. (KLEINMAN, 2003); household cleaning and hygiene products (LEONARD, 2010); pesticides (HILEMAN, 1998); tobacco (BARNES; HAMMOND; GLANTZ, 2006); and, pharmaceuticals (ANGELL, 2004). Some commodities, meanwhile, pose social risks. Acosta-Alzuru and Lester Roushanzamir (2003) and Steinberg (2010), for instance, note how two popular lines of dolls mostly for girls, American Girl™ and Barbie™, respectively, may misrepresent life as a girl — often prioritizing the White race, for example, and suggesting that all are wealthy and, indeed, actualized through consumerism.

Many potential problems associated with commodities appear related to companies' legal rights in many countries to minimize their costs for the sake of profit-maximization (BAKAN, 2004; MCMURTRY, 2013). It is common, for example, to allow cost *externalization*; that is, companies arranging for others to bear costs associated with production, distribution and uses of commodities. This may take various forms, including: reduced worker wages and benefits and uses of cheaper materials and energy sources. Moreover, some companies may *purposely* engineer their products and services to fail at strategic times — in a process known as *planned obsolescence* (LEONARD, 2010). Overall, with reference to Figure 2, it seems acceptable in the minds of some company officials to compromise the quality of the 'Worlds' they create; that is, their products and services. This implies, in turn, that it sometimes may be acceptable to risk compromises to the wellbeing of individuals, societies and environments for the sake of profits. Looking at a shiny new cell phone, for example, consumers may not be conscious — through distractions provided by its design, colour, etc. and related advertizing — of such potential problems as the toxicity of metals inside (e.g., cadmium) or poor working conditions of miners and production labourers. Despite the apparent hazards associated with commodities, meanwhile, it is apparent that many companies have actively campaigned to cast doubt on science outcomes indicating problems — such as human causes of acid precipitation and carcinogenic effects of chemicals in cigarettes (ORESQUES; CONWAY, 2010).

## School Science and Consumerism

Given the importance of potential citizen subjectification for capitalism (HARDT & NEGRI, 2009), it follows that education would be an essential actant in the global capitalist network (GCN). McLaren (2000), for one, advises that “the major purpose of education is to make the world safe for global capitalism” (p. 196). Indeed, some have identified a sub-set of the GCN, called the Global Education Reform Movement (GERM), that appears to be orchestrating educational actants to support neoliberal capitalism — including through: curriculum standardization, international and local competitiveness, testing and reporting and emphases on 'core' literacies (e.g., language(s), mathematics, science and information technology) supporting economic activities (SELLAR & LINGARD, 2013). Pressure on school systems to conform to such priorities seems *intense*. Education networks in the USA, for instance, appear to be in a veritable economic 'war' with countries like China and India, a conflict sometimes known as the 'neo-Sputnik' race (PIERCE, 2013).

Assuming fields of technoscience are essential for capitalist enrichment, a key actant in the global capitalist network likely is science education. There does, indeed, appear to be considerable evidence that school science serves capitalists by supplying them with citizens capable of fulfilling roles associated with the schematic in Figure 2. Generally, these seem to

fall into two broad categories; that is, *knowledge producers* and *knowledge consumers*. A brief review of how these functions may work is provided below, with elaboration given elsewhere (BENCZE; CARTER, 2011, in press). In knowledge economies promoted by neoliberal capitalists, specialist workers — such as scientists, engineers, accountants, lawyers, management consultants, investment bankers, etc. — are needed who may provide *immaterial* labour (LAZZARATO, 1996); that is, expertise for analyzing and manipulating symbols, including words, concepts, numbers and graphics, to develop and manage formulations (e.g., manufacturing & marketing) regarding commodities. Such an aim has, indeed, been made explicit in documentation surrounding recent science education reform<sup>1</sup> prioritizing identification and training of potential ‘STEM’ (science, technology, engineering & mathematics) workers. In the USA, for instance, STEM priorities are clear:

The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering. 4 percent of the nation’s workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent (ACHIEVE, 2013, p.2).

Regarding Figure 2, technoscientists would be able to produce marketable commodities (e.g., a car) and attach idealized Signs (e.g., ‘cool,’ ‘prestigious’ and/or ‘sleek’) to them. School science appears to select workers with such capabilities by determining which students have aptitudes for rapidly-processing *abstractions* (e.g., that a point mass occupies no space); e.g., for quickly comprehending laws and theories in the absence of practical applications. Because such capabilities are more likely to be exhibited by students rich in cultural capital (BOURDIEU, 1986), science education often may be considered a ‘survival of the richest’ experience (BENCZE; ALSOP, 2009). Such competitive environments may be contributing to extreme gaps between rich and poor now apparent worldwide (FREELAND, 2012).

Complementing selection of students who may develop and/or market for-profit commodities on behalf of elite capitalists appears to be generation of large numbers of students who may serve as *consumers* — for example, as: compliant workers and enthusiastic and naïve purchasers of idealized commodities (GIROUX; GIROUX, 2006). There appear to be at least three mechanisms through which school science may prepare students for such consumerism:

- Continuous re-identification: As in consumer societies, students often are expected to engage in cycles of consumption and disposal of new ‘commodities/semiotic messages’ (USHER, 2010). Students from different sub-cultures, for example, such as Indigenous Peoples, often are expected to abandon their cultural ways of knowing in favour of epistemologies of mainstream science (AIKENHEAD & JEGEDE, 1999). Moreover, they also may be asked to continuously change their identities as they are led from subject (e.g., Cells) to often-unrelated other subjects (e.g., Electrical Circuits).
- Technoscience: Perhaps mirroring societal consumerism, it is apparent that school science students are encouraged to develop affinities towards unrealistically-positive constructions that may mask compromises to the products they are

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<sup>1</sup> The STEM reform agenda can be seen in many countries, including the USA and UK, but also in countries like Brazil — through, for example, the *STEM Brazil* programme (<http://worldfund.org/en/programs/stem-brasil.html>) and the *Brazilian Scientific Mobility Programme* (<http://www.iie.org/Programs/Brazil-Scientific-Mobility>).



consuming. It appears, for instance, that school science often idealizes fields of professional science by portraying them as *Rationalist-Realist* (LOVING, 1991); that is, depicting scientists as strictly-logical and unbiased (e.g., politically or economically), fully adhering to empirical findings and able to achieve truths (HODSON, 2011). Meanwhile, problematic aspects of practices and products of fields of technoscience in partnerships with businesses — such as in minimization of testing of new pharmaceuticals (ANGELL, 2004) — often are omitted (CARTER, 2005). By accepting such overly positive portrayals of fields of technoscience, students/citizens may be more likely to enthusiastically consume/purchase potentially-problematic for-profit commodities.

- Alienation: Finally, students/citizens lacking expertise for creating their own products and services may be more amenable to consuming those (with semiotic messages) provided by capitalists. This can happen, for instance, if students are ‘alienated’ from knowledge building in school science. If, for example, students’ inquiries are excessively scaffolded by teachers, as often is recommended, they are unlikely to develop expertise and self-confidence for independent knowledge building — and, consequently, may be limited to consuming/purchasing capitalists’ potentially problematic commodities and labour instructions.

The nature and extent of citizen subjectification presented above seems highly undemocratic and, indeed, *dehumanizing* in a Freirean (1970) sense — colonizing us with neoliberal perspectives and practices limiting the extent to which we may be self-actualized (Santos, 2009). With an emphasis on consumerism, moreover, it is likely contributing to significant environmental degradation. There is, therefore, considerable need for more liberatory pedagogy that also improves environmental wellbeing.

## Actions Towards Social Justice & Environmental Sustainability Through School Science

A promising area of school science reform relating to concerns about subjectification and consumerism is its emphasis on *socioscientific issues*<sup>2</sup>. For at least the last forty years, scholars and policy-makers have been exploring ways to infuse STSE issues into science education (PEDRETTI; NAZIR, 2011). Although much progress has been made, school science systems often seem to limit students to negotiation of issues and defense of their personal positions on them. In a comprehensive review article, Levinson (2010) concluded that most STSE education limits students to either the first or second level (‘Deficit’ or ‘Deliberative,’ respectively) of his hierarchy, given in Table 1, for citizen engagement in socio-political issues. Although deliberations may give students some choices, such experiences may still promote consumerist orientations because authority still tends to rest with scientists and other professionals (LEVINSON, 2010).

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<sup>2</sup> Although the phrase socioscientific issues is used in many parts of the world, because examples reported here was set within the context of an Ontario, Canada, school, the phrase used for the controversies under discussion in this paper is *STSE issues*. These are issues pertaining to relationships among fields of science and technology and societies and environments.

Table 1: Levels of citizen engagement in STSE issues.

**Summary of four frameworks for democratic participation in a school context**

Framework	Socio-epistemic relations	Epistemology	Controversy and participation	Pedagogy	Implications for democratic participation
<b>Deficit</b>	Knowledge flow is from scientist-teacher-student	Science is the corpus of knowledge	Ability to engage is constrained by access to technical knowledge	Knowledge for addressing an issue can be brought to the attention of the student.	There is a socio-epistemic inequality between the scientist/teacher and students which limits ability to bring about political change from below but does not preclude influential specialists making a political impact.
<b>Deliberative</b>	Knowledge flow is predominantly from scientist to the teacher and students, the latter two might be working in concert.	Science is understood to be uncertain and fallible.	Dialogue is open. Lay participants are informed but often lack the political means to bring about change. In schools, students might have opportunities for deliberation through group work and school councils but action might be constrained depending on the democratic nature of the school.	Emphasis on critical thinking and understanding of scientific methods and procedures.	Participation is real but often ineffectual in generating democratic change because participants do not have the 'clout' to make crucial decisions.
<b>Science education as praxis</b>	Knowledge is distributed and emergent.	Knowledge is situated. Students become inducted into communal ways of knowing through legitimate peripheral participation in particular but changing contexts.	All participants work with a shared sense of social purpose.	Knowledge is provided on a need to know basis. The teacher is not epistemologically privileged.	Active and egalitarian participation to enhance change which might assume political literacy.
<b>Dissent and conflict</b>	This can be variable but is likely to have similar characteristics to science education as praxis.	What is known is contextualised by socio-political concerns.	Political action.	Knowledge provided on a need to know basis with an emphasis on political literacy.	Political understanding and action for change are foregrounded

Levinson, R. (2010). Science education and democratic participation: An uneasy congruence? *Studies in Science Education*, 46(1), 69-119; Table 1, pp. 83-84

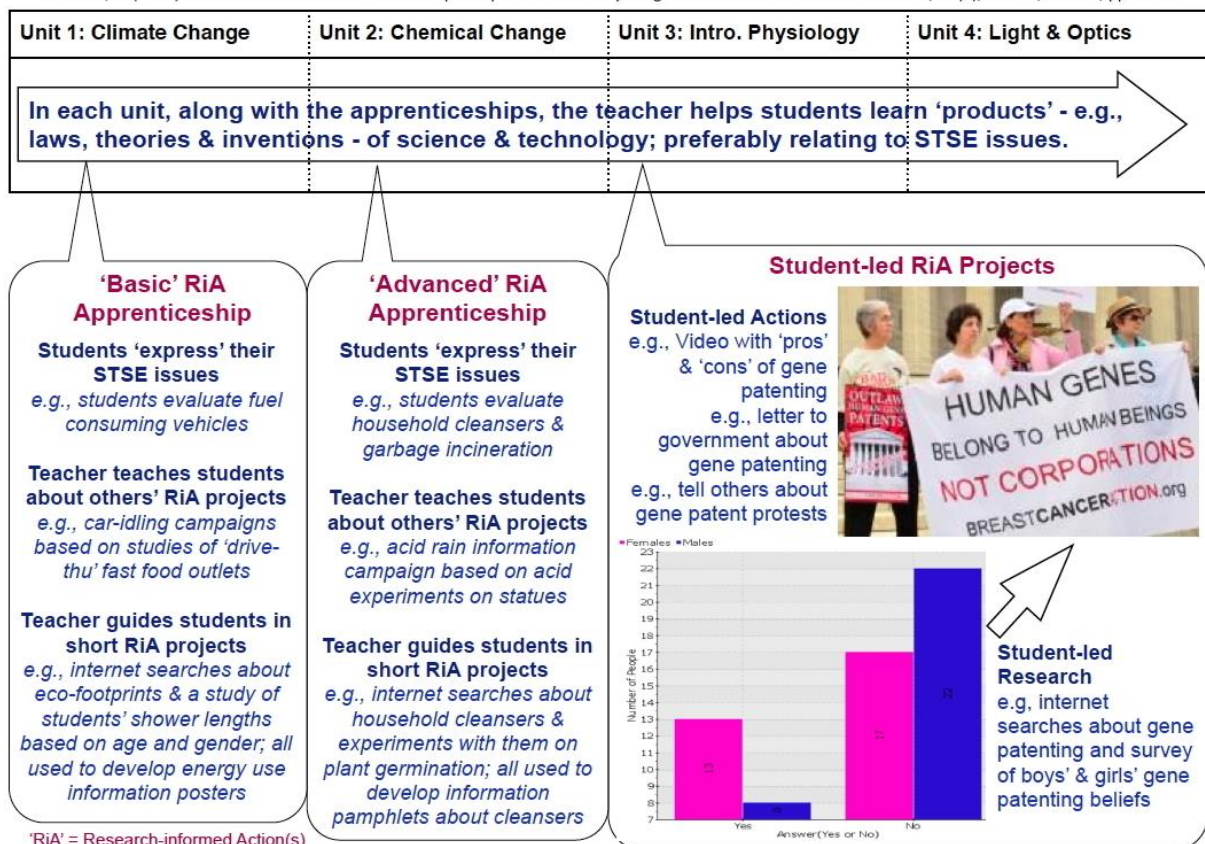


Figure 3: STEPWISE Instructional Framework.

For at least the reason that many STSE issues pose significant threats to the wellbeing of individuals, societies and environments, many scholars and others encourage teachers to enable and motivate students to take actions to address STSE issues (HODSON, 2011; LEVINSON, 2010; SANTOS, 2009). Since 2006, the first author of this paper has been working with teachers (e.g., BENCZE et al., 2012) and student-teachers (e.g., BENCZE; SPERLING, 2012), using the STEPWISE<sup>3</sup> educational framework, to promote student-led research-informed actions (RiA) to address STSE issues of their concern. Among the projects in which we have been engaged, one involving Mirjan Krstovic (co-author here) pertains directly to issues raised above. During the Feb. through June 2013 semester, Mirjan used, as he had in the past 3 semesters, the STEPWISE pedagogical framework shown in Figure 3 as a basis for promoting student-led research-informed actions to address STSE issues of students' choices. This framework is based on the premise that encouraging and enabling students to *self-direct* research (e.g., Internet searches and empirical social studies) gives them a measure of ownership that may deepen their commitments to issues and actions (WENGER, 1998). To assist in enlightening students about possibly-problematic hidden aspects of commodities, however, students were exposed to some principles of *actor network theory* (ANT)<sup>4</sup> (LATOUR, 2005). It was reasoned that doing so may provide students with access to more authentic contexts, perhaps including actants often hidden from consumers, relating to their issues of choice (PIERCE, 2013).

To help students to understand ANT principles, Mirjan used combinations of teacher demonstrations, video presentations and class discussions. A copy of Mirjan's full lesson sequence for this is given in Appendix A. A particularly-important aspect of these lessons was a Socratic class discussion surrounding an actor network (see Figure 4) that Mirjan constructed about cell phones. This lesson/discussion was nicely supplemented by showing students the activist video, *The Story of Stuff* (SoS)<sup>5</sup>, which is structured around the 'materials economy,' tracking commodities through this sequence: Extraction → Production → Distribution → Consumption → Disposal. The SoS also emphasizes *perceived obsolescence* and *planned obsolescence* (LEONARD, 2010), along with the Trojan horse metaphor discussed above regarding commodities.

After lessons to introduce students to STSE issues using actor network theory, student groups were invited to choose an issue, conduct some secondary research (e.g., Internet searches) to learn more about it and, then, illustrate how they conceived of it through their personally-drawn (and edited) actor networks. A typical such network produced by 'Connie,' a student (who worked alone) in Mirjan's class, is shown in Figure 5. Although some actant types, such as think tanks and transnational advocacy organizations (BALL, 2012) were absent, her network included a wide range of actant forms, including: living things (e.g., [human] teens, cheap labour, rabbits), human organizations (e.g., companies [e.g.,

<sup>3</sup> 'STEPWISE' is the acronym for *Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments.* It is a theoretical framework that encourages and enables students to use some of their education and other resources for actions that may improve the world. You can learn more about this framework at: [www.stepwiser.ca](http://www.stepwiser.ca)

<sup>4</sup> Recently, we have been exploring at least the following principles of ANT: Individual actants are *heterogeneous*, composed of influences from other actants; Types of actants include: *materials* (e.g. living & non-living things, inventions, inscriptions) and *semiotic messages*; Actants may co-affect each other, with effects that constantly change; Actants can align, particularly under influences from powerful actants, so that a common semiotic message is supported by all. Activism may involve introducing new actants and re-orienting existing ones so that dominant semiotic messages change.

<sup>5</sup> *The Story of Stuff* is an activist project aiming for improvements in social justice and environmental sustainability. The project consists of many resources, but focuses on a series of videos — the first of which was called 'The Story of Stuff,' with subsequent ones with names like, 'The Story of Electronics,' etc. — featuring the project's founder and director, Annie Leonard. Website: [www.thestoryofstuff.org](http://www.thestoryofstuff.org)



Maybelline™), factories), technologies (e.g., editing [software]), non-living things (e.g., aluminium, inscriptions (e.g., fake pictures), and semiotic messages (e.g., feel prettier, feel grown up). In illustrating relationships among them, moreover, she makes relatively-explicit reference to the Trojan horse metaphor — indicating prominent pro-capitalist actants (e.g., happy companies, advertising, planned obsolescence) perhaps distracting consumers from such negative effects as: [human] depression, fake results [of animal testing], non-renewable energy use. Uses of actor networks have been shown to provide students with these kinds of more realistic insights into STSE issues than is apparently being encouraged by the GCN-GERM (PIERCE, 2013). To supplement their understanding of their STSE issue, students were then encouraged, as indicated by the schematic in Figure 3, to design and conduct social (correlational) studies that may inform them about actions they might take to address their issue. In Connie’s case, she studied peers’ choices regarding makeup uses and gave this conclusion about her results:

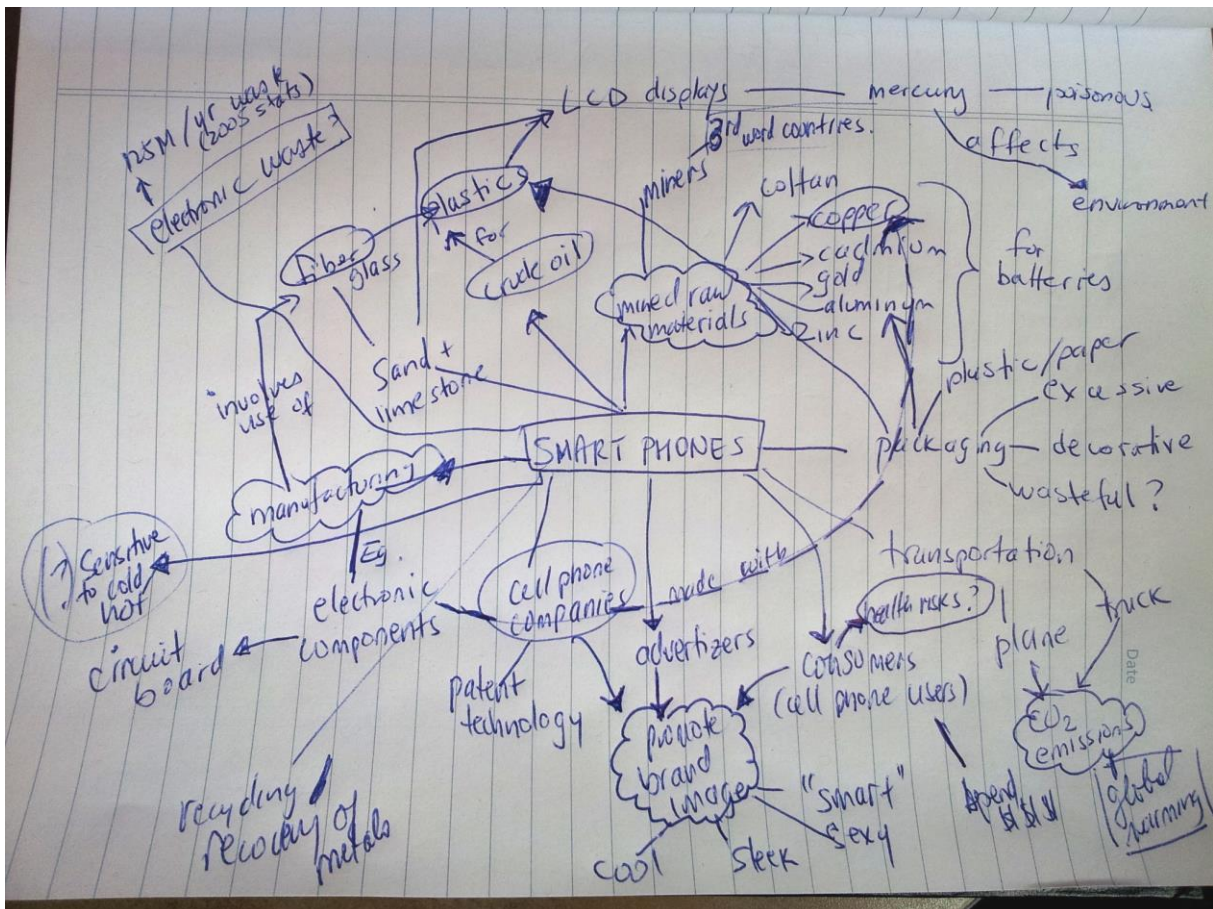


Figure 4: Mirjan’s Model Actor Network About Cell Phones.

I can conclude that the media does have a generally large impact on teenage girls makeup usage. Out of the 86% of girls who started wearing makeup at a pre-teen age 81% of them said that the media was the influence that got them interested in it. Also 93% of the girls who started wearing makeup at a young age say they wear makeup for more than half of the week. Only 30% of girls are not influenced from the media about their makeup choices. So the media has a very large impact on teenage girls makeup consumption, by impacting 70% of them (June 3, 2013)





[showing a woman’s picture being edited with Photoshop™], hiding what they don’t want their audiences to see so they can promote their businesses as best as possible; Ending: So, this is foundation’s life. Just like a human, it goes through many experiences that people would never know about. Just like a book, never judge it by its cover (April 25, 2013).

## Summary and Discussion

Although the wellbeing of individuals, societies and environments often appear to be under enormous threats from the global capitalist network (GCN) and, intimately connected to that, although science education systems frequently seem inescapably ensnared as instruments for generation of relatively few professional knowledge producers and large masses of citizens mainly prepared to serve as knowledge consumers for powerful elite, viable alternatives to this problematic dominant paradigm may exist. In this article, we have provided examples of school science practices — based on the ‘STEPWISE’ framework — that, if amplified, could contribute to improvements in social and environmental justice.

Unlike approaches associated with the GCN, such as the STEM agenda, school science practices illustrated here appeared to contribute to significant improvements in equity and diversity. Mirjan, the teacher whose work we featured, stated several times that prioritization of research-informed actions (RiAs) to address STSE issues of students’ choices appeared to increase *overall* student achievement:

I have had a lot of success with the STEPWISE framework. Students are more engaged on average. My weaker students (i.e. those who generally do poorly on knowledge-based tests) have done a lot better in class with the STEPWISE. Students like discussing socio-scientific issues and being empowered to act and make a difference in our society. Students’ inquiry projects (experiments and correlational studies) have more meaning since they are contextualized (Blog entry, Nov. 23, 2011).

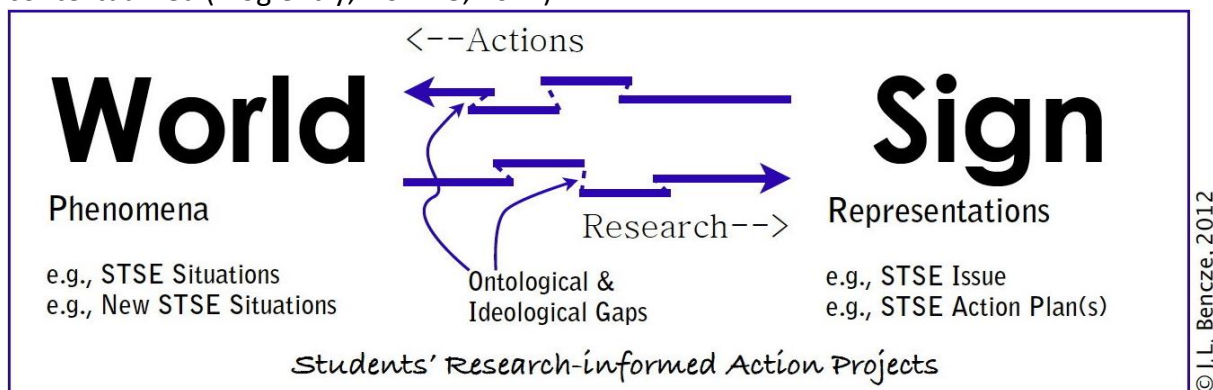


Figure 7: Research-informed Actions Framework.

We suggest that improvements in access to science literacy may arise, in part, because of the extent to which STEPWISE prioritizes student-led decision-making on many aspects of students’ research-informed actions to address STSE issues. This may be explained in terms of the schematic in Figure 7. According to Wenger (1998), the greater learners are personally-engaged in decision-making regarding reciprocal relationships between phenomena and representations of them, the deeper, more committed, may be their learning. In the case of RiA projects depicted in Figure 7, students had considerable control over STSE issues on which to focus, research questions, methods, conclusions (‘Signs’) and actions (adjusted Signs). For Mirjan, leaving learning decisions to students was crucial: “We

need a more active citizenry that is intrinsically motivated versus passive citizens who will do as they are told, because they will do something because there is an extrinsic motivator – which is money – at the end” (Mirjan, Interview, Jan. 14, 2013). Such a tack appears to align with ‘Science education as praxis’ (Table 1) (LEVINSON, 2010), which has its roots in Freirean liberatory pedagogy (SANTOS, 2009) — allowing students, often in social situations, to *self-determine* their thoughts and actions, rather than having them imposed on them, often in subliminal ways (e.g., FOUCAULT, 1977, 1991), by powerful others (e.g., through consumerism).

The approach depicted in Figure 3, while prioritizing students’ self-determination, was not entirely neutral. No formal educational experience can, of course, be unbiased. Indeed, through uses of actor network theory, we have introduced students to potentially-problematic actants associated with commodities (e.g., Figure 4). This tack is recommended for bringing more ‘realism’ and, therefore, democracy, to students’ engagement in STSE issues (PIERCE, 2013). This also aligns with Levinson’s (2010) call for significant ‘dissent and conflict’ (Table 1) in science education as a way of democratizing citizen engagement. It could be argued, however, that such overt efforts to, in effect, disrupt the GCN is, in itself, anti-democratic. We agree that this is, indeed, a tension of the approach offered here. On the other hand, it also could be argued that, given the extent to which the GCN appears to be overtly and covertly attempting to instil capitalism-friendly perspectives and practices into the minds of increasingly younger children, through, for example, advertizing (ACOSTA-ALZURU; LESTER ROUSHANZAMIR, 2003; BAKAN, 2011; BARBER, 2007; USHER, 2010), perhaps offering alternatives to this programme to youth may be justified. At the same time, it should be clear that, while dissent and conflict are urged here, student-led decision-making also was prioritized. We encouraged, for instance, students to make judgements *they* considered ethical in World  $\leftrightarrow$  Sign translations — including regarding ideological gaps in them (Figure 7).

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