EcoJust STEM Education to Counter Hyper-capitalist Contexts of Meaning and Being

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ABSTRACT

Many versions of 'STEM' (Science, Technology, Engineering & Mathematics) education, while promising better lives for citizens, appear to perpetuate capitalist interests. Many initiatives appear, for instance, to prioritize training of elite technical experts while de-emphasizing critical analyses of these fields and sociopolitical actions to address perceived personal, social and environmental harms. Such apolitical approaches to STEM education seem to be intensifying, moreover, through recent emergence of right-wing populism — with perhaps the most dramatic example being Donald Trump's US presidency. Although definitions vary, they often seem *reactionary* — emphasizing return to an earlier, often idealized, status quo, perhaps best signified by Trump's claim to "Make America Great Again." Promises for better futures, however, may be part of *disaster capitalism*; that is, further instilling capitalist perspectives and practices while citizens desperately hope for recovery from economic and social struggles. Indeed, while many voters saw Trump as saving them from economic destitution (e.g., loss of jobs and job security) resulting from neoliberalism, his government has now successfully minimized taxation for the rich. Apparent keys to such capital concentration have been fields of science and technology (and related disciplines) — which appear to have long been used in 'knowledge economies' to assist neoliberals in, for instance, promotion of consumerism. Cell phones are seen as 'sleek' and 'sexy,' for example, often distracting consumers from awareness of poor working conditions of labourers. Such subterfuge seems destined to continue. On the one hand, phenomena of the world (e.g., climate conditions) may be translated (as 'science') into idealized representations (e.g., denials of anthropogenic climate change) while, on the other hand, engineering generates — with increased deregulation — technologies (e.g., petroleum-fueled vehicles) that further enrich capitalists. Accordingly, this paper features analyses of a field-tested framework for science and technology education emphasizing matters of political economy and, associated with that, liberatory pedagogies prioritizing social justice and environmental wellbeing.

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INTRODUCTION

For at least the last century, there have been recommendations for teaching students about what frequently is called 'the nature of science' (NoS) (Lederman & Lederman, 2014). Through such education, students may not only learn about 'products' — including laws, theories, innovations — of fields of science and technology but also learn, for instance, about characteristics of practitioners involved, their approaches, products of their work and how products of their work are used. Broadly, educators and others may draw from studies of fields of science and practitioners within them using concepts, approaches, etc. from such fields as history, philosophy, psychology, economics and sociology (Hodson, 2008). Providing students with such more 'holistic' forms of science education has been justified from a great range of perspectives, including, for example, because it may assist people in judging relative merits of different societal knowledge systems — including those that some scholars consider outside boundaries of what may be considered 'science' (e.g., Matthews, 2017).

Despite long-standing attempts to encourage teachers and others to help students to develop deep and complex conceptions of the nature of science, many scholars in this field suggest that students' opportunities for such an education often are compromised (Abd-El-Khalick, 2014; Crawford, 2007; Hodson, 2008; Lederman & Lederman, 2014). As Clough (2018) recently said, "little of what is known [about NoS] is widely implemented in science classrooms" (p. 3).

Among aspects of the nature of science that appear to be frequently neglected in school science, perhaps particularly important are influences of powerful people (e.g., financiers) and organizations (e.g., corporations) on fields of science and technology and, indeed, myriad living, nonliving and symbolic entities — on a global scale — that seem to compromise wellbeing of individuals, societies and environments (e.g., Carter, 2008). Recent studies of 'STEM' (Science, Technology, Engineering & Mathematics) education initiatives, for instance, suggest that many of them minimize education that may be critical of relationships among powerful people and organizations and fields of science and technology — apparently prioritizing, instead, emphases on fundamental knowledge and skills that may help jurisdictions (including governments, companies, etc.) achieve successes in local and global economic competitions (Bencze et al., 2018; Hoeg & Bencze, 2017a,b; Gough, 2015; Zeidler, 2016). If, instead, science education were to significantly more greatly prioritize education that may be critical of power relations as they appear to influence science and technology, students of a subject like chemistry could learn about chemical and physical properties of elements such as aluminum but, given contexts for its extraction from earth, processing into a plethora of products that frequently end up back into the earth (e.g., in landfills), also learn about social justice problems, such as poor working conditions of labourers and associated environmental degradation, such as soil erosion at mining sites, harms that largely seem attributable to capital accumulation by investors and others (Levinson, 2014). Integrated into such enlightening education could be encouragement and support for students to develop and implement actions to address harms they perceive in relationships amongst fields of science and technology and societies and environments (STSE) (e.g., Hodson, 2011). Students educated in such ways may contribute to improvements to social justice and environmental health that have some association(s) with fields of science and technology (and related discplines).

In this article, after elaboration of potential and realized harms linked to influences of powerful people and groups on fields of science and technology and on other biotic and abiotic entities, perspectives and practices in science education that may contribute to increases in social justice and environmental health are discussed.

The Nature of Pro-capitalist Science & Technology

There is much to celebrate about fields of science and technology (S&T). Among many apparent benefits, humans enjoy longer lifespans, for instance, through numerous developments in medical and agricultural fields. Nevertheless, there appear to be causes for significant concerns associated with S&T fields. People cite possible harms, for instance, from many commercial products and services, such as: 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). There also is considerable worry about possible (and apparently realized) serious personal, social and environmental harms associated with dramatic increases in average global temperatures that often are linked to excessive fossil fuel uses (Klein, 2014).

Although it may seem reasonable to blame scientists and engineers and related professionals for various personal, social and environmental harms linked to their fields, it appears not to be that simple. Based, for example, on actor-network theory (ANT), ontological perspectives that largely developed from studies of scientists (e.g., Latour), that posits dynamic reciprocal relationships among all living, non-living and symbolic (semiotic) entities ('actants') (Latour, 2005), 'blame' could be considered distributed across networks in which S&T fields — among myriad other entities — are embedded. This, however, also may be too simplistic. Relatively early in development of ANT, it was acknowledged that power (and responsibility, blame, etc.) is not likely evenly-distributed across networks. In *Pasteurization of France*, for instance, Latour 1988[1984]) claimed that it was not until associations among various actants — such as laws, technologies, transportation mechanisms and public education — were established that pasteurization was widely-practised. Therefore, within large, global (or, perhaps, universal) networks, there appear to be coordinated 'sub-networks' that consist of living, nonliving and symbolic entities aligned (generally) to support particular purposes. Foucault (2008), in his analyses of

power, named such cooperating sets of actants *dispositifs*. We can imagine certain religions as functioning largely through dispositifs involving cooperation among spiritual leaders, practitioners, icons, technologies (e.g., devices for dispersing incense), etc. In this light, one can ask about possible dispositifs that engage fields of S&T in ways that appear to contribute to various personal, social and environmental harms.

There is much evidence and argument to indicate that most actants around the world are extremely influenced by relatively few people and organizations, many of which are linked to capitalist systems. Although financial and other elite have long had significant power over large fractions of societies, such influences have, apparently, dramatically escalated since about the 1970s when, largely in response to decreases in their shares of wealth, in part due to costs of infrastructure re-building and social programming after the second world war, economic elite, government officials and others worked to establish *neoliberal* socio-economic systems that, broadly, would assimilate governments, corporations, financiers, think tanks, transnational trade organizations, banks, transportation networks, trade agreements, perspectives and practices of large fractions of societies and many more entities into a 'super-dispositif' promoting policies and practices like competition, individualism, cost externalizations, privatization, etc. that, ultimately, would funnel more wealth and wellbeing towards socio-economic elite (Baker, 2006; Harvey, 2005; McMurtry, 2013; Springer, Birch & MacLeavy, 2016). This neoliberal dispositif appears to have, indeed, worked well, dramatically increasing differences between super-rich and most other people on the planet — wealth disparities that, moreover, are predicted to dramatically increase, despite such interruptions as the 2008 global financial crisis (Piketty, 2014).

Although highly globalizing neoliberal capitalism continues to appear quite strong in many places in the world, there is much evidence and argument to suggest it is evolving, if not radically changing, due to recent right-wing populist (RWP) movements — many of which claim to prioritize extreme nationalism. While such movements have grown in many 'Western' democratic countries (e.g., Austria, Brazil, Denmark, France, Hungary, Turkey and UK), perhaps the most important of them — due to its overall wealth and election of a RWP leader — is the USA (Klein, 2017; Pelinka, 2013; Swank & Betz, 2003; Taibbi, 2017). Given their relatively rapid emergence, definitions and effects of such movements vary. Nevertheless, it seems many may align well with Naomi Klein's (2007, 2017) conception of 'disaster capitalism'; that is, capitalists' exploitation of crises (natural or engineered) to further implement capitalism-friendly policies and practices. Right-wing populist leaders have, undoubtedly, exploited many kinds of crises, but it is apparent that prominent among these have been various personal and social difficulties experienced by large fractions of their countries' populations that seem linked to neoliberal globalization. While individual jurisdictions (e.g., cities and countries) have resisted homogenizing effects of globalizing neoliberal capitalism, perhaps combining foreign and local priorities and practices in processes called 'glocalization' (Matusitz & Lord, 2013; Ritzer, 2004; Roudometof, 2016), many people in several 'developed' democracies have arrived at various states of crisis — particularly in terms of job losses and/or precarity (e.g., part-time, on-call, with no/few benefits), because companies have (often with government support) moved production to places in the world with the least expensive labour, lowest taxes and least stringent environmental regulations (Bauman & Mauro, 2016; McMurtry, 2013; Rodrik, 2011). In many places in the world, particularly in the USA, such socio-economic policies and practices appear to have led to significant and dramatically-increasing differences between rich and poor (i.e., extreme wealth concentration) (Giroux, 2014; Hedges, 2017; Stiglitz, 2016). Oxfam (2017), for instance, recently reported that just forty-two individuals (billionaires, mostly White men) owned total wealth equivalent to about 3.7 billion people (approximately the poorest half of the world's population).

With so many people in crisis, RWP leaders appear to have gained popularity by blaming governments and other elites for their destitution, presenting themselves as their saviours — claiming, like Donald Trump, to dramatically (perhaps miraculously) rework governments and lead citizens to brighter futures (Bauman & Mauro, 2016; Danner, 2016; Kelsey, 2016). Their promises may be, however, largely illusory. In contrast, it is claimed that a major part of their image management is to prioritize *reactionary* themes, harkening back to a simpler, less globalized, past — about which it appears to be easier to romanticize than about uncertain futures (Laclau, 2005; Laclau & Mouffe, 1985; Lilla, 2016; Wullweber, 2015). A related tack, particularly associated with the US president, are uses of so-called 'gaslighting' tactics; that is, often long-term efforts — including through lies, denial, false praise, etc. — to destabilize others, causing them to doubt their identities and values (Behr, 2017). Aligned with such scenarios are contentions that government leaders mainly serve, somewhat like wolves in sheep's clothing, as benevolent figure heads, saviours and/or creators of appropriate images of a 'good' society — while, behind the scenes, real control over agendas is wielded by a so-called 'deep state'; that is, a network of powerful individuals (e.g., Koch Brothers) and groups (e.g., General Electric™) (Lofgren, 2016; Mayer, 2016). Techniques for creating hopes for a 'better' society also seem congruent with recent claims about the so-called *post-truth* era that many suggest characterizes much current discourse. Kirkpatrick (2017), for instance, suggests that elites have consistently worked to protect their positions through engineering of communities' zeitgeists and that a major tactic in this regard has been to promote perspectives and practices that purport to oppose grand narratives and, instead, support 'truths' in personal, local, contexts. Aligned with neoliberalism, 'truth' — varying, for instance, in extents to which there are connections to research-based data and theory — is whatever may be successful in what he calls the 'market of ideas.' With masses of people conditioned to hope for a better world as a solution to whatever is ailing them, disaster capitalists can then declare a state of exception (from normal social contract arrangements) and implement radical socio-economic policies and practices to further enrich elite (Agamben, 2005; Giroux, 2014). In the case of Donald Trump, it is apparent the US has a leader who not only promises a better world ("Make America Great Again") but

also serves to distract the public from awareness of his pro-capitalist agenda through a series of often-unpredictable and unusual statements (especially on Twitter™) and actions (Taibbi, 2017). At the same time, in an apparently novel twist in disaster capitalism, the deep state appears to have surfaced — in the sense that Trump and many of his government leaders have direct (and overt) ties to large corporations (e.g., Exxon Mobil™, Goldman Sachs™) that have gained their wealth largely through successive cases of disaster capitalism (Klein, 2017). Having noted their emergence, it remains uncertain at the time of writing of this paper (August 2018) the extent to which residual democratic structures and, moreover, general abhorrence to Mr. Trump's controversial positions (e.g., on race, gender, immigration, etc.) may temper abilities of the deep state to rapidly achieve it ends.

Apparently, regardless of specific techniques (e.g., globalizing or localizing), key to capitalists' successes are, to varying extents, many fields of science and technology (S&T) (Ziman, 2000). Among ways in which they appear to be used as instruments of wealth accumulation by capitalists, considerable emphases appear to be placed on encouraging moderately to very wealthy citizens to engage in repeated cycles of consumption and disposal of goods and services, partly because techniques for production of physical commodities had increased to the point of saturating markets (Barber, 2007; McMurtry, 2013; Usher, 2010). This can be understood in terms of core of the schema in Figure 1. Although development of products and services (World), like cars, perfumes and manufactured foods is and has been important, emphases are placed on representations (Signs) in order to encourage cycles of consumption and disposal of such commodities. It may be more accurate, however, to say that emphases are placed on *mis*-representations. On the one hand, there appear to be natural/unavoidable inefficiencies — called *ontological* gaps — in humans' translations between different ontological entities of the World (e.g., a tree) and Signs (e.g., drawing of a tree). On the other hand, humans may — to serve certain purposes — *intentionally* mistranslate between World and Sign, creating what may be called *ideological* gaps. Indeed, to encourage consumption, it is apparent that engineers (often with marketers) create designs that research suggests may cause people to envisage certain idealistic abstractions that may cause certain emotional attachments to commodities — such as certain 'sleekness' of car design that may be associated with a higher social status. Additionally, or in concert with such designs, marketers may create advertisements — such as showing a well-dressed person looking 'cool' and driving such a car — that reinforce idealistic abstractions. Indeed, it is apparent that consumers can be convinced to strongly associate designers'/marketers' idealized abstractions with commodities — thus creating various forms of brand identity and, often, very enthusiastic loyalty in commodity-consumer relationships. According to various authors (e.g., Barber, 2007; Usher 2010), many of whom have drawn on foundational work of Baudrillard (1998), effectiveness of idealized abstractions derives largely from their relative detachment from the actual phenomena, a *hyperreal* condition (Figure 1), which allows designers and marketers to continuously re-design the abstractions without having to significantly re-design the commodity — which can convince consumers to discard commodities in favour of newly-designed/marketed idealized abstractions (Barber, 2007; Leonard, 2010). Although there is much generation of solutions to personal, social and environmental harms through technology and science ('technoscience') developments, considerable innovation and entrepreneurship encouraged by capitalists, educators, government officials and others seems to prioritize creativity in development of sequences of idealized abstractions for promotion of cycles of consumption and disposal.

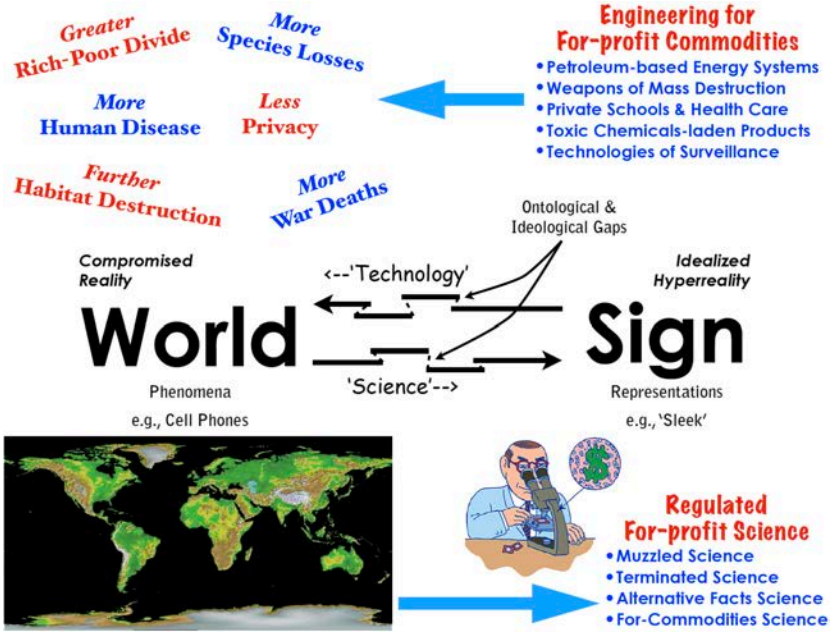

Figure 1: Capitalist-friendly Science & Technology.

With people mainly focusing on idealized abstractions linked to cycles of consumption and disposal, capitalists can more freely *externalize* their associated costs to generate profit (McMurtry, 2013). This can mean, for instance, reductions in costs for labour at stages from resource extraction through transportation, sales and marketing and on to disposal (e.g., lower wages, benefits and working conditions) and materials (e.g., less expensive ingredients in foods, sometimes lacking in nutritional value). Such reductions can, in turn, lead to numerous compromises to quality of goods and services — which can contribute to many personal, social and environmental harms (like those described above). Exacerbating such compromises appears to have been legal decisions (e.g., 1980 in the USA) to allow contracts between university-based technoscientists and companies/financiers, a move that tended to shift their foci from knowledge generation for general wellbeing to more that of private interests (Krimsky, 2003; Mirowski, 2011; Ziman, 2000).

Based on arguments above, consumers are purchasing (and often discarding) virtual 'Trojan horses,' commodities that, through idealized abstractions (e.g., 'sexy') on the surface, mask harmful features within (e.g., burning of fossil fuels) (Bencze & Carter,

2015). A helpful way to think of this is through actor-network theory ('ANT') (Latour, 2005), which posits that 'single' entities are, actually, complex, composed of aspects of networks of living, non-living and symbolic 'actants' (entities) to which they are connected. A specific concept in ANT that is helpful with regards to consumerism is *punctualization*; that is, making a network of relations appear as a single entity (Callon, 1991). As suggested by Pierce (2013), for example, genetically modified salmon can be seen as substantial sources of food compared to wild salmon, perhaps distracting customers from focusing on possibly-problematic actants — such as government regulation policies (FDA) and sea lice pests (pp. 111-136). A similar masquerade appears to apply to uses of micro-beads (tiny balls of plastic mixed into numerous hygiene and beauty products — which many activists want banned (see: goo.gl/vm8trG).

Apparently, uses of fields of technoscience like that described above — although apparently highly problematic — may become increasingly worrisome with advent of right-wing populist politics. For example, like a Trojan horse, having hoodwinked much of the US public regarding his claims to bring increased prosperity to their lives, President Trump and his team of very rich former corporate executives and war heroes (Taibbi, 2017) appear to have taken steps — in various domains — to dramatically further orient various S&T fields (and industries using them) towards for-profit activities that greatly de-emphasize wellbeing for many individuals, societies and environments. Such problematic subterfuge can, perhaps, be understood in terms of the schema in Figure 1. Text around the periphery of the World <——> Sign dialectic is meant to depict how a corporate coupe in the USA seems to be manipulating 'science' and 'engineering' (and technology) in ways prioritizing profit over living and non-living environments (Faturechi & Ivory, 2017; Rushe et al., 2017). Fields of 'science' (World Sign) may, for example, be muzzled (e.g., prevented from releasing findings incriminating certain commodities) or terminated (through funding cuts), such as was the case in Canada under its former conservative leader (Turner, 2013), and/or scientists may be paid to conduct science (or affix their names to articles written by company scientists) that purposely generates 'alternative facts' (findings denying problems with commodities and/or celebrating their merits), as has been the case for science regarding many commodities in the past (Oreskes & Conway, 2010; Taubes, 2017), and/or fields of science that promise to generate knowledge directly applicable to development of for-profit commodities will be preferentially-funded, as has commonly been the case for decades (Krimsky, 2003; Mirowski, 2011; Ziman, 2000). As a consequence of such changes in knowledge production about the world, it seems many potentially harmful technoscience-based industries (involving Sign-World translations) will be (and now are) supported, including those for: petroleum-based energy systems (e.g., coal & natural gas); weapons of mass destruction (e.g., drones); privatized schools and health care (e.g., charter schools and health insurance providers); toxic chemicals-laden products (e.g., carcinogens in cleaning products); and, technologies of surveillance (e.g., increased legal corporate access to social media contents). Adverse effects from such industries may include, but may not be limited to, harms like: more human disease, more war deaths, more species losses, further habitat destruction, less privacy and, apparently linked to all of this, greater rich-poor divides. Perhaps the most dramatic of such effects, while perhaps misleadingly slow and invisible to many people, are harms from S&T fields involved in fossil fuel extraction, processing, transportation, uses and disposal (Klein, 2014; Methmann, 2010). Forzieri et al. (2017), for instance, recently predicted a 50-fold increase in deaths by 2100 in Europe due to climate change. As suggested by Naomi Klein (2017), such harms are likely to escalate to planet-threatening proportions if right-wing populists like Donald Trump succeed in creating dramatic crises, such as wars, to justify even further states-of-exception that would give them a license to even more-dramatically implement pro-capitalist policies and practices that often disregard such potential harms.

Given severity of such potential and realized harms linked to fields of science and technology, various educators and others have strongly recommended that school science (and perhaps other courses) emphasize educating students about associated power-related problems and also help them to develop motivation, expertise and confidence for developing and implementing personal and social actions to address harms they perceive (Hodson, 2003, 2011; Roth & Désautels, 2002; Santos, 2009). Education about 'nature of science,' then would be significantly de-punctualized and problematized — providing resources enabling societies to work towards improvements in social justice and environmental wellbeing.

TOWARDS ECOJUST 'SCIENCE' EDUCATION

Preamble

By definition, disaster capitalism functions largely by exploiting citizens' states of crisis that involve confusion and worry — and that make them particularly susceptible to Trojan horse visions of idealized futures (Klein, 2007). Challenging such systems of doom may seem hopeless, given progress of right-wing populists (as described above). Nevertheless, in *No Is Not Enough*, Naomi Klein (2017) notes that many social action groups have been enraged and invigorated by emergence of right-wing populists — drawing, for example, unprecedented numbers at public rallies in opposition to perceived injustices. This may be explained in terms, particularly in the USA, of 'surfacing' of the deep state — in the sense of Trump's wealth and that of most of his cabinet members (many with ties to companies like Goldman Sachs™ and Exxon Mobil™) and, moreover, their apparently overly aggressive and transparent set of steps to further concentrate wealth into their own hands and that of relatives and friends/associates (Jilani, 2017; Rushe et al., 2017; Taibbi, 2017). Although some private sector members have railed against some of Trump's more radical stances on cultural matters (e.g., regarding, race and gender), it is as if the deep state 'iceberg' has risen, exposing more of itself for public scrutiny.

Although we may have become much more conscious of possible harms linked to RWP, as Klein (2017) also notes, most successful counter-movements have not just critiqued regimes but also have provided one or more visions of a better world. This seems aligned with Kuhn's (1970) suggestion that revolutionary change thrives on existence of alternative paradigms (if only emerging ones). Clearly, there are myriad right-wing populist perspectives and practices that could be critiqued and re-visioned. A prominent aspect of this, as argued above, seems to be STEM education — many initiatives of which appear to significantly downplay self-critique and sociopolitical actions for their revision (e.g., Bencze et al., 2018; Gough, 2015; Zeidler, 2016), and which may — as argued above — get much worse in right-wing populist contexts (Figure 1). Although there are, likely, various alternatives to mainstream pro-capitalist STEM education programmes, one that has been developing for at least the last decade is highlighted in the brief summary below.

Ecojustice Through 'RiNA' Projects

Since 2006, I have worked with graduate students in collaborations with educators in many different contexts (e.g., schools & after-school clubs) to develop and evaluate teaching and learning approaches and resources that may help students to develop more 'realistic' (including *problematized*) conceptions of relationships among fields of science, technology, societies and environments (STSE) and to develop expertise, confidence and motivation to design and carry out personal and social actions to address problems they perceive in them. To motivate students to develop and take actions to address harms linked to S&T fields, we have encouraged and enabled them to self-direct secondary (e.g., Internet searches) and primary (e.g., studies and/or experiments) research to learn more about STSE relationships. This can help them to identify with issues and problems and, therefore, be more motivated to act to address them. For example, as illustrated in Figure 2, based on Internet searches and a study of peers' shower lengths, students developed posters and pamphlets, etc. to educate others about contributions to climate change from energy uses - such as long, hot, showers. Over the years, students have developed and implemented many creative research-informed and negotiated action (RiNA) projects to improve wellbeing of individuals, societies and environments ('WISE'). Examples of such projects appear in two special issues of the *Journal for Activist Science & Technology Education* (JASTE) (goo.gl/N00b3s and bit.ly/2JGIgtf) edited by science teachers and featuring reports of RiNA projects written by students. Students often create educational (and 'activist') videos — such as those at: goo.gl/jeAihg; goo.gl/o5FC38; and, goo.gl/4KzwRN.

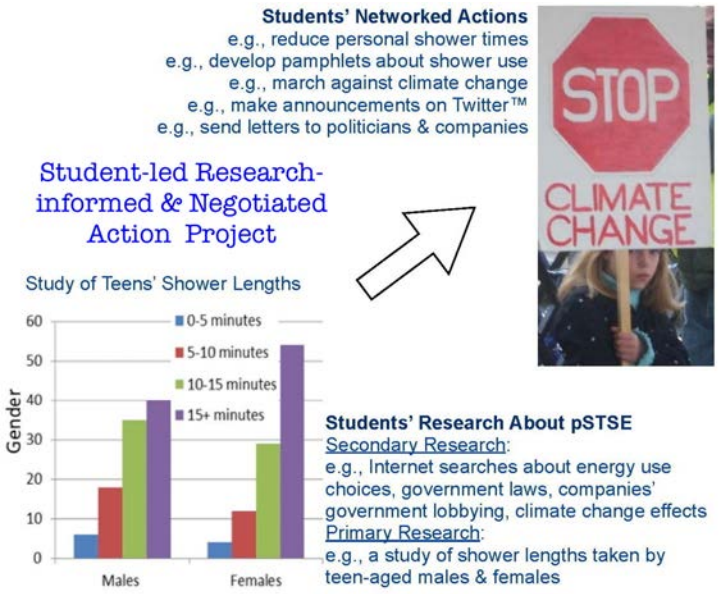

Figure 2: A Typical Student-led RiNA Project.

Although some students can independently develop and implement effective RiNA projects, particularly if they have experienced similar activist activities and if they have had some sort of advantaged (e.g., culturally and financially) backgrounds, most students struggle to do so without significant educational support from teachers, etc. Accordingly, in working with teachers and others, I developed a theoretical schema — called 'STEPWISE' — that teachers may use for developing lessons and activities aimed at helping students to more critically examine STSE relationships and, where, they identify harms, develop and implement actions to address them. This schema was adapted from curriculum teaching/learning expectations of official curriculum in my jurisdiction (MoE, 2008), organizing five curriculum learning domains/goals into a tetrahedron — with all domains co-influencing the others. 'STSE' Actions is located in the centre of this tetrahedron to prioritize encouragement of students to, in essence, altruistically 'spend' some of their literacy (e.g., knowledge about 'Products' [e.g., laws & theories] and 'Skills' [e.g., for inquiry, etc.]) to develop and implement personal and social actions to address harms to social justice and/or environmental wellbeing they perceive in STSE relationships. Early in its implementation, however, it quickly became apparent that the tetrahedral schema seemed too difficult for typical school science practices and, consequently, a framework like that in the lower right of Figure 3 was developed and found to be much more functional than the tetrahedral version. This schema has all elements of the original tetrahedral version of the framework, but is organized to gradually (in a 'stepwise' fashion) develop student's expertise, confidence and motivation to the point they can conduct independent ("SD/OE") RiNA projects. This approach consists of three general constructivism-informed 'phases,' which can vary in duration, direction, repetition and blending of each phase. Very broadly, these can be summarized as follows:

- Students Reflect: Often, the teacher provides stimuli to get students to reflect on and express their existing 'ASK' (attitudes, skills & knowledge) about STSE relationships, S&T knowledge and actions that may be necessary to address problems. It has been helpful, for example, to show them various products of S&T fields, such as: hamburgers and French fries, cell phones, drugs,

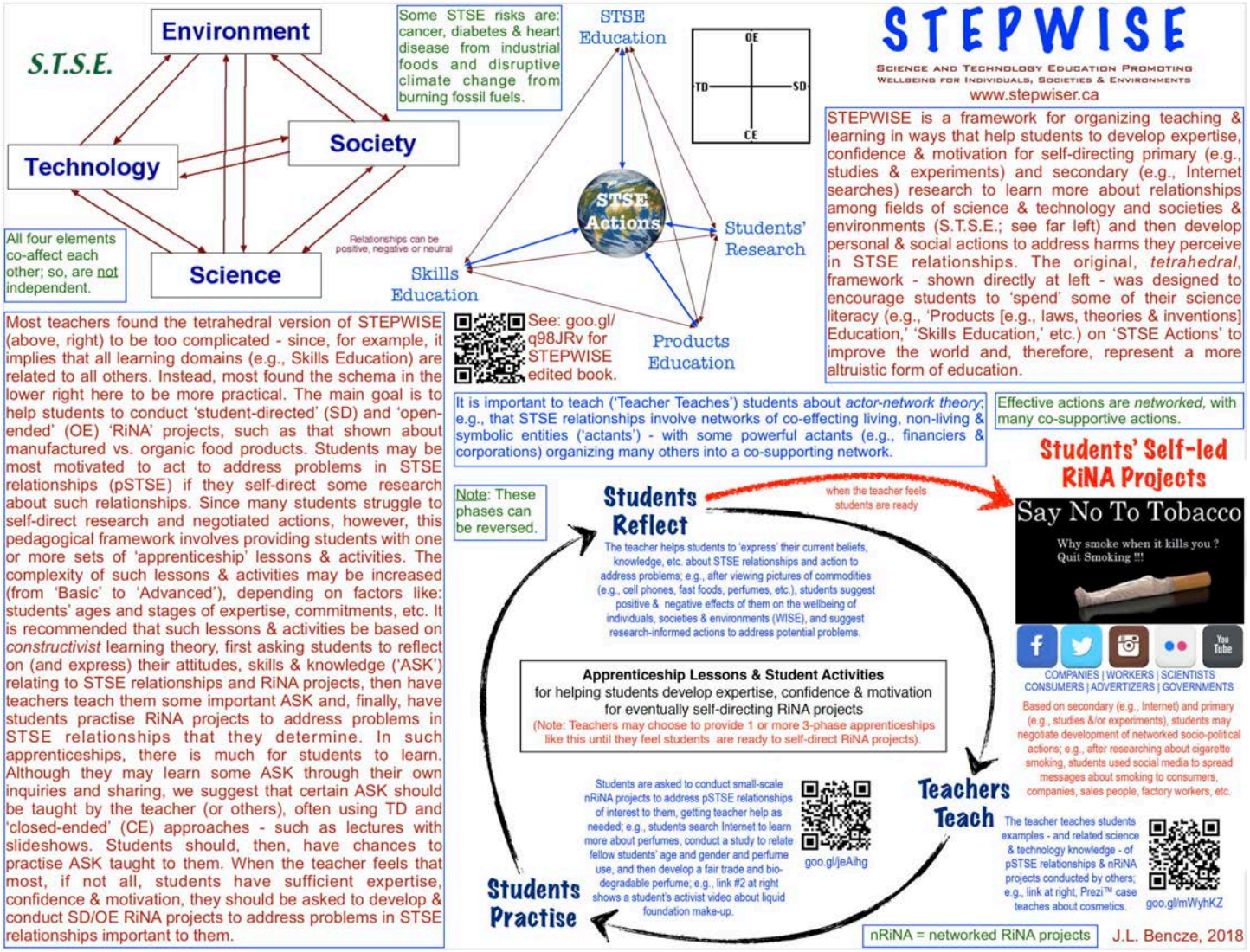

Figure 3: Annotated Summary of STEPWISE Pedagogy and RiNA Projects.

clothing fashions, cosmetics, weapons, etc. Students can say or write about what they like and dislike about these, and discuss people and groups who may like (e.g., companies & advertisers) and dislike (e.g., citizen activists, some government representatives) such products. Frequently, students' responses to such activities vary considerably — often because of differences in their experiences (e.g., culturally) and basic abilities (e.g., knowledge related to their families' wealth);

- Teacher Teaches: To avoid difficulties with discovery learning (Bencze & Alsop, 2009), the teacher provides lessons and activities to help students to learn very important ASK (relating to STSE & RiNA projects) that may be helpful to them. Using a general framework depicting various possible relationships among fields of science and technology and societies and environments (in Figure 1), the teacher may teach students about networks of relations involving influences of powerful people (e.g., financiers) and groups (e.g., corporations, free-market think tanks, transnational trade agreements) on S&T fields and other global actants — such as how governments and transnational trade agreements often allow food companies to add sugars/sweeteners, salts, fats, chemical colourings, flavours and preservatives to foods and that research suggests are linked to human illnesses, like heart disease, diabetes and cancer. The teacher also could show them a video that describes how other students researched food industry problems and developed and carried-out a campaign to educate citizens about possible harms from manufactured foods. We suggest such teaching should largely be led by the teacher, mainly because some students may struggle with learning such ASK through their own inquiries due to problems like family poverty and cultural and language differences; and,
- Students Practise: To deepen students' expertise, confidence and motivation for them, students are asked to develop and implement RiNA projects (e.g., like that in Figure 2) to address harms they determine in STSE relationships — obtaining help from the teacher, as needed and/or requested by them. Typically, the teacher will encourage small groups of students to choose an STSE issue/problem to explore and then ask them to complete a RiNA project to address it — providing them with deadlines for separate parts (e.g., issue/problem; research methods; actions) and help as requested by students.

At the end of one cycle of lessons and activities like that outlined above, the teachers may ask students to reflect again on their conceptions of STSE relationships and RiNA projects. The teacher may then decide either to provide at least one more such cycle of lessons and activities or, if students seem ready, to self-direct ("SD/OE") RiNA projects.

Once the teacher believes that most (if not all) students have expertise, confidence and motivation to self-direct RiNA projects to address harms they perceive in STSE relationships, the teacher should then ask students to develop, conduct and report on more challenging such projects. Typically, this means that the teacher will provide students with a formal assignment — often with a broad description of projects, deadlines for smaller parts of them (e.g., topics, methods, results, actions, etc.) and an assessment/evaluation scheme. Also, as a culminating event, teachers can ask students to give presentations about their projects in public fora (e.g., an STSE-Action Fair). Although these culminating projects should be largely student-directed and open-ended (see Figure 3), teachers find that many students appreciate receiving lists of possible project topics (e.g., as brief descriptions of controversies surrounding S&T products). In formal school contexts, 'guidance' also often occurs in terms of assessment/evaluation forms linked to such projects — the extent of guidance in which the teacher can vary, depending on perceptions of students' needs.

Although many more examples and rich descriptions are provided in the 'STEPWISE' edited book (Bencze, 2017a), annotations in Figure 3 provide some details regarding teaching/learning suggestions that our research indicate can help students to develop expertise, confidence and motivation for self-directing interesting and important RiNA projects to address possible harms linked to S&T fields interesting them.

An angle for curriculum development, implementation and research that perhaps provides a strong alternative to hyper-capitalist S&T education (e.g., Figure 1) involved encouragement of students in school science to develop (and implement) technology designs that, in addition to performing desired technological actions, attempted to address related problems of social justice and environmental wellbeing (Bencze & Krstovic, 2017). One project, summarized in Figure 4, seems to indicate potential for such projects to attend to matters of social justice and environmental wellbeing while also creating useful technological products. Briefly, after lessons and activities using the 3-phase framework in Figure 3 that included education about actor-network theory and ways to construct actor-network maps to depict phenomena relating to S&T fields, a group of students investigated network relations involving a popular cologne for men (and, perhaps, for women) and, in light of related education they had received from their teacher and through their

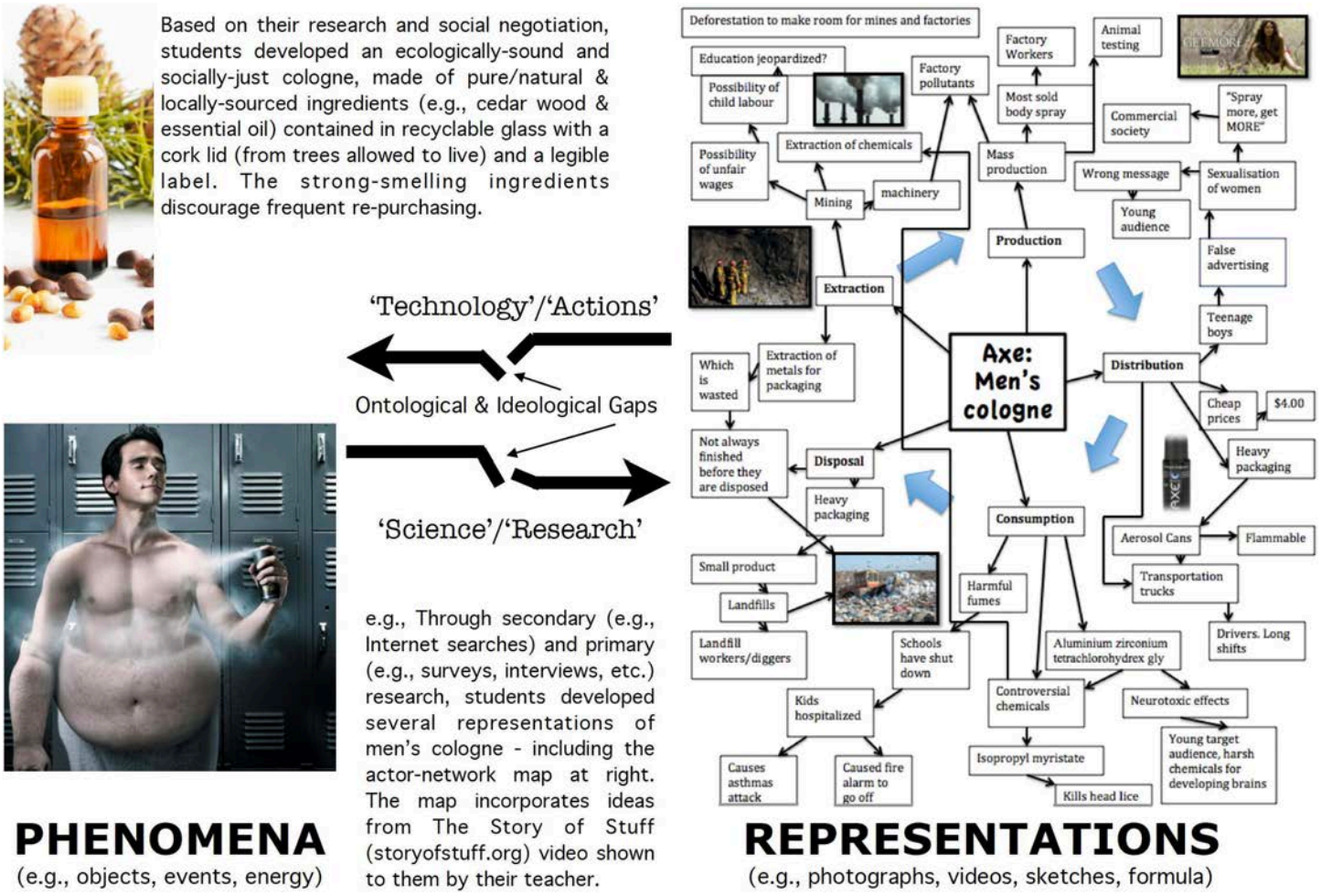

Figure 4: Students' ANT-based RiNA for EcoJust Technology Design.

secondary and primary research regarding such colognes, developed a design for a more socially just and environmentally sustainable cologne that they felt also had a pleasant odour.

Although RiNA projects facilitated through the STEPWISE pedagogical framework cannot fully address all aspects of 'hyper-capitalist' science education as depicted in Figure 1, they may help in this regard. Among ways to justify this claim, ontological, epistemological and axiological frames that are used to evaluate educational research (Creswell, 2007) and actions seem appropriate. Given that these three frames co-influence one another, however, it may be reasonable to consolidate them into two relevant aspects of hyper-capitalist science education; that is, *punctualization* and *de-problematization*. In de-punctualizing (exposing more network relations) their conceptions of the world (ontologies) involving the commodity of their studies to include such unfamiliar and problematic actants as poor labourers, students may be engaged in epistemological practices that involve different ideological (axiological) perspectives than marketers — who, in a hyper-capitalist world, may want to hide problematic actants from people. In other words, one response to hyper-capitalist S&T education is to promote RiNA projects that extensively de-punctualize phenomena in ways that expose roles of problematic influences of powerful people and groups on S&T fields and other global entities — with perhaps particular focus on S&T-related for-profit products and services — so that students might develop and implement personal and social actions to address such problematic situations.

SUMMARY AND WAYS FORWARD

Given various personal, social and environmental harms that appear linked to influences of certain individuals (e.g., financiers) and groups (e.g., transnational corporations, free-market think tanks and transnational trade organizations, etc.) on S&T fields and myriad other entities, worldwide, situations that seem extremely magnified — despite salvationary appearances — through actions of right-wing populist leaders, it appears that equally, if not more forceful, efforts appear necessary to overcome such influences and possibly bring about a more socially just and environmentally healthy world. In this paper, a field-tested framework for curriculum development and implementation in science and technology education has been highlighted as an educational alternative to STEM education initiatives that appear to promise a better world for all while distracting users (e.g., administrators, teachers, etc.) from perhaps due attention to significant personal, social and environmental harms associated with STEM fields under influences from right-wing populists. The approach ("STEPWISE") encourages and enables students to de-punctualize (elaborate network relations) apparently-isolated/single entities — with particular attention to for-profit commodities generated with involvement of S&T fields — to expose possible influences of powerful people and groups on STEM fields and myriad other entities so that students then might develop and implement research-informed and negotiated personal and social actions to try to minimize or eliminate such harmful relations. At the very least, it appears the STEPWISE framework provides students with a broad conception of 'science literacy' as outlined by Hodson (2003); that is, helping students with:

- Learning Science and Technology: acquiring and developing conceptual and theoretical knowledge in science and technology, and gaining familiarity with a range of technologies;
- Learning About Science and Technology: 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: 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; and,
- Engaging in Sociopolitical Action: acquiring the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern (p. 658).

Viewed another way, acknowledging the highly-contentious nature of concepts of 'science literacy,' the STEPWISE framework has been said to move students beyond Vision II forms of science literacy (arguably equivalent to Hodson's (2003) first two outcomes above) — which has been said to be the focus of many SSI education initiatives (Zeidler, 2014) — to embody a so-called Vision III version; that is, one that is "a politicised science education aiming at emancipation and societal participation, and includes aspects like socio- and eco-justice" (Sjöström et al., 2017, p. 182), which seems congruent with the latter two outcomes in Hodson's (2003) conception of science literacy (as above). While such an education may align with ecojustice education (Martusewicz, Edmundson & Lupinacci, 2015; Mueller & Tippins, 2012, 2015), perhaps the goal — given significant influences of right-wing populism — must go further, perhaps to the point of eventually replacing capitalism with something like ecosocialism (Löwy, 2015), prioritizing social and environmental justice through a socialist economic system. On that, it may be that some form of libertarian socialism (Chomsky, 2013) may be most appropriate; that is, one that balances individual and group rights and responsibilities.

Although the STEPWISE programme appears to have had some significant successes encouraging and enabling youth to more thoroughly and critically interrogate science and technology (or 'STEM') fields and their relationships with each other and myriad other entities of the world and then use findings etc. to inform their development of personal and social actions to address harms they identify (Bencze, 2017a), our research also suggests that such successes are restricted to certain relatively-rare educational contexts (Bencze, 2017b). Indeed, again referring to Foucault's (2008) concept of *dispositifs*, it is apparent that implementation of STEPWISE-

informed perspectives and practices were facilitated by networks often composed of cooperation among the following: i) an official curriculum mandate for education in STSE relationships, student-led science inquiries and citizen actions (as in MoE, 2008); ii) the teacher's knowledge of and support for *Naturalist-Antirealist* positions on Loving's (1991) *Scientific Theory Profile*[1]; iii) administrators' (e.g., principal, department head, etc.) support for, at least, teacher innovation and reflective practice; iv) students' ages, abilities and experiences (e.g., with RiNA); and, v) supports from an action research facilitator (a role often played by graduate students and me). In this vein of thought, Evans (2012) has suggested that such mobilization may be possible if ecojustice (and, perhaps, ecosocialist) actors systematically work to rally many and diverse living, non-living and symbolic (semiotic) actants in ways that an ecojust dispositif emerges/develops. Indeed, a small-scale version of such a counter-hegemonic dispositif seemed to emerge in the case of citizens' efforts to eliminate (what they determined to be) toxic dust (containing many heavy metals, such as lead and cobalt) dispersal from the local port onto their neighbourhood (Bencze & Pouliot, 2017). Although the local 'development' dispositif (which seems to promote growth of port activities, regardless of possible environmental hazards) seemed quite powerful, reductions in dust dispersal in this context offers some hope for those wanting a more ecojust world.

In eyes of activists, individuals/groups promoting economic growth with less than desirable attention to wellbeing of many individuals, societies and/or environments, may be considered *oppressors* (Freire, 1970). Educating students about potentially problematic power relations, as may be the case in pro-development dispositifs described here, may, therefore, represent a kind of *conscientization* — a critical consciousness about a social milieu (Freire, 1970). At the same time, educators in democracies may not want to be guilty of oppression, in the sense of providing students with mis-translations of 'real-world' documentaries like the one here — presenting pro-development individuals/groups in an unrealistically bad light. It seems that no educator can avoid ontological gaps and, likely, ideological gaps (see Figures 1 & 4). Accordingly, as Freire (1970) recommended, to be free of potential oppressors (including teachers), learners need to be given full control over 'praxis'; that is, critical, reflective, practice. Levinson (2010) echoes this call in his discussion of possible citizenship roles in the context of socioscientific issues education. This recommendation is, actually, built into the STEPWISE framework — when students are encouraged to engage in student-directed and open-ended (when conclusions are not predetermined; but, rather, determined by learners in the context of experiences and their existing theory, etc.) RiNA projects (see Figures 2,3 & 4). Indeed, there appears to be evidence to suggest that students may become relatively free of teacher influence in their RiNA projects, after having been provided with nurturing pedagogical lessons and activities beforehand (Bencze, 2017a; Bencze & Alsop, 2014).

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[1] The STP is a square grid, with two axes intersecting at right angles at the other's mid-point, for depicting various views of the nature of science. Its horizontal axis spans a continuum ranging from *Rationalist* through *Naturalist* views about the nature of data and theory negotiation for conclusions. Rationalists tend to believe in highly systematic methods, including logical judgements about theory. Naturalists, by contrast, assume conduct of science is highly situational and idiosyncratic, depending on psychological, social, cultural, political and other influences. The vertical axis depicts a continuum reflecting truth values of knowledge, from *Realist* through *Antirealist* positions. Realists believe that science knowledge claims may correspond to reality, while (extreme) Antirealists claim that each person's constructions are valid. Moderate Antirealists believe in useful knowledge.

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