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Climate Wars: Pro-ecojustice Educators vs. Pro-capitalist Networks

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Abstract: Humanity and much else on earth appear to be facing existential crises, like the climate emergency, and ongoing problems like cancer that may interact with other crises and create much worse polycrises. Although fields of science, technology, engineering and mathematics (STEM) are involved in many such crises, many analysts suggest that ultimate blame—while invariably uncertain—should be mainly directed at capitalists. It is apparent, that financiers and corporations have been highly successful at assembling massive 'teams' ('dispositifs') of supporters—including numerous other living (e.g., politicians and STEM workers), nonliving (e.g., massive extraction machines) and symbolic (e.g., 'efficiency') entities into extensive and deep assemblages promoting values like competitiveness, individualism and costs externalisations. Their complexity seems to make them highly resistant to change. In this article, a pedagogical schema is described and defended (with examples) that may help generate more citizens willing and able to critique relationships among STEM and other societal members and environments (STEM-SE) and independently develop and implement well-researched and negotiated powerful actions to overcome STEM-SE harms of their concern. Among many factors affecting the schema's successes, it seemed very helpful that the local curriculum was congruent, the teacher had more holistic and critical views about science, such as regarding its economic relations, and because the teacher agreed to directly teach students, with application activities, several possibly problematic STEM-SE relationships and sample possibly rectifying actions. STEM education schema like that, however, only seems broadly feasible with concerted community efforts to build more global ecojustice diapositifs.

Keywords: climate emergency, critical education, ecojustice, dispositifs, STEM

Resumo: A humanidade e muitas outras pessoas na Terra parecem estar a enfrentar crises existenciais, como a emergência climática, e problemas contínuos, como o cancro, que podem interagir com outras crises e criar poli crises muito piores. Embora os domínios da ciência, tecnologia, engenharia e matemática (STEM) estejam envolvidos em muitas dessas crises, muitos analistas sugerem que a culpa final - embora invariavelmente incerta - deve ser principalmente atribuída aos capitalistas. É evidente que os financiadores e as empresas têm sido muito bem-

-sucedidos na montagem de "equipas" ('dispositivos') maciças de apoiantes – incluindo numerosas outras entidades vivas (por exemplo, políticos e trabalhadores das STEM), não vivas (por exemplo, máquinas de extração maciças) e simbólicas (por exemplo, "eficiência") - em conjuntos extensos e profundos que promovem valores como a competitividade, o individualismo e a externalização dos custos. A sua complexidade parece torná-los altamente resistentes à mudança. Neste artigo, descreve-se e defende-se (com exemplos) um esquema pedagógico que pode ajudar a gerar mais cidadãos dispostos e capazes de criticar as relações entre as STEM e outros membros e ambientes sociais (STEM-SE) e de desenvolver e implementar de forma independente ações poderosas, bem estudadas e negociadas, para superar os danos das STEM-SE que os preocupam. Entre os muitos fatores que afetaram o sucesso do esquema, pareceu muito útil que o currículo local fosse congruente, que o professor tivesse visões mais holísticas e críticas sobre a ciência, nomeadamente no que diz respeito às suas relações económicas, e porque o professor concordou em ensinar diretamente aos alunos, com atividades de aplicação, várias relações STEM-SE possivelmente problemáticas e exemplos de ações possivelmente retificadoras. Um esquema de ensino STEM como este, no entanto, só parece amplamente viável com esforços concertados da comunidade para construir diapositivos de eco justiça mais globais.

Palavras-chave: eco justiça, educação crítica, emergência climática, dispositivos, STEM

Introductory Overview

Our world appears highly precarious for many (a)biotic things while relatively few others are largely secure. Such uneven risk sharing may not be an accident, however. Although proportionately few relatively wealthy people and companies in the world generate most 'greenhouse' gases, for example, most devastation—from floods, sea level rises, hurricanes, droughts, wildfires, etc.—tend to be borne by masses of disadvantaged people, other living things and environments. On one hand, the climate crisis is considered an existential risk. On the other hand, it should not likely be considered in isolation. It is apparent that it is just one of many significant crises—such as species losses, environmental pollution and potential food system collapses—that may interact to generate potentially more severe, albeit somewhat unpredictable, 'polycrises.' Indeed, given their networked nature, such combined crises seem highly resilient to efforts to overcome them. Moreover, there appears to be much evidence and sound arguments to suggest that—as elaborated below—that they are largely driven by relatively few rich and powerful individuals and groups. Many analysts have suggested that capitalists like financiers and corporations have—especially in the neoliberal period, since about 1970—been successful at creating complex and tightly-woven pro-capitalist 'dispositifs' (apparatuses); that is, actor-networks

of living (e.g., politicians, educators, entertainers, members of free-market think tanks, scientists, engineers, and many more) and nonliving (e.g., currencies, transportation and communication services) entities ('actants') that generally collaborate to promote such values as continuous growth, competitiveness, individualism, costs externalisations that help to concentrate wealth while risking wellbeing of much around them.

Given their breadth and depth and consequent resilience, along with orientations towards self-service, it seems clear that pro-capitalist dispositifs need dramatic revisions, if not replacement—in ways maximising global social justice and environmental vitality ('ecojustice'). Working to revise/replace networks likely will be very difficult, however, requiring multipronged approaches, involving governments, companies, citizen groups, etc. in a kind of 'war' among existing and new dispositifs.

Regarding the climate emergency, along with other aspects of polycrises, excellent contexts for possibly developing pro-ecojustice dispositifs seem to be STEM education—to a great extent, due to key roles for STEM fields in pro-capitalist dispositifs. In this article, I discuss and defend—with examples—uses of a pedagogical framework for directly teaching students about possibly problematic STEM, society and environment (STEM-SE) relationships and corresponding sample social actions and for preparing them to independently develop and implement well-informed social actions to help overcome risks and harms in STEM-SE relationships of their concerns. This approach, if supported by many living, nonliving and symbolic entities, may become more normalised and help increase global ecojustice. Risky Worlds

Relatively small segments of societies appear to have most influences, wealth and security while most other living and nonliving things experience varying kinds and extents of risks and harms. While millions suffered or died during the CoViD-19 pandemic (2019-c2022), for instance, the richest 1% amassed about 65% of all new global wealth—through, in part, pandemic-related activities like remote shopping (Oxfam, 2023). Similarly, after the 2007-08 Global Financial Crisis, governments provided companies that were said to be 'too big to fail'—rather than 'the general public'—with massive financial bailouts (Monbiot, 2017). While the rich generally get richer, much of the world is said to be experiencing 'a' polycrisis (Tooze, 2022); that is, myriad somewhat unpredictable interrelationships among numerous crises—such as the climate emergency (e.g., IPCC, 2023; Ripple et al., 2022), food systems collapses (Monbiot, 2022), mass extinctions (Bradshaw et al., 2021), nuclear

annihilation (BAS, 2023), financial crises (Klein, 2007), and human sovereignty losses to increasingly-sovereign artificial intelligence systems (Runciman, 2023).

Persistence of relatively stark—and, often, increasing—wealth and wellbeing differences between rich and everyone/everything else appears aligned with zero-sum thinking. Foster (1965) suggested that there have been long traditions of assuming that "an individual or a family can improve their position only at the expense of others" (p. 296; emphasis in original). Such conceptions of normal social and material relations seem highly problematic. Given resilience and longevity of such zero-sum thinking, however, transforming or replacing it seems difficult. Although there are, undoubtedly, numerous conceptions of being, much scholarship suggests that any one supposed isolated entity—like 'petroleum'—must be considered to be, ontologically, just one part of a large network (or 'web') of co-affecting entities. In actor-network theory (ANT) terms (Latour, 2005), we can think of entities like petroleum being part of large networks of interacting living, nonliving and semiotic (symbolic) entities. Such actor-networks are unlikely ever to be 'neutral,' however. Rather, it appears they often or always are biased—favouring perspectives, characteristics, preferences, etc. of certain actants. In other words, certain actants appear much more powerful than others, including regarding extents to which they may facilitate recruitments of numerous other actants to support their causes. Such 'biased' actor-networks appear congruent with Foucault's (1980) description of a dispositif (apparatus):

[A dispositif is] a thoroughly heterogenous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions ... The [dispositif] itself is the system of relations [among heterogeneous elements]. … [A dispositif also can be considered [a] formation which has as its major function at a given historical moment that of responding to an urgent need … [or] strategic imperative. (pp. 194-195)

Dispositifs, therefore, based on ANT perspectives, may be broadly defined as: networks of living, nonliving and semiotic actants that largely cooperate like parts of a machine to achieve certain goals.

Although many actants (e.g., religious symbols) may have significant influences within actor-networks, several analysts suggest that many or most of them are variably 'engineered' to mainly serve capitalists and capitalism (albeit both being very diverse and somewhat uncertain). Major actants within such pro-capitalist dispositifs are thought to include: fossil fuels (e.g., coal, oil & gas); individual financiers (e.g., Elon Musk);

corporations (e.g., ExxonMobil™); transnational groups (e.g., World Trade Organization™); free-market think tanks (e.g., Atlas Network™); many state/provincial and national governments; many universities, colleges and school systems; multiple currencies (including cryptocurrencies); communication (e.g., Internet) and transportation (e.g., sea shipping lanes) resources; legal arrangements (e.g., secret international free-market dispute tribunals); popular discourses (e.g., normalised consumption-disposal cycles). In many ways, capitalist actor-networks tend to promote such values as continual growth, competitiveness, individualism, possessiveness, and cost externalisation (e.g., making others pay for environmental and social harms) (Foucault, 2008; Hardt & Negri, 2019; Latour, 2021; McMurtry, 1999; Piketty, 2020). Given perpetual self-interests of such systems that often appear to cause much 'collateral' damage, many pro-capitalist entities are said to be like metastasising cancer cells (McMurtry, 1999). Bakan (2020), meanwhile, suggests they seem like psychopaths—extremely, for example, self-interested and indifferent towards others' suffering. Similarly, in light of disproportionate shares of harms to disadvantaged peoples (e.g., in the so-called 'global south') from pro-capitalist activities (e.g., Svampa, 2019), such as disruptive climate events (e.g., hurricanes), analysts suggest that advantaged people in societies are, perhaps unconsciously, playing a kind of necropolitics—essentially, deciding who lives and who dies (Mbembe, 2019).

Where inequitable and environmentally destructive socioeconomic systems like pro-capitalist dispositifs described above exist, many analysts suggest that they must be dramatically reformed or replaced to prioritise increased social justice and environmental vitality. Accordingly, a group of prominent scientists advised that:

[t]he gravity of the situation requires fundamental changes to global capitalism, education, and equality, which include inter alia … abolition of perpetual economic growth, properly pricing externalities, a rapid exit from fossil-fuel use, strict regulation of markets and property acquisition, reigning in corporate lobbying, and the empowerment of women. (Bradshaw et al., 2021)

Towards Ecojust Worldings

In light of myriad apparent risks and harms (e.g., climate crises) stemming from activities of pro-capitalist dispositifs, there is much support for developing alternative sociopolitical systems that promote increased global social justice and environmental vitality. A strong candidate appears to be ecojustice education, which is claimed to challenge root metaphors (e.g., that guide language and discourse) often associated with capitalism, including:

Individualism (e.g., seeing individuals as isolated and not responsible for other entities); Continuous Progress (e.g., perpetually promoting change and 'improvement'); Rationalism/Scientism (e.g., decisions about phenomena should be highly rational, particularly using 'Western' science); Commodification/Consumerism (e.g., superficial positive semiotics occludes related problems); Androcentrism (females must defer to males); Ethnocentrism (e.g., certain ethnocultural groups are superior to others); and, Ableism (e.g., valuing certain individual characteristics, like intelligence, athleticism and humour). (Martusewicz, Edmundson & Lupinacci, 2021; précised from p. 58)

Adequately addressing such root metaphors to promote ecojustice will not be easy. Extremely resilient pro-capitalist 'machines' are unlikely to be re-arranged or replaced in short order. Nevertheless, given apparent severity of polycrises, it seems essential that we continue to strive for increased global ecojustice—through, for example, promoting more altruistic orientations in societies.

If, as argued above, many or most personal, social and environmental problems faced by humanity can be mainly blamed on pro-capitalist dispositifs, then societal members need to work in multiple ways and contexts to significantly revise or replace pro-capitalist dispositifs with those, like ecojustice education, favouring global social justice and environmental vitality (e.g., acknowledging ecocentrism as central to ecojustice). Given enormity and complexity of pro-capitalist dispositifs, this would involve recruitment to ecojustice causes of myriad actants, like: governments; corporations; worker groups; transnational groups (e.g., WTO); think tanks (of different political leanings); universities; advertisers; more ecojust technologies (e.g., windmills); etc. With such diversity and complexity, it is difficult to know where to start such a monumental task.

Challenging pro-capitalist dispositifs may seem like doing 'battle' with a virtual Borg , a fictional human-machine sentient 'being' with collectivist and acquisitive traits. One consolation with challenging such a 'beast' is that some experimental social research suggests that new perspectives and possible practices may need only to achieve about 25% popularity before reaching 'social tipping points'—at which new ideas, etc. quickly diffuse among other social and material actants (Otto et al., 2020). Nevertheless, as discussed above, pro-capitalist dispositifs are extremely resilient and, moreover, often demonstrate considerable adaptability—changing foci as contexts change, such as massive increases in profiteering from online communications resulting from the CoViD-19 pandemic.

An aspect of pro-capitalist dispositifs that may, however, be their 'Achilles heels' is their tendencies to prioritise subterfuge; that is, intentional manipulation of people's

perspectives and practices. Rationale for doing so may be that, like magicians, capitalists must 'distract' viewers (e.g., consumers) from awareness of their often covert tactics. The climate emergency, for example, which is said to be one of a few existential crises (Ord, 2020), appears to be instructive about features common to many crises; that is, public propaganda or 'disinformation'—including omissions and distortions (Herman & Chomsky, 2002 [1988]; Huckin, 2019; Mann, 2021; Osborne & Pimentel, 2023). The young activist, Greta Thunberg (2023), for example, suggests that this crisis can largely be attributed to our current "age of the great greenwashing machine" (p. 2). In many self-identifying democracies, for example, governments portray themselves as being 'progressive'—such as through highly necessary equity, diversity and inclusion projects — while using images about them (which often are less ambitious than claimed) as 'smokescreens' enabling them to further implement neoliberal policies like tax reductions for elite and de-regulations of harmful extractive industries like fossil fuel processing (Fraser, 2017). Indeed, private sector interests, including financiers, corporations, transnational free-market entities, etc., often seem to condition the 'public'—particularly in 'democracies' (Gramsci, 2003 [c1929-1935])—to support fossil fuel extraction and uses associated with the climate emergency (Klein, 2014). For example, Exxon™ apparently learned about 50 years ago from its scientists that petroleum combustion would likely contribute to global warming (to extents close to those now experienced) and, yet, hid such information and, moreover, spent generously to convince 'the public' otherwise (Dembicki, 2022; Michaels, 2020). Similarly, some of the world's richest banks, while publicly touting green technologies, secretly massively funded large-scale petroleum exploration and implementation projects (Slawson, 2023). Despite strong science supports for anthropogenic climate change, such programmes of deception have been extremely successful in maintaining and augmenting fossil fuel exploration and uses—with prominent organisations like the Intergovernmental Panel on Climate Change (IPCC, 2023) and groups of concerned climate scientists (Ripple, 2022) warning that our world appears perilously close to 'tipping points,' beyond which indicators like ocean acidity, sea ice thicknesses and biodiversity losses are unlikely to recover to sustainable levels (Richardson et al., 2023).

If propaganda is a defining feature of pro-capitalist dispositifs, at least in putative democracies, a major avenue for projects to expand and deepen pro-ecojustice dispositifs is public education. Indeed, it has been said that "… the major purpose of education is to make the world safe for global capitalism" (McLaren, 2000, p. 196) and, accordingly, must be considered a major site of ecojustice activism. 'Education,' however, is a very broad

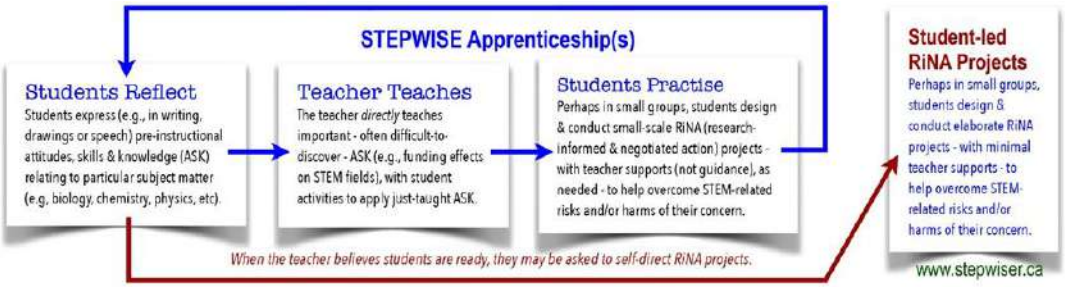
field. Given apparent ('rough') correlations between developments in STEM fields and societal zeitgeists (e.g., general ideologies of an age) (Jasanoff, 2015), though, a major site of pro-ecojustice reform may be science (or STEM) education. There have, indeed, been many calls for more socially and politically active science education (e.g., Bencze & Alsop, 2014; Hodson, 2011; Roth & Désautels, 2002; Santos, 2009). And, recently, prominent educational researchers have recommended foci in science/STEM education on ways elite often promote disinformation about their activities (Osborne & Pimentel, 2023).

Possibilities for Pro-ecojustice STEM Education

After different apparently problematic developments relating to STEM fields (e.g., acid rain; cancer; nuclear weapons), scholarly fields of Science and Technology Studies (STS) developed to investigate such problems (Sismondo, 2008) and, then, related programmes for school science were developed that were gradually field-tested for teaching students about Science-in-Context (SinC)—including Science, Technology, Society and Environment (STSE), then socioscientific issues (SSI) and socially-acute questions (SAQ) education (Bencze et al., 2020). Although such approaches aim to educate students about problematic relationships among STEM fields and societies and environments (STEM-SE), they commonly—although certainly not entirely—focus on individual students' development of attitudes, skills and knowledge (ASK) enabling and encouraging them to engage in well-researched and logically-argued personal decisions on controversies like company-sponsored space explorations (Levinson, 2010). Education about issues in such ways would seem to help students to be enculturated into norms common to many representative democracies, in which most citizens only periodically vote to determine politicians (and, likely, related experts) who may or may not represent their perspectives and practices (Wood, 1998). For dramatic changes that are thought needed to prioritise ecojustice goals, it is apparent to many analysts that these may only occur with more direct actions to convince politicians and other key agents (e.g., think tank leaders) to promote ecojustice (Hodson, 2011).

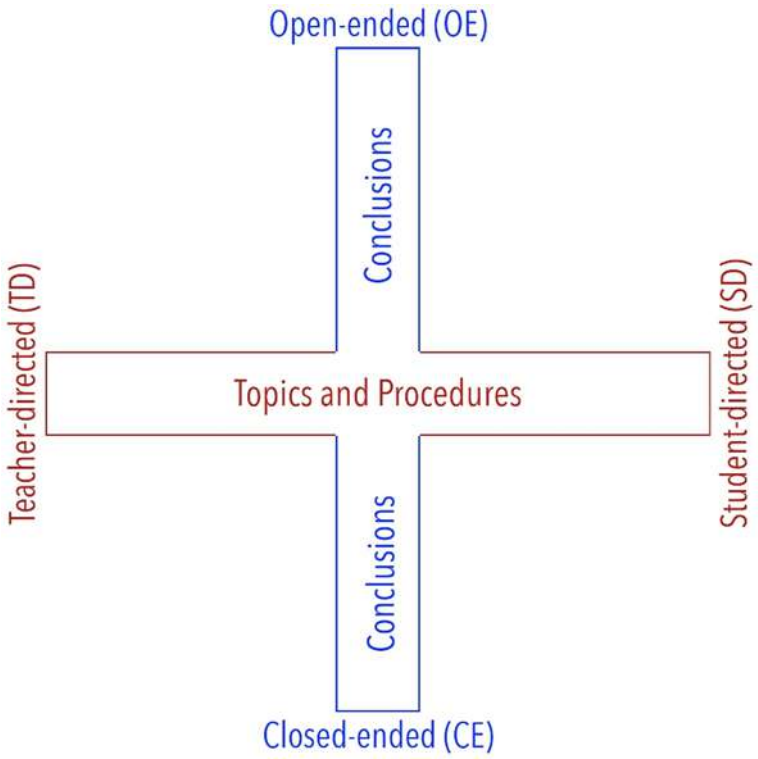
A SinC programme that has prioritised civic actions to help overcome harms of students' concerns in STEM-SE relationships is STEPWISE . It shows promise in educating students about possibly problematic STEM-SE relationships and in preparing them to self-develop and implement personal and sociopolitical actions to address their STEM-SE concerns (Bencze, 2017).

Figure 1: STEPWISE Pedagogical Schema.



The STEPWISE framework shown in Figure 1 was developed (2006-08) using research-informed principles and practices. Constructivist learning theory (Osborne & Wittrock, 1985), for instance, was used to justify the first step (Students Reflect) in the 3-phase 'apprenticeship.' By asking students to express (e.g., orally or in writing) what they (dis-)like about petroleum, for example, they—and the teacher—may become more conscious of their existing attitudes, skills and knowledge (ASK). Such reflection activities need to be mainly student-directed (SD) and open-ended (OE) in terms of Lock's (1990) learning control framework depicted in Figure 2—although there likely will be some TD to set up the activities. Enabling and encouraging students to relatively freely express their 'personal' (albeit socially-influenced) ASK about phenomena is very important in, for example, allowing them to later more consciously consider alternatives (perhaps presented by the teacher) and in honouring their ASK, which may not align with powerful mainstream STEM research—such as those linked to Indigenous ways of knowing—but be essential to maintaining one's cultural identity (Aikenhead & Jegede, 1999). Indeed, we have found that students develop considerable 'pride' in expressing their ASK, which they may later explore in their RiNA projects.

Figure 2: Learning Control Variations.



A particularly salient feature of STEPWISE is its promotion of direct application-based teaching (ABT) in the Teacher Teaches phase of the pedagogy (Figure 1). Doing so is intended to overcome at least three major practices apparently promoted by pro-capitalist networks: i) inquiry-based learning (IBL); ii) pro-capitalist STEM education; and, iii) public propaganda. Each of these tactics appears to limit public education, including in ways that may dissuade citizens from critiquing and trying to reform dominant systems—so-called 'dissent and conflict' (Levinson, 2010). Popular IBL approaches often engage students in empirical (or other) activities that expect them to discover pre-specified ASK. Some prominent proponents described it, for example, this way:

Within a classroom, scientific inquiry involves student-centered projects, with students actively engaged in inquiry processes and meaning construction, with teacher guidance, to achieve meaningful understanding of scientifically accepted ideas targeted by the curriculum. (Schwartz, Lederman & Crawford, 2004, p. 612)

Expecting students to discover important pre-specified ASK from their inquiries can be highly discriminatory for many students, especially, apparently, those whose

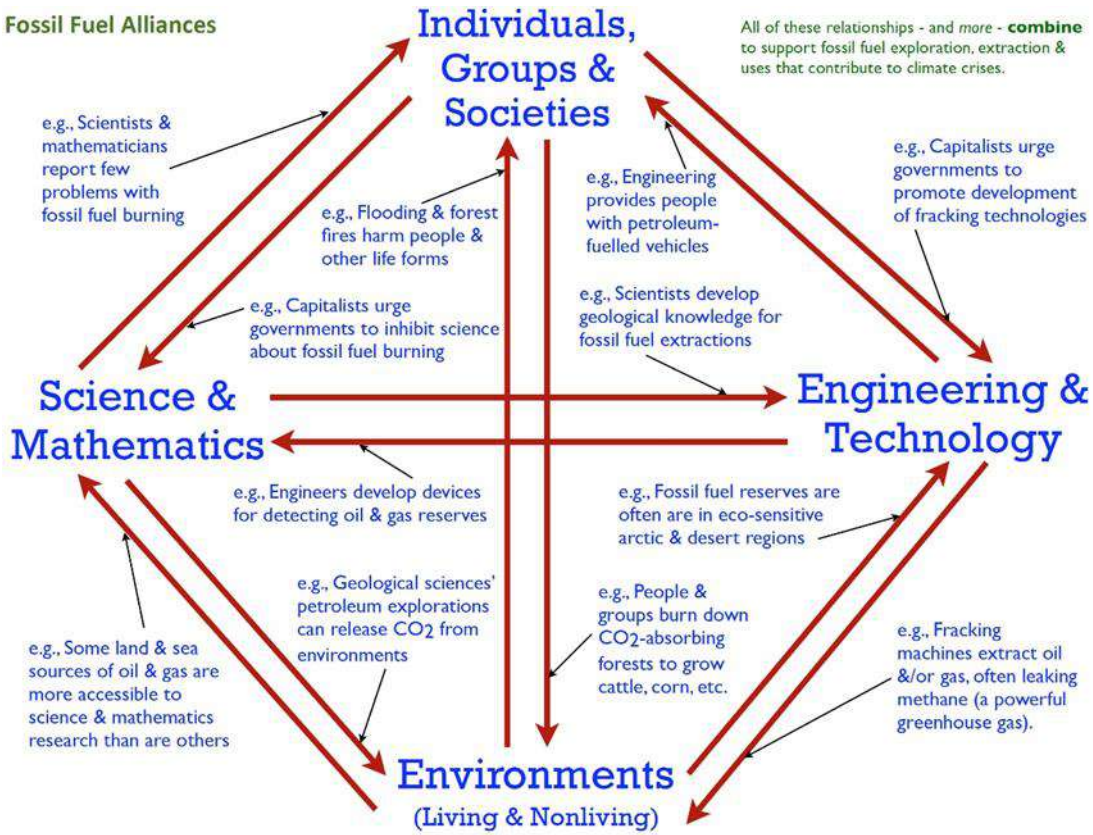
cultural and social capital are not mainstream (Bourdieu, 1986)—thus, limiting their constructions from experience. In other words, IBL can be a kind of 'survival of the richest' (Bencze & Alsop, 2009). Such a classist orientation appears familiar and, indeed, seems to align with capitalists' needs for fewer experts to serve as knowledge builders—particularly in light, for example, of recent advances in generative artificial intelligence systems. But, general assumptions for a stratified society also seem evident in, for example, development of the latest US science education standards. In planning for this document, the US National Research Council (NRC, 2011, p. 2) seemed to indicate their elite priorities for STEM education:

The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering. . . . [Four] percent of the nation's workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent.

Teaching students about important, difficult-to-discover, ASK can help more, if not all, students to gain cultural capital useful in their everyday lives and, as necessary, for dissent and conflict (as above). Such application-based teaching (with examples below) also can help supplement disinformation (see above) available to students through their secondary research. At the same time, such ABT can urge teachers to adapt learning goals in many STEM education curricula, which tend to be highly reductionist (e.g., not much acknowledgement of pro-capitalist dispositifs) and sanitised (e.g., little attention to possibly problematic business-STEM relationships) (Bencze et al., 2018; Hoeg & Bencze, 2017; Pierce, 2013). Regarding the latter problem, there is much research to suggest that private sector funding of STEM work—whether in private or public contexts—can, to varying extents, corrupt investigators' topic choices, methods, results and results dispersal (Angell, 2004; Krimsky, 2019; Mirowski, 2011; Ziman, 2000). Such capitalist pressures on STEM fields have been associated, as discussed above, with numerous harms to wellbeing of individuals, societies and environments—including, of course, the climate emergency.

As described above, to compensate for different 'deficiencies' in important ASK (e.g., possibly problematic STEM-SE relationships), the Teacher Teaches phase begins with teacher input; that is, relatively teacher-directed and closed-ended (Figure 2) lessons to teach students about possibly problematic STEM-SE relationships and corresponding sample RiNA projects. Doing so is an example of de-punctualization (Callon, 1991); that is, educating someone about oft-ignored complex—possibly problematic—relationships in which entities/actants are embedded. Recently, for example, we have used schema like that in Figure 3 to gradually introduce students to STEM-SE dispositifs and, in this case, fossil fuel issues. After discussions with students about the schema's details, students may then be asked to complete a blank schema for other commodities. Such teacher-student discussions about possibly problematic STEM-SE relationships may then lead to early discussions with students about possible actions to overcome perceived problems.

Figure 3: Some STEM-SE Relationships Involving Fossil Fuels.

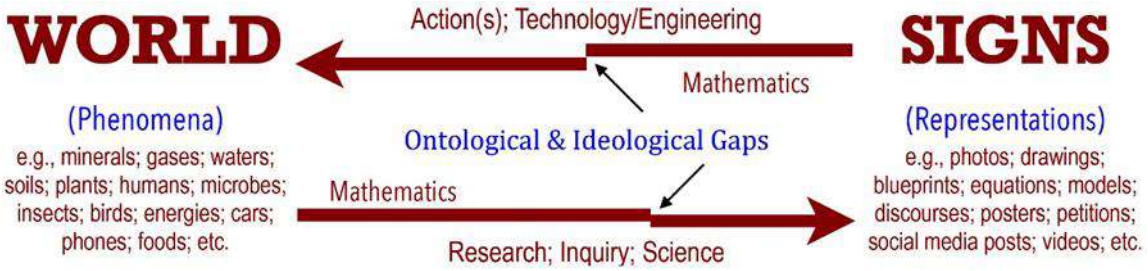


Many teachers in our work appear to have indicated that it makes most sense to teach students about STEM-SE relationships, possible harms and issues and corresponding RiNA projects, more or less, in synchrony. For example, to show students examples of RiNA projects, we have prepared lessons (via the video at: youtu.be/uGt7DJsIrY0) to teach students about a citizen dispositif acting to eliminate perceived toxic dust (e.g., containing heavy metals like lead and arsenic) being dispersed from open piles of nickel ore stored at their city's marine port. Ore handling and shipping appear largely supported by a 'development' dispositif consisting, for example, of the city's mayor, shipping companies and port authority leaders. Further details about this case are described in Bencze and Pouliot (2017) and in Pouliot (2015). Often, teachers used a lecture and student questioning style, along with multimedia resources to teach such specific examples of possibly problematic STEM-SE relationships and corresponding RiNA projects. We also have prepared a graphic novel (tinyurl.com/yxa9ptq6) about the above dust controversy that teachers can ask students to analyse after being taught about STEM-SE relationships and RiNA projects. Teachers also may use samples of students' previous RiNA projects, like those at tinyurl.com/yckyv75p, to teach about such relationships.

Although direct teaching like that described above can be effective in helping many students to come to learn about possibly problematic STEM-SE relationships and possibly rectifying RiNA projects, students also need to be engaged in activities in which they have opportunities to apply newly-taught ASK in contexts having meaning for them. This tack can be justified using knowledge duality theory (Wenger, 1998)—which posits that depth of and commitments to learning increase as students are given increasing controls over both directions in translations between "World" and "Signs" regarding the schema in Figure 4. We suggest that such ceding of learning control (relatively TD/CE to highly SD/OE, Figure 2) occur gradually. The teacher first may use more TD/CE approaches to show students examples of RiNA projects (in the teacher input step in the Teacher Teaches phase, Figure 1). But, then, in the student application step, students may be given increasing controls over project directions and conclusions. Excellent kinds of activities in this regard are case methods (i.e., documentaries of STEM-SE

situations, plus student activities and questions about them). For such purposes, we have prepared a lesson set (on video at: youtu.be/2-1hYf8YQDM) to engage students in a case method about plastic water bottle uses—in which students may apply ASK they hopefully learned in the teacher input step (above).

Figure 4: STEM Field Processes.



After teaching and learning in the Teacher Teaches phase of the STEPWISE pedagogy (Figure 1), students may then be asked to design and conduct small-scale RiNA projects (in the Students Practise phase), receiving some teacher supports (not guidance)—as requested by them. Such more SD/OE projects provide students with much more control for deepening their learning and, finally, when the teacher asks students to independently design and conduct open-ended RiNA projects, students may have developed relatively deep understandings and strong commitments to ASK they used in their projects. Achievements of such student-led projects in school science is, perhaps, a strong indication of an education programme prioritising democracy—particularly in terms of (eventual) increased self-determination (Apple, 1990).

Since the STEPWISE pedagogical framework was developed (c2008), we have used action research to explore its usefulness in primary, secondary and tertiary formal and in less-formal after-school club contexts. As may be expected, the nature of teachers' lessons varied somewhat, as did 'quality' (e.g., networked nature) of students' RiNA projects. Having said that, we have tended to take more 'liberal' perspectives on evaluations of student achievement—acknowledging multiple and diverse factors, such as students' ages, access to cultural capital and teachers' levels of experience and expertise with such projects and with mentoring them. Accordingly, we cannot define 'perfect' characteristics of such projects. However,

we may be able to confidently say that students have generated ‘relatively well researched and planned’ social actions to address STEM-SE harms of their concern. Many of these have been accepted by reviewers of refereed publications. There are, for example, several project descriptions shared in three refereed edited books: Activist Science and Technology Education (Bencze & Alsop, 2014), Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments (Bencze, 2017) and Building Networks for Critical and Altruistic Science Education (Bencze, 2025). Students also have written reports of their RiNA projects in the four school-based issues of the community-reviewed, open access, journal JASTE: tinyurl.com/y9axcbou; bit.ly/2JGIgtf; tinyurl.com/yb45cbmv; and, tinyurl.com/3s6z59v2. And, we have posted brief descriptions (typically, with videos) of several student projects on the STEPWISE website, at: tinyurl.com/yckyv75p.

In teaching about and evaluating students’ RiNA projects, it is apparent that students may have two broad choices of action types. This can be understood in terms of the schema in Figure 4—which may represent STEM fields and RiNA projects. After students conduct secondary (e.g., Internet searches) and primary (e.g., a correlational study) research (World □ Signs), they might develop and implement two different general kinds of actions (Signs □ World); that is, i) Propositional Actions, such as suggestions for changes in the World; e.g., on posters, blogs and in letters to government/business, or ii) Actualising Actions, such as to develop new, perhaps ecojust, technologies. New technologies may be considered to have more direct—‘actualising’—effects on the World than proposals for change. An example of a propositional action was a student’s online report (tinyurl.com/yvvkvsta) to educate people about food choices and climate crises, based on his secondary research into climate change and primary research to determine gender differences in orientations towards food and climate. Alternatively, students may use their research and prior education to design and develop technologies possibly addressing their concerns—as “actualising” actions—that prioritise ecojustice goals. A 10th grade science student with interests in visual arts, for example, designed and developed a glove for handling fine art paper. Although its design (two fingers and a thumb exposed while 2 other fingers

are covered) may not have been obviously about climate change, the student did justify it terms of the climate emergency:

My product's smudge-free material is so that people don't have to erase and waste so many pieces of paper trying to make a clean and precise drawing. This makes sure that less paper is wasted, and therefore less trees have to be chopped down. Trees absorb carbon dioxide, and losing them will accelerate climate change, so my hidden message is to be more sustainable and not waste as much material as we normally do. (Student Report, Feb. 12, 2024)

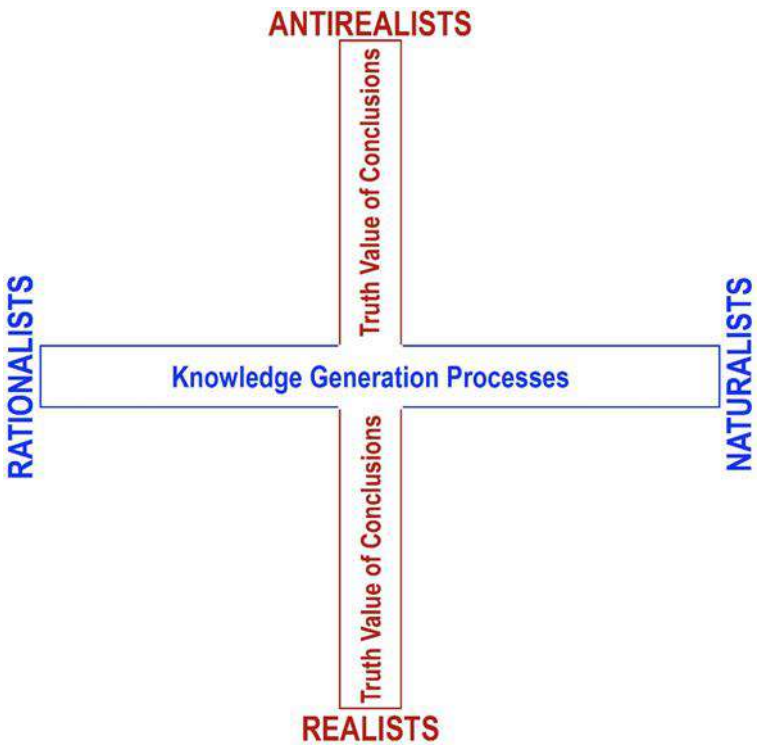
Although most students generated relatively functional ecojust technologies, few students chose topics mainly focused on climate crises, which are said to threaten humanity's (and other life forms') existence (Ord, 2020). Most students seemed to choose topics that have more apparent personal relevance to them than the relatively slow-moving and often 'remote' climate crisis. Recent 10th-grade engineering design topics included, for example, a: body lotion; computer cable protector; fruit preservative; hair mask; seeds-embedded writing paper; salt and fertilizer roller; water-proofing spray; etc. Given seriousness of climate crises, therefore, it seems clear that action researchers perhaps should investigate apparent student reluctance—when given free choice—to focus their RiNA projects largely on them.

Coda

If humanity is to rescue itself from existential collapses from, for example, the climate emergency, it appears necessary to dramatically reform, if not replace, pro-capitalist dispositifs. Given their resilience from alliances of such (a)biotic actants as wealthy financiers, pro-capitalist government leaders, corporations, transnational economic groups, transnational trade agreements, advertisers, currencies, normative discourses (e.g., zero-sum thinking) and identities aligned with Homo economicus, STEM fields, education systems, social media, and many more, transforming or replacing them likely will be 'challenging.' An 'Achilles heel' of pro-capitalist dispositifs, however, may be to focus on their relatively successful uses of subterfuge, public propaganda, fake news, disinformation, etc. to, largely, distract, discourage, confuse, etc. members of 'the public' and limit their opposition to capitalist activities. As illustrated and argued in this article, science-in-context

pedagogical practices, like STEPWISE, can be 'successful'—definitions for which are, albeit, debatable—in designing and implementing well-researched and negotiated personal and sociopolitical actions to help overcome harms in STEM-SE relationships of their concern. It appears particularly important for such pedagogies to prioritise application-based teaching to help overcome pacifying tactics like inquiry-based learning, public propaganda and sanitised STEM curricula.

Figure 5: Scientific Theory Profile.



Although STEPWISE-like pedagogies may help many students to become much more critical and activist regarding STEM-related harms like climate crises, we are often reminded of needs for existence of a local 'mini-dispositif' of actants like: congruent local curricula, open-minded administrators and colleagues, availability of relevant pedagogical materials—all largely supporting values, principles, etc. inherent to STEPWISE, etc. (Bencze & Krstovic, 2017). Among such actants, a particularly important one appears to be teachers' views of the nature of science. Teachers supporting STEPWISE tend to adhere to more Naturalist-Antirealist perspectives on Loving's (1991) Scientific Theory Profile (Figure 5). Believing, for

example, that many science fields often are influenced by such 'non-logical' factors as gender, race, politics and economics (Naturalist views), teachers may be more likely to allow students more opportunities to self-determine some knowledge (Bencze, Bowen & Alsop, 2006). We have continually seen that cooperation among such actants is necessary for teachers to adopt STEPWISE approaches. It seems that existence of such pro-STEPWISE dispositifs is relatively rare, however, and, so, activists will likely have to encourage many studies and actions to engage myriad living, nonliving and symbolic actants in support of global ecojustice.

References

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36(*3), 269-287.

Angell, M. (2004). *The truth about the drug companies: How they deceive us and what to do about it.* Random House.

Apple, M. W. (1990). *Ideology and curriculum*. Routledge.

Bakan, J. (2020). *The new corporation: How "good" corporations are bad for democracy.* Vintage.

Ball, S. J. (2012). *Global education inc.: New policy networks and the neo-liberal imaginary.* Routledge.

Bencze, J. L. (ed.) (2017). *Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments: STEPWISE*. Springer.

Bencze, J. L. (ed.) (2025). *Building networks for critical and altruistic science education.* Springer. https://link.springer.com/book/9783031838361

Bencze, J. L., & Alsop, S. (2009). A critical and creative inquiry into school science inquiry. In W.-M. Roth & K. Tobin (Eds.), *World of science education: North America* (pp. 27-47). Sense.

Bencze, L., & Alsop, S. (eds.) (2014). *Activist science and technology education.* Springer. doi: 10.1007/978-94-007-4360-1

Bencze, L., Bowen, M., & Alsop, S. (2006). Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education, 90*(3), 400-419.

Bencze, L., & Krstovic, M. (2017). Resisting the Borg: Science teaching for common wellbeing. In J. L. Bencze (Ed.), *Science and technology education promoting wellbeing for individuals, societies and environments* (pp. 227-276). Dordrecht: Springer.

Bencze, L., & Pouliot, C. (2017). Battle of the bands: Toxic dust, active citizenship and science education. In J.L. Bencze (Ed.), *Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments: STEPWISE* (pp. 381-404). Springer.

Bencze, L., Pouliot, C., Pedretti, E., Simonneaux, L., Simonneaux, J., & Zeidler, D. (2020). SAQ, SSI and STSE education: Defending and extending 'Science-in-Context'. *Cultural Studies of Science Education, 15*(3), 825-851.

Bencze, L., Reiss, M., Sharma, A., & Weinstein, M. (2018). STEM education as 'Trojan horse': Deconstructed and reinvented for all. In L. Bryan & K. Tobin (Eds.), *13 questions: Reframing education's conversation: Science* (pp. 69-87). Peter Lang.

Bourdieu, P. (1986). The forms of capital. In J. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241-258). Greenwood.

Bradshaw, C. J. A., Ehrlich, P. R., Beattie, A., et al. (2021, Jan. 13). Underestimating the challenges of avoiding a ghastly future. *Frontiers in Conservation Science, 1*. https://www.frontiersin.org/journals/conservation-science/articles/10.3389/fcosc.2020.615419/full

Bulletin of the Atomic Scientists (Science and Security Board) (2023). *A time of unprecedented danger: It is 90 seconds to midnight* (2023 Doomsday Clock Statement, J. Mecklin, Ed.). BAS. Bulletin of Atomic Scientists.

Callon, M. (1991). Techno-economic networks and irreversibility. In J. Law (Ed.), *A sociology of monsters: Essays on power, technology and domination* (pp. 132-161). Routledge.

Dembicki, G. (2022). *The petroleum papers: Inside the far-right conspiracy to cover up climate change.* Greystone.

Foster, G. M. (1965). Peasant society and the image of limited good. *American Anthropologist, 67*(2), 293-315.

Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings, 1972-1977* (G. Colin, ed.). Pantheon.

Foucault, M. (2008). *The birth of biopolitics: Lectures at the Collège de France 1978-1979* (Ed.: M. Sennelart; General Eds.: F. Ewald & A. Fontana; Trans.: G. Burchell). Palgrave Macmillan.

Fraser, N. (2017). From progressive neoliberalism to Trump—and beyond. *American Affairs, 1*(4), 46–64.

Gramsci, A. (2003). *Selections from the Prison Notebooks [c1929-1935] of Antonio Gramsci.* (Ed./Trans.: Q. Hoare & G. Nowell Smith). International Publishers.

Hardt, M., & Negri, A. (2019). Empire, twenty years on. *New Left Review, 120*, 67-92.

Herman, E. S., & Chomsky, N. (2002 [1988]). *Manufacturing consent: The political economy of the mass media* (2nd ed.). Pantheon.

Hodson, D. (2011). *Looking to the future: Building a curriculum for social activism*. Sense.

Hoeg, D., & Bencze, L. (2017). Values underpinning STEM education in the USA: An analysis of the Next Generation Science Standards. *Science Education, 101*(2), 278–301.

Huckin, T. (2019). Propaganda by omission: The case of topical silence. In A. Murray & K. Durrheim (Eds.), *Qualitative Studies of Silence: The Unsaid as Social Action* (pp. 186-205). Cambridge University Press. doi:10.1017/9781108345552.011

Intergovernmental *Panel on Climate Change (2023). Climate change 2023, Synthesis report: Summary for policy makers*. IPCC. Intergovernmental Panel on Climate Change. doi: 10.59327/IPCC/AR6-9789291691647.001

Jasanoff, S. (2015). Future imperfect: Science, technology, and the imaginations of modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power* (pp. 1-33). University of Chicago Press.

Klein, N. (2007). *The shock doctrine: The rise of disaster capitalism.* Henry Holt.

Klein, N. (2014). *This changes everything: Capitalism vs. the climate.* Simon & Schuster.

Krimsky, S. (2019). *Conflicts of interest in science: How corporate-funded academic research can threaten public health.* Simon & Schuster.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory.* Oxford University Press.

Latour, B. (2021). *After lockdown: A metamorphosis* (J. Rose, Trans.). Polity Press.

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

Mann, M.E. (2021). *The new climate war: The fight to take back our planet. PublicAffairs,* Hatchette Book Group.

Martusewicz, R., Edmundson, J., & Lupinacci, J. (eds.) (2021). *Ecojustice education: Towards diverse, democratic, and sustainable communities (3rd ed.).* Routledge.

Mbembe, A. (2019). *Necropolitics.* Duke University Press

McMurtry, J. (1999). *The cancer stage of capitalism.* Pluto.

Michaels, D. (2020). *The triumph of doubt: Dark money and the science of deception.* Oxford University Press.

Mirowski, P. (2011). *Science-mart: Privatizing American science.* Harvard University Press.

Monbiot, G. (2017). *Out of the wreckage: A new politics for an age of crisis.* Verso.

Monbiot, G. (2022). *Regenesis: Feeding the world without devouring the planet*. Allen Lane.

National Research Council (2011). *Successful STEM education: Identifying effective approaches in science, technology, engineering, and mathematics.* NRC. National Academies Press.

Omura, K., Otsuki, G. J., Satsuka, S., & Morita, A. (eds.) (2019). *The world multiple: The quotidian politics of knowing and generating entangled worlds*. Routledge.

Ord, T. (2020). *The precipice: Existential risk and the future of humanity.* Bloomsbury.

Osborne, J., & Pimentel, D. (2023). Science education in an age of misinformation. *Science Education, 107*(3), 553-571.

Osborne, R., & Wittrock, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education, 12*(1), 59-87.

Otto, I. M., Donges, J. F., Cremades, R., et al. (2020). Social tipping dynamics for stabilizing Earth's climate by 2050. *Proceedings of the National Academy of Sciences, 117*(5), 2354–2365. doi: 10.1073/pnas.1900577117

Oxfam (2023). *Survival of the richest: How we must tax the super-rich now to fight inequality.* Oxfam International.

Pierce, C. (2013). *Education in the age of biocapitalism: Optimizing educational life for a flat world.* Palgrave Macmillan.

Piketty, T. (2020). *Capital and ideology (trans. A. Goldhammer).* Harvard University Press.

Pouliot, C. (2015). Quand les citoyen.ne.s soulèvent la poussière. Carte blanche.

Richardson, K., Steffen, W., Lucht, W. et al. (2023). *Earth beyond six of nine planetary boundaries. Science Advances, 9*(37),. doi: 10.1126/sciadv.adh2458

Ripple, W.J., Moomaw, W.R., Wolf, C., et al. (2022). Six steps to integrate climate mitigation with adaptation for social justice. *Environmental Science & Policy, 128*(Complete), 41-44.

Roth, W.-M., & Désautels, J. (eds.) (2002). *Science education as/for sociopolitical action.* Peter Lang.

Runciman, D. (2023). *The handover: How we gave control of our lives to corporations, states and AIs.* Profile Books.

Santos, W. L. P. dos (2009). Scientific literacy: A Freirean perspective as a radical view of humanistic science education. *Science Education, 93*(2), 361-382.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Sismondo, S. (2008). Science and technology studies and an engaged program. In E. J. Hackett, O. Amsterdamska, M. Lynch & J. Wajcman (Eds.), *The handbook of science and technology studies (3rd ed.)* (pp. 13-31). MIT Press.

Slawson, N. (2023, Sept. 12). First thing: World Bank spent billions of dollars backing fossil fuels in 2022, study finds. The Guardian. https://www.theguardian.com/us-news/2023/sep/12/first-thing-world-bank-spent-billions-of-dollars-backing-fossil-fuels-in-2022-study-finds

Svampa, M. (2019). *Neo-extractivism in Latin America: Socio-environmental conflicts, the territorial turn, and new political narratives* (1st ed.). Cambridge University Press.

Thunberg, G. (2023). *The climate book*. Penguin.

Tooze, A. (2022, Oct. 29). Welcome to the world of the polycrisis. Financial Times, London. https://www.ft.com/content/498398e7-11b1-494b-9cd3-6d669dc3de33

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge University Press.

Wood, G. H. (1998). Democracy and the curriculum. In L. E. Beyer & M. W. Apple (Eds.), *The curriculum: Problems, politics and possibilities* (pp. 177-198). SUNY Press.

Ziman, J. (2000). *Real science: What it is, and what it means*. Cambridge University Press.

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