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FORUM

On the road to science education for sustainability?

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Abstract In this paper I discuss three issues relevant to the ideas introduced by Colucci-Gray, Perazzone, Dodman and Camino (2012) in their three-part paper on epistemological reflections and educational practice for science education for sustainability: (1) social studies of science for science education, (2) education for sustainability or sustainable development, and (3) curriculum studies and action-research. For the first issue, I address the need for science education efforts dedicated to an epistemological renewal to take seriously into consideration the contributions of the social studies of science. This perspective may be fruitful for an education for sustainability that also requires one to consider the political dimension of environmental issues and their intrinsic power relationships. It also encourages the abandonment of dichotomies that hamper democratic participation: experts/lay people, science/society, scientific knowledge/values, etc. For the second issue, my commentary focuses on the challenges that education for sustainability or sustainable development pose to science education with a shift from subject matter contents to socio-educative aims and socio-political actions. These challenges lead to the third issue with an invitation to apprehend science education for sustainability within the frameworks of curriculum theory and design-based research.

Keywords Curriculum · Sustainability · Sustainable development · Social studies of science

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This review essay addresses issues raised in Laura Colucci-Gray, Anna Perazzone, Martin Dodman and Elena Camino's paper entitled: Science Education for sustainability: Epistemological reflections and educational practices: From Natural Science to trans-disciplinarity: *Cultural Studies of Science Education*. doi:10.1007/s11422-012-9405-3.

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Social studies of science for an epistemological renewal in science education

Philosophers, sociologists, and historians of science adopt different positions on science and scientific knowledge. In the last 30 years, studies of science have increasingly highlighted the variety and local contingency of scientific practices, away from the idea of a single scientific method approach or universal method. *Science studies* (or *Social Studies of Science*) emphasize the social dimension of knowledge production. For those who abide to this movement, science and society cannot be considered as separate universes; on the contrary, they mutually interact and are interdependent. Science and society are co-built: science is constitutive of and creates society (Hacking 1999). It is then essential to understand science as practices in various places and not to seek to identify it with a unique essence or nature of science. Social studies of science consider science to be an institution and not just knowledge, "as a set of practices […] and not just as a conceptual whole" (Pestre 2006, p. 3). This has contributed to the dissolution of the entity *science*, the deconstruction of a singular essence of science, and its de-idealization and conceptualization as diverse practices located in social activities and plural relationships in response to a variety of purposes. Science is no longer driven from within, it is no longer a "field" with unified rules of operation whose principles are simple—science is industrial technology here, political action or management there, fundamental research, reductionist activity or modeling elsewhere. Science changes over time, it is local in its determinations and methods of proof. In short, science has no essence (Pestre 2006, p. 6).

The major contribution of science studies over the last 30 years has been to make science a historical object, thus abandoning the idea of an essence of science to one that analyzes, understands and thinks about diversity and practices of science. Research in sociology of science questions the myth of the possibility of objective knowledge. The definition of scientific knowledge as an adequate measure of an empirical reality that is external to the knower is no longer admissible (Pickering 1984). It is no longer possible to consider the knowing subject and its object of knowledge as independent of one another. Rather it is important to grasp the social and cognitive arrangements that are inextricably developed, translated, adapted and transformed by the actors (Latour and Woolgar 1986). These studies of science have shown that the validity of a scientific statement is measured by the stability of its acceptance by other researchers. In other words, knowledge is established because scientists have worked to its stabilization. Different communities structure the knowledge that they are interested in a network of relationships and socio-political context [actor-network theory (Callon 1986)]. Science is depicted in this framework as a social practice, a cultural activity, an institution historically designed to carry out projects of a certain type of society. These projects can be socio-technical innovations: for example, long distance shipping to own new territories and new people in the seventeenth century, thermal engines and industrial development in the eighteenth century, nuclear power and bomb since WW2, etc. Their technoscientific complexity is (re)defined and (re)constructed in society.

One consequence of these sociological studies is that the idea of knowledge as "socially constructed" has become widespread and has caused great controversy. Thus, the work of the "new" sociology of science goes against the strong ordinary scientism of certain scholars who insist that science reveals the truth of things. An arrogant science that pretends to speak the real can only lead to a submission to the facts. We get the science that we have not made nor (re)discovered by ourselves from our fathers (and our mothers, as would add the tenants of feminist approaches), "but this does not imply a passive attitude

to exempt thinking" (Canguilhem 1971, p. 177). Within each situation, there is a plurality of choices and "the search for truth is a choice that does not exclude its opposite" (p. 177).

The social studies of science have attempted to undermine the positions of authority that science tend to occupy in society and has called for the recognition of the limits of the scientific status (Collins 1985). The idea is "that no God is in science (that is to say that we enunciate, at best, incomplete and partial truths) and that no one escapes his/her condition to be finite (we try to say the truth and to transcend our condition, but never be fully successful)" (Pestre 2006, p. 21). In addition, they have enriched our ways of seeing science by moving our eyes away from a science focused on an issue to a broader vision of practices involving heterogeneous dynamics in the whole of society. Pestre (2006) notes that

> What we put under the term 'science' is by no means an 'object' focused and stable over time that it would be simple to describe (science as a coherent system of statements, science as an activity of knowledge). Science (or should we say the 'practices of science' or 'practices involving science'?) is made of a very wide range of relationships that involve issues of definitions and stakes that vary depending on the individuals; productions of all kinds - from the writings, numbers, techniques; practices instrumental, computational, simulation-; values and standards - epistemological, moral, behavioral-; institutional realities - laboratories, start-ups, engineering schools; modes of political integration and sociability - the living room of Charcot, the group of amateurs, the professional corporation - and many more. (p. 104)

These approaches of science studies that I have briefly provided here invite the reader to consider science as heterogeneous practices in society. This has implications for science education, and particularly for the integration in the scientific curriculum of socio-environmental issues. As highlighted by Colucci-Gray, Perazzone, Dodman and Camino (2012) in parts 1 and 2 of their article, the development of an action-research agenda to address today's environmental emergencies needs the theoretical basis of the "conceptual changes characterizing the nature of science-society interactions". The authors provided clear and convincing arguments against traditional approaches to science learning and teaching that continue to promote and consolidate a positivistic and reductionist idea of science aimed towards control and domination of nature. As an alternative, they proposed a framework for an "epistemology of science education that enables constructive, dialogical processes between actors in the global era". This framework for a science education dedicated to sustainability implies "changes in subject-object relationship, modifications of contents and methodological choices, and changes of aims". A major epistemological reference to this framework is the idea of post-normal science (Funtowicz 2001) based on "two crucial properties of complex systems: radical uncertainty and the plurality of legitimate perspectives". According to Colucci-Gray et al. (2012) post-normal science is "appropriate for dealing with situations in which facts are uncertain, value are in conflict, the stakes are high and there is a need for urgent decisions. Such methodology is founded upon the process of "open dialogue" amongst all relevant stakeholders, that is all the people who have the right to participate (as they are involved in the problem) and who express the desire to be involved in finding a solution." Public dialogue is offered in this perspective as a "creative decision-making process involving experts from different disciplines as well as citizens and lay people carrying their own practical knowledge. The process of knowledge-construction is equated to a process of dialogue in which participants share a variety of perspectives, languages, interpretations, in a concrete practice of

participatory democracy". Expanding on these ideas introduced in the original paper, I would like to focus my argument now on the political dimension of the issues opened to public dialogue and the power relationships implied in this dialogue, all in light of the considerations of science in society provided by the social studies of science.

In public debates or participatory democracy, the involvement of "experts" and 'non-experts' or 'lay-people' in the debate about socio-environmental issues may reproduce the division between "those who know" (experts) and "those who don't" (non-experts) if insufficient attention is paid to the unequal distribution of power in such contexts. It constitutes an ironic vision of politics to consider democracy as a dialogical process in which all stakeholders of an issue may equally debate to reach a collectively shared decision. Colucci-Gray et al. (2012) underlined their epistemological standpoint that "science can no longer be conceived a neutral body of knowledge but it is referred as a crucial element in the organization of human societies, developing at the intersection of power relationships and driven by the pursuit of aims connected to specific interests". In the same vein, paraphrasing the authors, politics in a democracy cannot be conceived as a smooth chain of events elaborated within a peaceful process, but it is referred as a crucial element in the organization of human societies, developed at the intersection of power relationships and driven by the pursuit of specific interests. Conflicts will necessarily arise between diverse interests and values of the stakeholders on a socio-environmental issue. Therefore, these power relationships have to be seriously taken into account when integrating in-class discussions about socio-environmental issues.

The various stakes and political choices and their consequences in/for society have to be understood explicitly. For instance, which sources of energy to choose? Which modes of energy production and consumption to privilege? What kind of pollutions generated by the various modes?… Asking those questions focuses on the political dimension of socio-environmental issues and the various interests of concerned groups (electrical companies, environmentalists, consumers, etc.). From this perspective, as Colucci-Gray et al. (2012) stated, "environmental emergencies and the close interrelationships between techno-science, economics and social transformations constitute key drivers for rethinking our culture and, more specifically, the aims, strategies and content of science education."

Another perspective would consist of privileging the ethical dimension of socio-environmental issues, where the Earth is considered a moral entity so that one might wonder whether it has become sacred, replacing a mythical holy science as promising progress. As Colucci-Gray et al. (2012) underlined, we need to prevent ourselves from "thingifying" nature to keep open the stakes of socio-environmental issues. These stakes are differently apprehended by various stakeholders and have to be discussed in class rather than being imposed as obvious and consensual observation. Doing so, an education for sustainability also poses the question of the best type of development aimed for sustainability.

Challenges of education for sustainability or sustainable development

Education for sustainability or sustainable development does not define an object of teaching but a goal. It can be a social analysis of environmental issues, socio-political actions, a behavior change, or change of worldviews away from the myth of progress. As underlined by Colucci-Gray et al. (2012), the educational system is still characterized by a disciplinary approach to knowledge. A crucial question then arises: How can education for sustainability or sustainable development be introduced into the curriculum?

Colucci-Gray et al. (2012) suggest an inter or trans-disciplinary approach of conceptual tools for education for sustainability. In this regard, part 3 of the article presents an empirical study focusing on disciplinary and meta-disciplinary concepts that "allow students to make links across the different topics of the Life Sciences" Beginning with the disciplinary contents of biology, this section discusses the difficulties and risks associated with the socio-educative aim to educate to sustainability or sustainable development.

Firstly, how are social issues considered within the disciplines? Answering this question can draw a line between disciplines, across scientific disciplines and educative activities dedicated to education (i.e. health education, environmental education, education for sustainable development), and between the different activities according to their educational goals. The answer "no consideration of social issues" is likely to fit those subject matters or activities (disciplinary or otherwise) operating according to the following four principles [4R model of Audigier (1993)]: teaching of Results, to establish stable and consensual References, within a Realist approach and a Rejection of political dimensions.

Secondly, addressing education for sustainability from the biological science discipline comprises the risk of operating a drawdown on conceptual contents or topics (climate, water, energy, etc.). The case of climate seems emblematic in this regard: often seen as a thematic choice for education for sustainable development it can be presented in class as a result of a consensus and not as a controversial topic involving various types of knowledge (Albe and Gombert 2012). What is therefore the educational purpose of promoting an in-class discussion of a topic if presented as stabilized (i.e. non-controversial)? Teaching? Instruction? Enforcement? A scientific discipline-based approach to a socio-scientific or socio-environmental controversy would be both a betrayal of the goals of science education research and the scientific disciplines themselves. It generates difficulties for the scientific disciplines, making them to pretend to address issues they are not used to deal with. It is an impossible task that may destabilize them, which also generate discomfort for science teachers since it creates an unbearable tension between instruction to stabilized and uncontroversial contents and social issues for which in the political register different groups have different interests. The great debate, the major issue for science education, is indeed that of the potential contributions of scientific disciplines to education for sustainability or sustainable development. It is addressed in the next section.

Theoretical and practical principles for science education for sustainability

This debate of the potential contributions of scientific disciplines constitutes an invitation to apprehend science education for sustainability within a broader focus than a disciplinary, inter or trans-disciplinary one. The framework of curriculum theory and design appears to me as a potentially fruitful way to address this debate.

Any curriculum is primarily a political, economic, institutional object (Ross 2000) prior to the teaching of contents. The education to sustainability and today's concerns of "environmental emergencies and the close interrelationships between techno-science, economics and social transformations" [Colucci-Gray et al. (2012)] leads to take into consideration the interplay of knowledge, curriculum and power. Scholars such as Young (2007), Bernstein (1971), Bourdieu (1989), among others, have brought to the fore that curriculum planners need to consider both the context in which they finds themselves and the intellectual traditions they uphold. Mobilizing curriculum theory might help for a more open-ended clarification of the principles and social organization on which the science education curriculum for sustainability is or would be based.

Dewey's work may also be a source to think a science education curriculum for sustainability or sustainable development, as the aim of curriculum is emancipation or empowerment. Dewey (1938/1997) considered that curriculum should ultimately produce students who would be able to deal effectively with the modern world. Therefore, curriculum should not be presented as a set of abstractions, but should include the subject's preconceptions and his or her world views, an idea consistent with the proposals of Colucci-Gray et al. (2012).

Curriculum design is also an approach that can be explored to discuss possibilities and constraints of science education for sustainability. Expanding on the activities of action-research presented by Colucci-Gray et al. (2012), I would propose to adopt the framework of the design-based research methodology (Cobb, Confrey, Di Dessa, Lehrer, and Schauble 2003). In this framework, the development and implementation of activities to educate for sustainability or sustainable development follow a double perspective: interventionist and analytical. Design experiments are theory-oriented tests to develop domain specific theories by studying both students' learning and the means designed to support that learning. These theories, developed during an iterative design process featuring cycles of intervention and revision, are humble in the sense that they target domain-specific learning processes, but also because they are accountable to the activity of design. Ideally, design experiments provide a greater understanding of a *learning ecology* (Cobb et al. 2003):

> We use the metaphor of an ecology to emphasize that designed contexts are conceptualized as interacting systems rather than as either a collection of activities or a list of separate factors that influence learning. Beyond just creating designs that are effective and that can sometimes be affected by "tinkering to perfection," a design theory explains why designs work and suggests how they may be adapted to new circumstances. (p. 9).

A learning ecology can be considered as a complex interacting system involving multiple elements. These elements include the problems that students are asked to solve, the kinds of discourse that are encouraged, the norms of participation that are established, the tools and related material means provided, and the practical means by which classroom teachers can orchestrate relations among these elements (Cobb et al. 2003). A theory-oriented initial design is developed as a conjecture about the means of supporting a particular form of learning that is to be tested. According to the design-based research principles, a model elaboration is the first phase of the research. This test is theory-driven within a model, which is humble, local and contingent, and would be revised along an iterative process. The aim is to create a small-scale version of a learning ecology so that it can be studied in depth and detail (Steffe and Thompson 2000). Design elaboration focuses on the kinds of discourse that are encouraged and the norms of participation that are established (Cobb et al. 2003).

In this context, regular debriefing and planning sessions with researchers and practitioners serve as the forum in which past events are interpreted and prospective events are planned. These sessions are the sites where the intelligence of the study is generated and communicated (Cobb et al. 2003). Ultimately, the research team assumes responsibility for instruction during classroom experiments (Confrey and Lachance 2000). Thus, a learning ecology of science education for sustainability may be fruitful to document the potential interrelations of science education, environmental education, in their disciplinary, inter or trans-disciplinary forms, and curricular forms.

Conclusion

The article by Colucci-Gray et al. (2012) offers to see in details the complexity of epistemological, theoretical and methodological dimensions of science education for sustainability. Here, I have touched upon a number of issues grounded in science education, sociology of education, sociology, history and philosophy of science in a way that can only be superficial. The intention was not to treat them in some details but to show how these disciplines can be brought together to explore the complex issues related to education for sustainability or sustainable development. I have briefly examined the implications for science education to adopt an epistemological basis grounded in social studies of science. The consideration of science in society might help to apprehend political dimensions of socio-environmental issues and power relationships related to the diverse interests involved. Much deeper exploration remains to be performed with regards to how this could be achieved in class. I have also briefly explored the challenges of education for sustainability or sustainable development to stimulate a discussion about the theoretical and practical principles that would be most appropriate for science education for sustainability, an issue that requires much examination in the near future.

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