Science
Education

ISSUES AND TRENDS

Sustainability in Science Education? How the Next Generation Science Standards Approach Sustainability, and Why It Matters

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Received 14 March 2014; accepted 8 July 2014
DOI 10.1002/sce.21137
Published online 31 October 2014 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: In this essay, we explore how sustainability is embodied in the Next Generation Science Standards (NGSS), analyzing how the NGSS explicitly define and implicitly characterize sustainability. We identify three themes (universalism, scientism, and technocentrism) that are common in scientific discourse around sustainability and show how they appear in the NGSS. Taken together, these themes evoke a technology-centered perspective called ecological modernization that defines sustainability as a set of global problems affecting all humans equally and solvable through the application of science and technology. We argue that students who are taught to think about sustainability from this perspective will be less able to see its ethical and political dimensions and less prepared for the political realities of a pluralist, democratic society that must balance the needs of multiple groups and integrate science with other sources of knowledge to develop contextualized responses to sustainability challenges. One compelling alternative is a systematic collaboration between science educators and social studies educators, in which the complementary pedagogical strengths of both fields are combined to provide realistic and powerful preparation for future sustainability challenges. © 2014 Wiley Periodicals, Inc. *Sci Ed* **99:**121–144, 2015

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INTRODUCTION

The long list of topics covered by the Next Generation Science Standards (NGSS) includes a subcategory called "human sustainability" (Next Generation Science Standards Lead States, 2013, p. 287). It is one of five earth and space sciences topics that the NGSS recommend be taught in U.S. high schools. To demonstrate success in this topic, students must, among other things,

- create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity, and
- evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost–benefit ratios. (p. 287)

As the standards filter into U.S. school districts and classrooms, human sustainability is one of the topics most likely to attract attention. Some will argue that sustainability is inherently political and therefore inappropriate for public schools (Disinger, 2005). Yet there is a long history of addressing resource management, biodiversity, and other related topics within science education. In the United States, at least, ideas that now fall under the rubric of sustainability have played an important and recurring role in both science curriculum and science pedagogy. In the waning years of the nineteenth century, an environmentally themed curriculum movement called Nature Study helped introduce science to the elementary grades (Kohlstedt, 2005). During the infamous dust bowl years of the 1930s, topics such as erosion and the water cycle became embedded in the secondary science curriculum (Disinger, 2001). Starting in the 1970s, the Science–Technology–Society movement drew attention to the social implications of scientific and technological change (Pedretti & Nazir, 2011). And the influential 1980s-era report *Science for All Americans* argued that "science fosters the kind of intelligent respect for nature that should inform decisions on the uses of technology; without that respect, we are in danger of recklessly destroying our life-support system" (Rutherford & Ahlgren, 1991, p. xiv). At each of these historical moments, U.S. science education approached humanity's relationship to nonhuman nature in ways that reflected the anxieties and priorities of the times, whether they were an urbanizing nation, the catastrophic loss of agricultural productivity, or the threat of mass extinction.

Today, those anxieties have coalesced around the word sustainability (Yates, 2012), and sustainability has, not surprisingly, found its way into science education. Sustainability raises interesting questions for science education because the relationship between sustainability and science, more broadly, is complex and subject to ongoing debate (Miller, 2013). Unlike "biodiversity," for instance, the concept of sustainability did not originate within the sciences and is widely used in business, social policy, and popular cultural contexts (Dryzek, 2005; Yates, 2012). Although the NGSS locate "human sustainability" within the earth and space sciences, no single branch of the natural sciences "owns" sustainability; to the contrary, many scholars argue that addressing sustainability will require a new, interdisciplinary field of research (e.g., Clark, 2010). Furthermore, some self-identified sustainability advocates distrust science and technology as a solution, citing the role of scientific and technological change in increasing global inequality and accelerating the destruction of nonhuman nature (e.g., Barry, 1994).

For these reasons (and others we will discuss below), it is not obvious how sustainability fits within science education. Some scholars (Gough, 2002; Hodson, 2003) argue that sustainability, while not scientific per se, offers an engaging and dynamic context for science education that could increase student interest and provide useful preparation for public engagement around science-inflected issues such as climate change mitigation and adaptation (see also Fensham, 2011; Feinstein, 2011). Others, such as Carter (2008), argue that sustainability should be treated not as an engaging context for science teaching but rather as a new epistemic and pedagogical perspective with the potential to transform both the goals and the strategies of science education.

Yet there may also be risks involved in incorporating sustainability into science education. What concerns us, in particular, is the possibility that science education will advance an oversimplified idea of sustainability that diminishes its social and ethical dimensions, exaggerating the role of technology and the importance of technical expertise at the expense of non-STEM (science, technology, engineering, and mathematics) disciplines and nontechnical expertise. Rather than supporting a generation of students to engage with science in realistic and productive ways as they address sustainability challenges, this approach might lead students to systematically misinterpret and underestimate the challenges that confront their local, regional, and global communities.

With these concerns in mind, this essay examines how the current wave of U.S. science education reform adopts and adapts the discourse of sustainability. We focus on one document in particular—the NGSS. As Tyack (1995) has argued, educational reform is politically and socially complex and one document can never fully embody the plurality of perspectives within a field. This is particularly true in the United States, where there is no national curriculum and most authority for education devolves to state and local control. Yet the NGSS are still an important bellwether of science education in the United States. The 1996 *National Science Education Standards*, which are the most obvious precursor to the NGSS, exerted a strong influence on curriculum, pedagogy, and assessment, despite being a purely advisory document (National Research Council [NRC], 2003). Like the 1996 standards, the NGSS were developed through a very public, multiyear committee process, during which a wide range of stakeholders and experts from around the country participated either as committee members or through offering comments on public drafts (NRC, 2012). In addition to prominent research and policy organizations, the National Science Teachers Association (a professional association for U.S. science teachers) was intimately involved as a partner in the process. *Unlike* the 1996 standards, the second phase of development for the NGSS was conducted in partnership with a consortium of 26 state governments that "provided leadership to the standards writing team" (Achieve Inc., 2014a). The involvement of states was intended to facilitate adoption of the standards at the state level, and although only 11 states (plus the District of Columbia) had formally adopted the NGSS at the time of writing, those states represent a significant fraction of the U.S. population, and many other states have demonstrated a strong inclination to consider the NGSS in the formulation of their own curriculum and assessment practices (Achieve Inc., 2014b).

Our analysis is situated in the U.S. national context, but the challenges we describe are relevant to many countries that are grappling with the relationship between sustainability and science education. In countries where sustainability (or sustainable development) is a more prominent political issue, there is considerably greater pressure to incorporate it into the curriculum (Læssøe et al., 2009). This does not mean that sustainability is always situated within the science curriculum. For example, Blum, Nazir, Breiting, Goh, and Pedretti (2013) describe how sustainability-related topics are taught both in and out of science classrooms in Denmark and Singapore. Yet when sustainability is taught in the context of science, researchers and educators around the world report political and conceptual challenges. In Malawi, for example, teachers resisted the idea that outside technology offers the solution to domestic sustainability challenges, seeing it as reflective of their country's legacy of colonialism and preferring to connect sustainability with local and indigenous knowledge traditions (Glasson et al., 2006). In the United Kingdom, Ashley (2000) found that science educators and curriculum developers were uncomfortable with (and often avoided) the issue of scientific uncertainty that characterizes many discussions of sustainability. And in Canada, Hodson (2003) describes the political dangers of incorporating sustainability into the science curriculum in a context where sustainability is perceived to be a highly partisan issue. It is our hope that this analysis of sustainability in U.S. science education can contribute to the rich discussion that is already taking place internationally.

THE COMPLEX AND CONTESTED IDEA OF SUSTAINABILITY

In the past 25 years, sustainability has gone from an obscure policy term to a commonplace verging on cliché (Yates, 2012). The current use of the word can be traced back to a 1987 report from the World Commission on Environment and Development (WCED) entitled *Our Common Future*.[1] The WCED report popularized the phrase *sustainable development*, which it defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 41).[2] This definition is often referred to by the shorthand phrase *intergenerational equity*. The WCED's other defining contribution was the idea that sustainable development relies on coordinated progress toward social equity, environmental integrity, and economic prosperity—goals that have often been portrayed as incompatible. John Elkington, one of the first people to write about sustainability in business contexts, famously referred to this as the *triple bottom line* of people, planet, profit (Elkington, 1994), a formulation that persists as shorthand for a more complex and contested idea.

Social equity is sometimes neglected in discussions of sustainability, which tend to focus on the relationship between environmental and economic systems (Dryzek, 2005), but equity was a major focus of the WCED report. In the chapter where sustainable development is defined, the authors resolutely argued that environmental, economic, and equity concerns could not be separated, observing that, "a world in which poverty and inequity are endemic will always be prone to ecological and other crises" (WCED, 1987, p. 41). This claim has considerable empirical support; for example, Agyeman, Bullard, and Evans (2003) offer a compelling summary of evidence linking material inequity and environmental degradation at multiple scales of analysis. Furthermore, it is clear that the authors of the WCED report saw equity as an ethical as well as a practical concern and that their concern extended beyond intergenerational equity to encompass "equity within each generation" (WCED, 1987, p. 41).

Critics have not been gentle to either sustainable development or education for sustainable development (ESD), the educational movement associated with it. This is in part because the word "development" is associated with an environmentally and socially destructive regime of economic policy (Sachs, 1992). As a result, though ESD remains a popular term in international policy discourse, especially in the European Union (Læssøe et al., 2009), many educators have dropped the word development and adopted the simpler language of "education for sustainability" or "sustainability education" (Bonnett, 1999). The triple bottom line also draws fire among those who fear that considering its three dimensions together will lead to unacceptable environmental and social costs—particularly if economic, equity, and environmental concerns are seen as interchangeable quantities comprising a single, maximizable bottom line (Dryzek, 2005). This concern is fueled by the near-ubiquitous use of three overlapping circles to represent sustainability. In this representation,

[1] This report is often referred to as "The Brundtland Report" after its lead author.

[2] Dryzek (2005) observes that "Sustainable development as a concept did not begin with Brundtland. The two words have been joined occasionally since the early 1970s, when sustainable development was actually a radical discourse for the Third World" (p. 145).

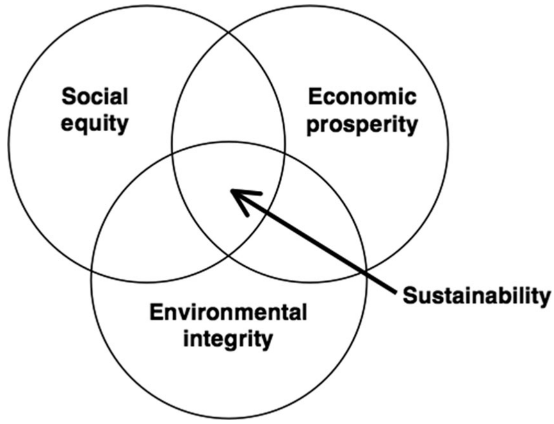

Figure 1. The overlapping circles representation of sustainability.

shown in Figure 1, each circle represents one of the constituent dimensions, and their area of mutual intersection is labeled "sustainability." Although scholars who use the overlapping circles representation often argue that the three domains must be pursued together to achieve any of them (Lozano, 2008), the representation itself can easily be interpreted to mean that sustainability includes only a little bit of each domain and that the pursuit of environmental integrity (for example) should be limited to the things that fit within the intersection.

Debates over the strengths and weaknesses of the overlapping circles diagram are part of a broader discussion about the relative importance of humans and human systems in environmental politics. Dryzek (2005) points out that sustainability is only one among many environmental discourses and that some of these discourses assign natural systems an intrinsic value that cannot be weighed against human economic well-being or social justice (see also Barry, 1994; O'Riordan, 1981). For their part, many proponents of sustainability openly admit to having an anthropocentric (vs. ecocentric) perspective. For example, Clark (2010) describes sustainability as "a project that seeks to understand what is, can be, and ought to be the *human* use of the Earth" (p. 82, our emphasis).

Both the critics and the proponents of sustainability err to the extent that they treat sustainability as a monolithic concept or unified social movement rather than a fluid discourse, with many definitions circulating in both popular and scholarly discussion. The economist Robert Solow (1993) observed that the fluid nature of sustainability is part of its appeal. Yet Solow and others (Yates, 2012; McKeown & Nolet, 2013; Dryzek, 2005) point out that sustainability has considerable cultural power even while debates about its meaning continue.[3] Indeed, Dryzek (2005) argues that

> the proliferation of definitions is not just a matter of analysts trying to add conceptual precision. It is also an issue of different interests with different substantive concerns trying to stake their claims .... if sustainable development is indeed emerging as a dominant discourse, astute actors recognize that its terms should be cast in terms favorable to them .... (p. 146)

[3]Consider, by comparison, the enduring relevance of "science literacy," which Roberts (1983) referred to as a powerful slogan whose meaning was perpetually and perhaps usefully unclear.

To the extent that the discourse of sustainability has power to shape peoples' thoughts and action, then, struggles over its meaning can be read as power struggles in which different priorities and visions for the future are asserted and contested.

In this context, it does not make sense to ask whether the NGSS get sustainability *right*; instead, we focus on which *version* of sustainability the NGSS articulate, and how this version might influence students' understanding of the relationship between nature and society. We assume that the authors of the NGSS did not invent an entirely new perspective on sustainability, but rather borrowed from readily available discourses on its meaning and implications. In particular, we considered the possibility that the NGSS' perspective on sustainability draws on the uses and definitions of sustainability in contemporary science. In the United States, scientists have historically played a significant role in science education, especially during periods of curriculum reform (e.g., Rudolph, 2002). The NGSS fit this long-term trend: Scientists and scientific societies were directly involved in the writing of the conceptual framework that guided the NGSS (NRC, 2012) and also developed many of the NGSS' source documents, such as disciplinary content standards (e.g., the Earth Science Literacy Principles). Given these direct collaborations and source materials, we asked whether the discourses about sustainability that circulate within the natural sciences would be evident in the NGSS. To help us understand the logic and implications of the NGSS' perspective on sustainability, we draw on previous research that has analyzed scientists' perspectives on sustainability as well as primary source material such as the position papers of scientific societies.

UNPACKING SUSTAINABILITY IN THE NEXT GENERATION SCIENCE STANDARDS

The NGSS comprise a complex and multifaceted document. The authors attempt to connect principles with practice, grounding each standard in the NRC's (2012) *Framework for K-12 Science Education* while anticipating the needs of classroom planning and large-scale assessment. Each topic in the NGSS is broken down into a set of performance expectations, which may include bracketed clarification statements. Below each set of performance expectations are three columns that link the topic to particular science and engineering practices, disciplinary core ideas, and crosscutting concepts (as well as connections to nature of science and to engineering, technology, and applications of science). For instance, while the topic called human sustainability is located in the high school earth and space sciences domain, it is connected through the references in these columns to a number of other topics, core ideas, and appendices. An additional layer of meaning can be found in the narrative sections referred to as storylines, which appear at the beginning of each domain and grade band (e.g., high school). These storylines describe the themes that weave through the topics that follow and describe how they connect with each other to make a coherent whole.

In addition to facilitating connections between themes and topics, this multilayered structure enables the NGSS to reflect some of the diversity of perspectives that arose during their development.[4] Thus, boldly stated performance expectations may be qualified in the columns below and in the appendices they reference. The complex structure of the NGSS also preserves some measure of disagreement. As detailed below, we occasionally uncovered internal tensions in our analysis—places where the different layers seemed to

[4]For instance, the appendix on science, technology, society and the environment (STSE) offers insight into the process by which these ideas were peripherally inserted into the crosscutting concepts column: "There is a broad consensus that these two core ideas [of STSE] belong in the NGSS but a majority of state teams recommended that these ideas could best be illustrated through their connections to the natural science disciplines" (p. 444).

contradict each other, or where a nuanced perspective was buried several layers below the performance expectations.

Our analysis encompassed the entire set of documents that comprise the NGSS. We began with the human sustainability topic[5] itself. The organization of the NGSS is designed to emphasize explicit connections between topics through shared disciplinary core ideas. In keeping with this emphasis, we traced the disciplinary core ideas found under human sustainability to other topics with identical core ideas. For example, human sustainability contains the disciplinary core idea "designing solutions to engineering problems," which is also contained within the high school topic of engineering design. This method of tracing disciplinary core ideas led us to include the following topics within a second round of close analysis: weather and climate (middle and high school), earth's systems (middle and high school), human impacts (middle school), and engineering design (middle and high school). We examined the storylines that offer greater context for these topics, including the storylines for earth and space sciences (middle and high school) and engineering design (middle and high school), and traced each item listed in the boxes below the performance expectations to its further elaborations in the appendices. For instance, human sustainability contains four connections to engineering, technology, and the applications of science, which are explained more fully in "Appendix J—Science, Technology, Society and the Environment." Finally, we tracked the use of particular words associated with sustainability through the entire NGSS. We identified all other instances of the term "sustainability" and "sustaining" that appear in the NGSS. This led us to include the storyline for life sciences (middle school) and the topic of interdependent relationships in ecosystems (high school). We also identified any other instances of the terms "social" and "economic," as they appear multiple times within the human sustainability topic. This led us to include the topic of interdependent relationships in ecosystems (middle school). In general, although we focused our analysis on the sections identified here, we also read through the entire set of NGSS documents in search of confirmatory and disconfirmatory evidence for our analytic themes.

Three major themes emerged from our examination of sustainability in the NGSS: universalism, scientism, and technocentrism. In keeping with our premise that the NGSS draw on broader social and scientific discussions about sustainability, these themes were not derived through purely inductive, grounded theory methods. Instead, each theme was developed through an iterative process in which we compared excerpts from the NGSS with scientific position papers about sustainability and social scientific research on the uses and meanings of sustainability in science and policy discourse. In the paragraphs below, we describe and illustrate the internal logic of these themes. Making these themes and their internal logics visible is the first step in opening them up to questioning. Our aim is not solely to critique the idea of sustainability found in the NGSS, but to offer an analytical foundation for deeper dialogue about how (and to what ends) sustainability is incorporated within science education.

[5]The NGSS online interface allows users to organize the standards by topic or by disciplinary core idea. The performance expectations are the same in both arrangements, but their grouping and association with items from other dimensions differ slightly. In the topic-centered arrangement of the NGSS, human sustainability is one of 16 topics at the high school level, found under the earth and space sciences domain. In the disciplinary core idea-centered arrangement of the NGSS, there is no topic called human sustainability and its performance expectations are all found under the disciplinary core idea of "ESS3: Earth and Human Activity," which includes an additional performance expectation about global climate models.

Universalism

Throughout the topic of human sustainability, the NGSS consistently emphasize a global system in which humanity is a single, indivisible element. The topic includes no specific places or proper nouns except Earth, which is composed of various "spheres": the atmosphere, the hydrosphere, the geosphere, the cryosphere, and the biosphere (p. 287). None of the dozens of examples that accompany the performance expectations (e.g., soil erosion or waste management) are situated in a specific location (p. 287).[6] This is in keeping with the standards' overarching premise that the "universe is a vast, single system in which basic laws are consistent" (p. 434), but it also reflects an important choice about how to present that system for the purposes of teaching and learning: the choice to teach the global system first (and perhaps exclusively), rather than teaching about global processes through, or in parallel with, their local manifestations.[7] Emphasizing a single, consistent system does not require omitting specific examples, nor does the national scope of the standards preclude consideration of local concerns. As a counterexample, another national standards document prepared around the same time invites teachers and students to "use sources of information in the community" and "conduct interviews of individuals in the community" as a means of understanding broader trends and principles (National Council for the Social Studies, 2013, p. 164).

Within this portrayal of the world as an undifferentiated system, humans are rendered into a single variable. Throughout the NGSS, human activity is presented in global, aggregate terms such as mass migrations, global per capita consumption, and agricultural efficiency (p. 287). The negative consequences of human activity are implicitly ascribed to all people evenly. For instance, biodiversity loss is attributed to increases in *human* population and consumption (p. 287), with no indication of the historical, political, and economic dimensions of various contributions to the loss of biodiversity. It is interesting to note, though, that population growth (which is currently associated with the global South[8]) is framed in normative terms as "overpopulation" (p. 269), whereas the per capita consumption of nations in the global North, vastly greater than that of nations in the South, is never called "overconsumption."

The NGSS offer two accounts of the interaction between people and nonhuman elements of the global system. Under the disciplinary core idea of "natural hazards" (ESS3.A), Earth affects humans; whereas under the disciplinary core idea of "natural resources" (ESS3.B), humans affect the Earth (p. 287). The NGSS' focus on a single, universal system, and on humans as a unified element within that system, means that there is no account of the effect that one group of humans has on another. In fact, there is almost no account of the consequences of human activity for humans, full stop. The sole exception is found in the middle school human impacts topic, in a subsection of the crosscutting concepts box, under the heading "Connections to Engineering, Technology, and Applications of Science." Here, it is noted that "all human activity draws on natural resources and has both short

[6]In the human sustainability topic, the only reference to the local is generic rather than particular: "local efforts (such as reducing, reusing, and recycling resources)" (p. 287).

[7]Although we do not emphasize it here, we are also sympathetic to a more radical critique of universalism—that it is *not possible* to understand sustainability challenges entirely as local manifestations of global systems. This critique rests on the unique, irreducible significance of local entities, and is in ontological tension, if not outright conflict, with the premise of "a vast, single system in which basic laws are consistent" (NGSS Lead States, 2013, p. 434).

[8]There is no entirely satisfactory language for referring to what were previously called First-World and Third-World countries, or industrialized and developing nations. We use the language of global North and global South because it is currently common parlance in social science and development literature and avoids the value-laden and potentially misleading attributions of "developed" or "wealthy."

and long-term consequences, positive as well as negative, for the health of people and the natural environment" (p. 241). Yet although the possibility of human–human impacts is acknowledged, it is still outlined in neutral, undifferentiated terms, giving the impression that all humans equally contribute to and benefit or suffer from phenomena such as surface mining, pollution, or climate change. Although the NRC's (2012) *Framework for K-12 Science Education* refers to uneven impacts of climate change for different regions and human populations (chapter 7, p. 18), this idea is not taken up in the NGSS. Instead, the standards ask students to explain how the "uneven distributions of Earth's mineral, energy and groundwater resources are the result of past and current geoscience processes" (p. 238). Here, differential access to natural resources is framed as the result of natural processes—the consequence of geoscience rather than geopolitics—and thus ethically neutral. In this way, resource distribution is portrayed as uneven as opposed to unjust.

Research from science studies demonstrates that the universalist perspective on sustainability found in the NGSS reflects a similar trend in the natural sciences. Jasanoff (2004) traces this trend—the notion of "Our Common Earth"—back to the image of Earth as a pale blue dot taken by the Apollo missions and outlines how this discourse has become nearly ubiquitous among scientists working on environmental topics. Taylor and Buttel (1992) argue that scientists do not merely perceive problems as global, they actively construct them as such; in their words, "we know [environmental problems] are global because scientists and political actors jointly construct them in global terms" (p. 406). More recently, Miller (2013) interviewed prominent scientists and reviewed key documents in the field of sustainability science and found that sustainability was frequently defined in terms of monolithic, planet-scale concepts such as "world population," "the planet's life support system," and "human needs." Each of these constructs portrays the problems of sustainability as universal (e.g., Parris & Kates, 2003; Hassan, 2001). This is in keeping with a broader tendency for

> science as law building and universalizing to ignore (or at least diminish) the particularities of place, while alternative approaches are more inclined to accept that time, place and context may provide important explanations that may limit the direct formulation or application of universal laws. (Harrison et al., 2004, p. 438)

In the NGSS, as in the natural sciences, a universal perspective on sustainability is troubling because it obscures the fact that sustainability-related problems afflict some humans more than others and that human actions, embodied in contemporary policies and social institutions, contribute to poverty, hunger, and environmental vulnerability (Jasanoff, 1996; Redclift, 1992). To put it more bluntly, some humans are more responsible for existing sustainability challenges and some humans suffer their consequences more acutely. This is true both across national boundaries (e.g., Samson, Berteaux, McGill, & Humphries, 2011) and within them (Newell, 2005). By framing sustainability in global terms, universalist definitions also mask locally and culturally situated differences of opinion over what constitutes sustainability and what course of action is most sustainable (Agyeman et al., 2003; Colucci-Gray, Camino, Barbiero, & Gray, 2006). Miller (2013) contrasts universalist sustainability with what he calls procedural sustainability, which "is defined through a participatory or democratic process contingent on place and time" (p. 284). Procedural sustainability results in local compromises, in which both the aims of sustainability and appropriate responses to sustainability challenges may look different in different places (e.g., O'Riordan, 2004).

Intriguingly, there is one place where the NGSS seem to embrace something closer to a procedural vision of sustainability—the case studies connected to Appendix D ("All

Standards, All Students"), which are available only online. Local phenomena take center stage in the case studies devoted to "economically disadvantaged students" (Case Study 1), "students from racial and ethnic groups" (Case Study 2), and "English language learners" (Case Study 4). Each case study highlights strategies that connect science to students' home cultures, local communities and sense of place; Case Study 2 specifically centers on a local sustainability challenge of biofuel production in the surrounding community (p. 3). On closer inspection, however, these examples do not necessarily affirm a vision of procedural sustainability, where local knowledge and concerns take precedence over a universalist approach in guiding investigations of sustainability. Rather, Appendix D states, "It is through these connections that students who have traditionally been alienated from science recognize science as relevant to their lives and future" (NGSS Lead States, 2013, p. 366). In other words, the local dimensions of sustainability are not a part of science that is important for all students to learn, but rather an effective strategy to bring marginalized students from the periphery to the center, where universal science is located. Ironically, the examples most likely to reveal the inequities inherent in sustainability challenges are targeted at the students most likely to suffer from those inequities in the first place.

Scientism

The universalism that characterizes the NGSS' approach to sustainability can be interpreted as an ontological stance—a statement about the sort of system in which sustainability takes place. A close reading of the NGSS also reveals an epistemological stance—a statement about the sort of knowledge that is most relevant to sustainability. The NGSS build a subtle argument that the natural sciences, and quantitative methods within the natural sciences, are the best way of understanding sustainability challenges.

The first step in building this argument is depicting the social dimensions of sustainability as secondary—either nested within and dependent on natural systems, or of relatively minor importance, capable only of constraining and contextualizing knowledge claims that are, in essence, claims about the natural world. Within the topic of human sustainability, the performance expectations make no reference to social, cultural, and political systems (p. 287). Rather, "social" and "cultural" appear in small text in the columns below, where they are presented as a set of parenthetical factors—constraints that can be accounted for in the context of engineering (p. 288). Within the disciplinary core ideas, social systems are mentioned in ways that emphasize their dependence on natural systems. For example, one disciplinary core idea asserts that "Sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth" (p. 269), whereas another contends that "The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources" (p. 287). In both core ideas, natural systems are *the* defining territory of sustainability, rather than one of three salient domains: Proper management of biodiversity and natural resources is presented as necessary and perhaps sufficient to meet economic needs and social interests. This runs directly counter to the arguments of other sustainability scholars that natural systems also depend on social systems—that, for instance, social equity is needed to preserve biodiversity (Agyeman et al., 2003)

This basic logic—that sustainability challenges are primarily scientific, and should be understood through the natural sciences and related STEM disciplines—plays out across the various examples provided in the NGSS, including "predicting natural hazards," "managing natural resources," or "reducing human impacts on natural systems" (p. 287). In these examples, the NGSS explicitly emphasize the value of quantitative scientific methods for understanding sustainability and responding to real-world problems. Students are

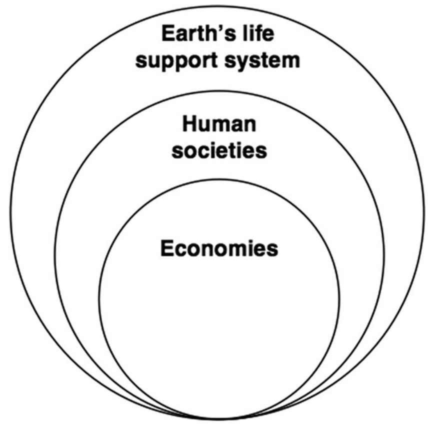

Figure 2. The hierarchical model of sustainability, redrawn from Fischer et al. (2007).

expected to base their understanding of human sustainability on quantitative databases, computational simulations, and "simplified spreadsheet calculations" (p. 287). Although one performance expectation asks students to analyze a major global challenge using both "qualitative and quantitative criteria" (p. 291), the disciplinary core idea below clarifies that "all constraints should be quantified to the extent possible" (p. 291). Thus, sustainability is understood through a set of variables that describe the natural world in (mostly) quantitative terms. When social variables intrude, they do so as post hoc modifiers of solutions discovered through science and technology or as domains in which scientific and technological solutions can have an impact. For instance, an engineering core idea states: "When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts" (p. 288). The importance of social sciences or other epistemic domains in elucidating core challenges and identifying solutions is almost entirely ignored, despite the large body of research indicating that sociopolitical concerns shape the "problems chosen, categories used, relationships investigated, and confirming evidence required" in most or all environmental science[9] (Taylor & Buttel, 1992, p. 406).

Outside of science education, scientists also tend to position natural science knowledge as central to sustainability and reduce other sorts of knowledge to a secondary role (Colucci-Gray, 2013; Redclift, 2005). The primacy of natural systems over social and economic systems in the NGSS neatly reflects a hierarchical model of sustainability described by Fischer et al. (2007). This model replaces the three overlapping domains of environment, economy, and equity with three circles nested within each other (Figure 2).

The outermost circle, which is labeled "Earth's life support system," contains a second circle labeled "human societies," within which is a third circle labeled "economies." Fischer et al. (2007) argue that

> Sustainability is not a relativistic concept because the biophysical limits to sustaining life on Earth are absolute . . . . A hierarchical conceptualization recognizes that although some trade-offs between the biophysical, social and economic spheres are possible, the absolute

[9]For example, a vast social scientific literature explores the social nature of vulnerability to natural hazards, collectively demonstrating that the risks associated with flooding (for example) have as much to do with social systems as natural ones and that vulnerability cannot be defined in purely natural scientific terms (e.g., Gallopín, 2006).

> limits of these trade-offs are dictated by the need to maintain a functioning life-support system. (p. 622)

This quote reveals two important assumptions in the hierarchical model. First, while Fischer et al. are at pains to point out the "hard limits" of the biophysical sphere, they appear not to believe in similar limits for the social and economic spheres, beyond which these domains will drastically disrupt the biophysical sphere. This is an oddly partial perspective: To take just one example, anthropogenic climate change could easily be interpreted as a violation of limits within the social and/or economic spheres that increasingly threatens to disrupt the biophysical sphere. Second, Fischer et al. argue that the "absolute" limits of the biophysical system mean that sustainability cannot be interpreted in multiple ways, or seen from multiple perspectives—it is not, in their word, "relativistic." They dismiss the idea that sustainability has subjective, local, or cultural meaning or that these meanings reveal anything about what sustainability is; to learn that, they imply that one must rely on the natural sciences. Similar to the approach taken in the NGSS, Fischer et al. carve out a limited role for social and economic knowledge, which they believe can help to inform action so long as the results are "compatible with the ultimate biophysical imperative" (p. 622).

Even in the more overtly interdisciplinary community of sustainability scientists, Miller (2013) found a similar tendency to seek scientific knowledge first and, often, above all. Sustainability scientists offer a slightly broader vision of the knowledge they believe to be most critical to sustainability, including social phenomena as part of the "coupled human–environment systems" (Miller, 2013, p. 286) that they perceive as key to understanding sustainability. Yet fundamental knowledge about these coupled systems is still, in their view, the epistemic territory of scientists (Miller, 2013). Instead of dismissing the importance of social phenomena altogether, they carve out a relevant subset of these phenomena and claim them as the core territory of sustainability science (Clark, 2010).

Fischer et al.'s hierarchical model, the coupled systems approach of sustainability scientists, and the NGSS all take a stance toward sustainability that resembles scientism: the idea that most if not all questions can be answered by science (Sorell, 2013). This is what distinguishes the approach taken in the NGSS from the understandable need to focus on science in a set of standards devoted to that topic. Rather than depicting sustainability as a complex problem requiring multiple sources of knowledge, and then emphasizing the specific contribution of science, the NGSS repeatedly imply that sustainability is a scientific problem that can best be understood in scientific terms.

Technocentrism

One defining characteristic of the NGSS is its broad embrace of engineering and technology. Our analysis of sustainability in the NGSS revealed an unexpectedly strong role for engineering—indeed, engineering is central to the NGSS treatment of human sustainability. The topic is linked to the core idea of "Designing Solutions to Engineering Problems" (p. 288), and the majority of its performance expectations are framed in terms of engineering practices (p. 287). A vein of technological optimism runs through each of these passages. For example, one disciplinary core idea notes that "Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation" (p. 288). Another core idea highlights the major role of scientists and engineers in guiding the responsible management of resources (p. 288). This optimism reaches its apogee when students are asked to consider "large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean)" (p. 287), a course of action that is scientifically controversial at best (Clark, 2010). In each of these examples, the emphasis on engineering in the NGSS reinforces the portrayal of sustainability as a set of problems to be addressed with technical knowledge and technological solutions—a portrayal that we came to think of as technocentric.

By suggesting that science can and should inform policy, the NGSS raise interesting and politically fraught questions about scientific neutrality. The authors, aware of these questions and perhaps seeking to forestall criticism, linked the topic of human sustainability to nature of science statements that argue for a strict separation between science and ethics, values, and decision making (p. 288). In shifting sustainability content from science to engineering, however, they carefully preserve a link between technical knowledge, technology, and decision making. As noted earlier, the topic of human sustainability is linked to an engineering practice stating that design solutions should consider "relevant factors (e.g., economic, societal, environmental, ethical considerations)" (p. 288). In other words, engineering is portrayed as capable of integrating science knowledge with nonscientific criteria like ethics to guide societal decision making. We see this also in the performance expectations, where the NGSS ask students to "evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios" (p. 287). The explicit goal of this exercise is to produce a recommendation—a statement of what should be done. Although a bracketed clarification states, "Science knowledge indicates what can happen in natural systems—not what should happen" (p. 287), engineering is permitted this role, as a bridge between supposedly neutral science and a society facing sustainability challenges.

Similar to the technocentric trend in the NGSS, some members of the scientific community envision an activist role for scientific knowledge, in which every problem has a single best solution that can be identified by scientific and technical experts (Funtowicz, Ravetz, & O'Connor, 1998). In this vision, "citizens' representatives, democratically elected, take decisions according to the experts' advice . . . from which practical actions can follow" (Colucci-Gray et al., 2006, p. 236). Returning to an earlier example, Fischer et al. (2007) argue that

> First, meaningful sustainability targets must be identified, and the sustainability gap must be explicitly recognized and quantified . . . . Targets relating to the life-support system and key ecosystem services of the Earth can be derived from a risk framework informed by the biophysical sciences. (p. 622)

Miller (2013) refers to this as the *knowledge-first* perspective on sustainability, and it bears a strong resemblance to a long-standing idea about the proper relationship between science and policy that Funtowicz and Strand (2007) call the modern model. In the modern model,

> To develop a policy was thus a matter of becoming informed by science and then, in a second step, to sort out diverse values and preferences . . . . rational actors act within the modern model and choose those policy options that, according to the scientific evidence, best meet their preferences. (Funtowicz & Strand, p. 263)

Local stakeholders and nonscience experts do have a role in the modern model, but it is limited to applying science by choosing the policy option that scientific data suggest is best suited to local values and policy preferences. Yet Funtowicz and Strand argue that the real relationship between science and policy is far more complex than the modern model.

Later, in our discussion, we will consider how adopting the modern model limits the NGSS' approach to sustainability.

Pulling the Themes Together: Ecological Modernization

Given the prominence of engineering within the human sustainability topic, it is perhaps not surprising that the idea of sustainability reemerges within the NGSS engineering design standards. This domain culminates with a focus on solving complex, real-world problems, such as the need to provide food and fresh water to future generations (pp. 290–292). By the end of high school, students are expected to show mastery of all of the engineering practices by

> analyzing major global challenges, quantifying criteria and constraints for solutions; breaking down a complex problem into smaller, more manageable problems, evaluating alternative solutions based on prioritized criteria and trade-offs, and using a computer simulation to model the impact of proposed solutions. (p. 290)

This passage, perhaps better than any other, encapsulates the construction of sustainability within the NGSS. First, the focus on global challenges suggests that local phenomena are merely manifestations of universal processes. Second, the emphasis on quantification filters out sources of information that are inherently qualitative. Third, solutions are modeled and prioritized using computer simulations, with the presumption that a best solution can be found and presented to policy makers for implementation. At each step, context, complexity, and conflict are minimized to produce the conditions for certainty, calculation, and clear-cut comparison of design solutions. The use of prioritized criteria presumes a consensus about the goals of sustainability that is unwarranted by the literature (Dryzek, 2005)—yet for global challenges to be treated as engineering problems, they must first be delimited as a set of neutral, quantitative problems, biophysical rather than sociopolitical. Accepting these underlying assumptions of universalism and scientism enables a technocentric approach to sustainability. In the terms of the NGSS, "While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering" (p. 290). Although the "at least in part" clause can be read as a placeholder for broader notions of sustainability, the NGSS offer no indication of what else, apart from the natural sciences and engineering, might be of use.

We contend that the vision of sustainability in the NGSS matches trends in the natural sciences. Taken as a whole, this vision of sustainability resembles *ecological modernization*, a technology-centered, managerial perspective on sustainability that numerous scholars have identified in the political and environmental discourses of the United States and other countries in the global North (Blowers, 1997; Bäckstrand, 2004; Dryzek, 2005).[10] Ecological modernization is guided by the assumption that "industrial innovation encouraged by a market economy and facilitated by an enabling state will ensure environmental conservation" (Blowers, 1997, p. 847)—a faith in the power of technical progress that we associate with scientism. Evoking the technocentric language of the NGSS, ecological modernization posits that "technological changes [can] make industrial production processes less polluting and less resource intensive and yet more productive and profitable" (Lélé, 1991, p. 613), and that "some kind of paternalistic relationship exists between politicians advised by scientific 'experts' and a technologically and scientifically naive general public" (Ashley, 2000,

[10] Orr (1992) is more blunt, calling this perspective "technological sustainability," whereas Ashley (2000) calls it "technological managerialism."

p. 271). In short, expertly managed growth and the fruits of technological advancement will solve all sustainability problems.

WHAT IS AT STAKE?

When all of the pieces are put together, and the overt messages of the performance expectations are compared with the subtle messages of phrasing and document structure, the NGSS present a vision of sustainability that is in accord with certain trends in the natural sciences (as well as beyond them), but that lacks the strong ethical component and the awareness of social complexity that can be found in other discussions about sustainability (Agyeman et al., 2003; Dryzek, 2005; Redclift, 1992; WCED, 1987). Is this necessarily bad? If science education presents this narrower vision of sustainability, isn't that better than science presenting no vision of sustainability at all?

We believe that incorporating this narrower vision of sustainability into the new standards for U.S. science education is an incomplete good—a step in the right direction, but one that carries the risk of real negative consequences for students and for society. We are encouraged by the growing focus on concrete sustainability challenges, which is an important improvement over past standards documents and curricula that focused almost entirely on understanding natural systems in the abstract (Gough, 2002). But we are concerned that taking the approach outlined in the NGSS would lead students to think of sustainability in the reduced terms of ecological modernization. If this happens, they may ultimately be less prepared to see the ethical and political dimensions of emerging sustainability challenges. Having completed multiple engineering-framed sustainability activities, each of which "reinforce[s] the notion that technology is a necessary part of society and that there is a techno-fix to many of societies' problems" (Pedretti & Nazir, 2011, p. 619), they may be more willing to believe that new technologies, without the need for sociopolitical change, hold the key to a more sustainable future. When they participate in debates or discussions about policy, they may be accustomed to thinking in the distinctly technocratic terms of universal solutions guided by scientific expertise and unprepared for the political realities of a pluralist, democratic society that must balance the needs of multiple groups and integrate science with other sources of knowledge to develop contextualized responses to sustainability challenges.

It is instructive to imagine how the NGSS' vision of sustainability might inform teaching and learning[11] about a particular topic such as climate change. On the basis of our analysis of the NGSS, we would expect climate change to be presented primarily in physical science terms as a geophysical phenomenon resulting from the changing chemical composition of the atmosphere. It would be described, emphatically, as a *global* issue, a framing subtly reinforced in the NGSS by its placement within earth and space sciences, where biological localities such as ecosystems are swapped out for geophysical averages of temperature and precipitation. Questions about climate change—how much, where, with what consequences—would be presented as questions that science can answer, and the scientific pursuit of these answers would be portrayed as apolitical. Students in our hypothetical classroom would learn about the relationship between human behavior and climate change in terms of the carbon cycle and the burning of fossil fuels, but they would probably not

[11] We recognize that the relationship between standards and classroom practice is not straightforward. Our aim here is simply to illustrate some of the possible consequences of constructing sustainability in this way, given that the NGSS offer teachers a particular way of reasoning about sustainability and will likely affect the representation of sustainability in the official curricula and assessments that will be made available to teachers nationwide.

be asked to think about who has historically burned and continues to burn the majority of the fuels and who, both across and within societies, is harmed most by the practice (e.g., Samson et al., 2011). Burning fossil fuels would probably be framed as something that humans (in general) do and that humans may, in turn, be affected by. Students and teachers would discuss the potential impacts of climate change in relatively precise geophysical terms (such as degrees of warming and meters of sea level rise) but very vague social terms. If students were asked to consider possible solutions, they would be encouraged to propose new technologies, changes in the balance of existing technologies, and regulatory regimes that aimed to change carbon consumption. Other sorts of change—including normative changes, social movements, or policy changes that *indirectly* influence climate—would receive little or no attention.

For most students in the United States, this would far exceed their current exposure to climate change. In that sense, the narrow vision of sustainability improves upon the status quo. On the other hand, students would emerge from their schooling unprepared for the social and ethical complexity of climate change. More confident in their grasp of the physical basis of climate change, they might still systematically misunderstand how our current social and political structures contribute to climate change and how cultural forces and values both embedded within and far beyond the scope of science shape political discourse about climate change mitigation and adaptation. Outside of the science classroom, some debates about climate change pivot on the historical role of the industrialized global North and the needs of the global South, as well as the responsibility of the comparatively less vulnerable to the more vulnerable (Hulme, 2009; Nixon, 2011). Although social equity is treated as a peripheral topic in science education, it is increasingly clear that a lack of material resources inhibits both climate change mitigation and adaptation and that policies addressing poverty should be an integral piece of the global climate change agenda (Parry, Canziani, Palutikof, van der Linden, & Hansen, 2007).

Students' preparedness to anticipate and weigh the human consequences of climate change would also be quite limited. Accustomed to thinking in universalist, global terms, they would be likely to underestimate both the profound cultural costs of climate change to indigenous groups and the disproportionate vulnerability of some geographic regions and demographic subgroups, even in wealthy countries such as the United States (Newell, 2005). Knowingly or not, their solutions would be grounded in what is palatable and comprehensible to them, and they would be likely to favor technological change over social and political change. Like many scientists, these students might be too quick to equate international and intranational resistance to new climate policies with climate change denial and scientific ignorance, rejecting or marginalizing accounts of climate change that originate from other disciplines and other cultural perspectives (Hulme, 2009). For example, they would be unprepared to engage with the critique posed by scientists at India's Centre for Science and the Environment who dispute the seemingly neutral category of "greenhouse gas emissions" and instead distinguish between "subsistence emissions" and "luxury emissions," with "the former generated by the poor to meet their basic needs, the latter produced through the needless consumption of the wealthy" (Jasanoff, 2004, p. 47). Unaccustomed to thinking of sustainability in ethical and social terms, they might be confused by opposition to policies that, for example, enable countries in the global North to maintain their current emissions levels by planting trees in the global South (Bäckstrand & Lövbrand, 2006). Without vivid, qualitative accounts grounded in local knowledge and more precise social analyses provided by other disciplines, students would continue to perceive the costs and consequences of climate change as abstract and remote.

Although climate change has a unique urgency, the narrow treatment of sustainability in the NGSS could lead to predictable misunderstandings across many other topics as well. For example, teaching and learning about agricultural biotechnology would probably focus on questions of health and environmental risk, missing the fact that much resistance to agricultural biotechnology is based on ethical and economic objections—in particular, how new technologies disproportionately benefit the wealthy and harm those who are already vulnerable (Priest, 2001). This, rather than any ignorance of science, explains why resistance often comes from communities whose social and cultural welfare is at risk, whether they are small producers who have historically kept a portion of their harvest for seed or entire nations who wish to preserve local ways of farming (e.g., Wynne, 1992). Here, as with climate change, students would emerge with a one-sided perspective on an important sustainability challenge.

Above and beyond the implications for any single topic of study, there is a definite irony in turning to science and technology for solutions to all sustainability problems. The push for sustainable development in the 1980s was a response to unchecked growth and its associated environmental and social harms (Dryzek, 2005; WCED, 1987). Both growth and harms were abetted (if not "caused" in any simple sense) by technological change. We owe our awareness of environmental and social harms to science (though certainly not to science exclusively). Yet science also abetted those harms in the first place, both by making us aware of earlier natural risks and by contributing to the development of new technologies (Beck, 1992). An overconfident reliance on science and technology seems to ignore this historical reality, threatening a return to the circular discourse of scientific and technological progress that contributed to current sustainability challenges. Although we cannot afford to ignore the tools that science and technology provide, a more cautious—what sociologists would call reflexive—approach is now required. In the words of Funtowicz et al. (1998), "we must now integrate the awareness that science-based interventions in complex natural processes can constitute, in themselves, a self-renewing source of problems that may jeopardize community livelihoods, health and future economic prospects" (p. 102).

BROADENING AND DEEPENING THE DIALOGUE

How can science education contribute to addressing the emerging challenges of sustainability without encouraging students to adopt the perspective of ecological modernization? Although we have critiqued the representation of sustainability in the NGSS, we do not think it would be fruitful to exclude consideration of sustainability challenges from science education altogether. Science and technology may be insufficient for addressing many of these challenges, but that does not mean they are unnecessary. Scientific knowledge is, and is likely to remain, an important part of public debates and policy decisions on sustainability. School-based science education still reaches a larger and broader audience than any other science education platform. It is many children's first and best chance to learn about the role of science in public life. Omitting the topic of sustainability entirely would be more troubling than including it, even in the limited form adopted by the NGSS.

One alternative is to reconstruct science education so that it is capable of addressing the social and ethical dimensions of sustainability and of weighing the contributions of science alongside other ways of knowing. An international group of science education reformers including Jenkins (1994), Gough (2002), Aikenhead (2006), Carter (2008), Calabrese Barton (2001), and Colucci-Gray et al. (2006) have argued for this course of action. Drawing on science and technology studies (e.g., Haraway, 1991), sociology (e.g., Turnbull, 1997), and science policy research (e.g., Funtowicz & Strand, 2007), these scholars advocate for a more pluralistic and socially engaged type of science education that

> would include an understanding of networks and systems both natural and social, ecological knowledge, futures, permaculture design, and energy studies, along with the more traditional concepts of science. It would work with social groups so that students could engage in real science-based problems located in their local community or in the cyber community. (Carter, 2008, p. 173)

Many of these scholars have gone beyond advocacy, working with schools and teachers to put their ideals into practice (Colucci-Gray et al., 2006; Pedretti & Nazir, 2011). Their work provides compelling evidence that different forms of science education are possible, but it also highlights numerous challenges facing educators who wish to enact an alternative vision of science and sustainability education. Some, such as Gruenewald (2005) and Buxton (2010), point to the constraints of test-based accountability. Others describe the difficulty of overturning longstanding educational narratives that represent science in artificially simple ways (Jenkins, 2007, 2013). For example, Ashley (2000) described how the National Curriculum of England and Wales "promoted the notion of science as the ultimate authority" (p. 271) in a way that was out of keeping with the more tempered view of scientists who are themselves "far more realistic about risk, uncertainty and the limits of science" (p. 271). Gough (2002), analyzing the Australian educational system, summed up the situation by observing that "while there have been changes to the rhetoric of science education . . . there have been and continue to be powerful forces resisting [these] types of changes" (p. 1205). In short, obstacles to wholesale transformation of science education are many and formidable. Even if such transformation is our long-term goal, it is worth asking what else can be done while we work toward that goal.

A second alternative would be for science education to approach sustainability in equal partnership with other disciplines. Because the NGSS are explicitly interdisciplinary (within the STEM disciplines) and make some connections with standards documents from other subjects, it is important to clarify how this alternative is any different. As we have discussed above, the NGSS convey a marked ambivalence toward non-STEM disciplines, implying that their contributions to the problems of sustainability are minor contextual factors that can, at best, be shoehorned into an engineering analysis of costs and benefits after the central scientific work has been completed. The need for epistemological compatibility with science (e.g., to produce knowledge that fits into a computational simulation or cost–benefit calculation) suppresses many of the distinguishing features of other disciplines. For science education to contribute to a socially and ethically rich version of sustainability, science educators must prioritize complementarity over compatibility. This does not mean that the NGSS should attempt to do the work of all disciplines, but it does mean that the standards, and the educators who use them, should acknowledge that sustainability is a challenge that cuts across many fields and draw attention to the places where sustainability poses questions that science cannot answer. Indeed, they must deliberately identify the fields of education that approach knowledge and decision making in very different ways. This means that the familiar partnership of the STEM disciplines is not enough. Engineers and mathematicians bring their own approaches to sustainability, but they are not, in Lucas's (1980) words, "historians, aestheticians, political scientists, and economists" (p. 8).

We believe that a promising way for science education to address sustainability is through systematic collaboration with social studies education. Here, we strongly agree with the *Framework for K-12 Science Education*, whose authors argued that

> Applications of natural sciences and engineering to address important global issues—such as climate change, the production and distribution of food, the supply of water, and population growth—require knowledge from the social sciences about social systems,

> cultures, and economics; societal decisions about the advancement of science also require a knowledge of ethics. (NRC, 2012, p. 306)[12]

Science education has developed its own disciplinary strategies for incorporating moral reasoning (e.g., Zeidler, 2005) and examining the social repercussions of science and technology (e.g., Pedretti & Nazir, 2011), but in most places these strategies remain marginal—alternative pedagogies that stretch the current cultural norms and institutional priorities of science education. In contrast, social studies education prioritizes topics such as the framing of policy, the cultural significance of place, the legitimacy of competing perspectives, and questions of social justice (National Council for the Social Studies, 2013). Furthermore, pedagogies of discussion and debate in the social studies are more finely attuned to controversy and civic decision making. Crocco, Mari, and Chandler (2013) point out that "the issues-oriented pedagogical approaches that have been prominent within social studies are ideally suited to addressing questions" related to sustainability (p. 170). Hess (2009), in particular, provides a nuanced analysis of pedagogical approaches to controversy that are of obvious value for many sustainability-related topics.

Even a cursory examination of standards documents reveals many places where the sustainability-related work of social studies educators has the potential to connect with and enrich that of science educators. For example, the newly released *C3 Framework for Social Studies* asks students to "[e]valuate how political and economic decisions throughout time have influenced cultural and environmental characteristics of various places and regions" (National Council for the Social Studies, 2013); an earlier iteration (National Council for the Social Studies, 2010) suggests that students consider how "science, technology, and their consequences are unevenly available across the globe" (p. 151) and grapple with "the different interpretations of the benefits and problems associated with the interactions of humans with the environment" (p. 133). In our home state, the social studies standards dictate that students should "analyze and illustrate the ways in which the unequal global distribution of natural resources influences trade and shapes economic patterns" (Wisconsin Department of Public Instruction, 1998). These learning objectives overlap with topics in the NGSS, but approach them from a perspective that is markedly different—different enough to challenge the epistemological tendencies of science and to complement them. We agree with the National Council for the Social Studies (2013) that

> a contemporary environmental question such as "What path should a new transcontinental pipeline take?" or "Should the pipeline be built at all?" demands the use of economic, historical, and civic as well as spatial concepts and tools. (p. 18)

Clearly, these questions can be informed by STEM fields as well. It is our position that an adequate treatment of sustainability challenges would require collaboration between educators in the two fields.

Because collaboration is a vague idea, it is worth specifying what sort of collaboration we are advocating. First, some might interpret "interdisciplinary collaboration" to mean that science educators should look to the social studies for inspiration, co-opting a few topics or pedagogical strategies and otherwise carrying on as normal. Without significant changes to teacher education, it seems unlikely that science teachers will be given the supports needed to develop this repertoire of discursive practices from the social studies, or

[12] Although the NRC *Framework* was used to guide the development of the NGSS, this particular admonition to collaborate across disciplinary lines is not present in the NGSS; the document intended to guide curriculum, instruction, and assessment.

that civic, historical, and social scientific content would receive a sufficiently compelling treatment. Science teachers might also unintentionally reinforce the idea that the natural sciences and engineering are rigorous and concrete whereas the social sciences and political processes are chaotic and irrational (Lucas, 1980).

Second, we do not think it is sufficient for science and social studies to address sustainability separately and in parallel. This path, which follows the rhetoric of "alignment across the curriculum," is far easier than creating the conditions for coordinated action across classes, schedules, and departments. Unfortunately, it also increases the likelihood that students will perceive sustainability challenges as divided into two categories, some belonging in science and others in social studies. Even if science and social studies teachers cover the same topics with the same degree of emphasis, the separation between classes may give students the impression that scientific and social processes take place separately and do not affect each other except in the final stages of policy formation. In reality, the combined effects of scientific uncertainty and social urgency bring science and politics together early and often, particularly when questions of sustainability are at stake (Funtowicz & Ravetz, 1993); indeed, sustainability scholars argue that social and environmental concerns are often inextricably linked (Agyeman et al., 2003; Kates et al., 2001).

To bring science and social studies together to offer students an adequate preparation for engaging with sustainability challenges, we believe that teachers from both fields should collaborate on the planning, design, and implementation of lessons that address critical sustainability topics. Project-based learning offers one promising setting for this type of collaboration, particularly when school schedules enable science and social studies teachers to work with the same set of students, developing complex understandings over time. Of course, the integration of curriculum and pedagogy across disciplinary lines is profoundly challenging (Grossman, Wineburg, & Woolworth, 2001), but when the structures of schooling make it impossible to actually share responsibility for these lessons, science and social studies teachers might still help each other learn their respective pedagogical strategies and deepen their understanding of different disciplinary perspectives on issues of shared concern. The fruits of their coplanning could then be embedded in existing science and social studies classes, including increasingly common environmental science elective courses.

If we look beyond K-12 education, there is ample precedent for science educators working with educators in the humanities and social sciences in pursuit of sustainability. In higher education, this sort of multi- and interdisciplinary collaboration has become a common feature of schoolwide sustainability initiatives (Jones, Selby, & Sterling, 2010). Environmental educators, who wrestle with some of the same issues outlined here, often describe their work as innately interdisciplinary, and environmental education has thrived in informal contexts (e.g., Stapp et al., 1969; Dillon & Scott, 2002; Dillon, 2003).[13] We recognize that higher education and informal education are far less constrained than K-12 education, and we are not naïve about the difficulty of the approach we propose (e.g., Grossman et al., 2001; Meister & Nolan, 2001). Yet we are convinced that there is a particular urgency, and a particular value, in seeking collaboration across disciplines within the K-12 system.

[13] Though others have argued that environmental education (EE) must forge an a-disciplinary identity, independent of the academic disciplines. For more on the inter-, multi-, or a-disciplinarity of EE, see Lucas (1977, 1980).

CONCLUSION

In this essay, we have argued that the NGSS portray sustainability as a set of global problems that affect all humans equally and can be solved through appropriate application of science and technology. This vision of sustainability, which reflects a broader cultural narrative of ecological modernization, obscures the ethical and social complexity of sustainability challenges. It hides the fact that some humans are more responsible for environmental degradation, some humans have benefitted more from environmental degradation, some have had more opportunities to participate in decision making about socioenvironmental issues, and some have suffered more from their consequences. It offers a limited, secondary role to the knowledge produced by non-STEM disciplines and makes almost no mention of locally and culturally situated understandings. Finally, it glosses over the unavoidable reality of democratic societies—that any truly significant sustainability issue will be the focus of incompatible perspectives that cannot be accounted for in cost–benefit analyses like those the NGSS repeatedly recommend. It is true that the NGSS are firmly embedded in the U.S. educational context and that other countries may approach the relationship between sustainability and science education differently. In our analysis, however, we have shown that the treatment of sustainability in the NGSS reflects broader trends in how many scientists use and define sustainability internationally, which makes it more likely that science education in other countries' systems will also tilt toward this narrower vision of sustainability.

There are real risks in approaching sustainability this way—risks that cannot be avoided by integrating more technology, mathematics, and engineering into the science curriculum. In our view, one promising way to avoid these risks is for science education and social studies education to seek new partnerships, addressing sustainability through curricular and pedagogical collaboration that combines the indispensible strengths of both fields. We are aware of the practical and structural difficulties that stand in the way of such collaboration, but we think it is worth pursuing, particularly in places where a wholesale reconstruction of both the science curriculum and the infrastructure of science teacher education is not yet conceivable. As difficult as it may be, combining the efforts of science and social studies educators may be the best way to provide students with realistic and powerful preparation for the sustainability challenges that their generation will face.

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