Visions for Sustainability

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Vision without action is useless.
But action without vision
is directionless and feeble.
Vision is absolutely necessary
to guide and motivate.
(Donella Meadows)

Interactions between different logical levels
produce phenomena unseen at either level.
(Gregory Bateson)

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Global Issues and Events. Relationships, Understanding and Actions at Individual and Community Levels

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The period between the two solstices of 2016 and the fifth and sixth issues of *Visions for Sustainability* has witnessed some events of considerable global significance. The 'Paris agreement' - a formal convention that followed COP 21 - has been either signed or ratified by 116 out of 197 party states. In the meantime, the 28th Meeting of the Parties (MOP 28) held in Kigali (Rwanda) on October 8-14 2016 will probably emerge as one of the most important international agreements on banning a single category of substances, that of ozone depleting chemicals.

In the same period, however, other events have given cause for considerable concern. Data provided by the network of weather stations around the world registered global temperatures in 2016 as the highest ever recorded, further highlighting the urgency of acting to reverse this trend. At the same time, the election of Donald Trump as president of the United States has regrettably confirmed that country's lack of desire to assume a guiding role in the search for solutions to global environmental problems. Indeed, no country seems to be willing to play such a role, while, unfortunately, there are many, including the United States themselves, that vie with each other for geo-political dominance.

This does not mean that even an apparently favourable result in any presidential election could ever be sufficient to bring about rapid change and put humanity on a more sustainable pathway within the perennial tangle of conflicting interests in the political, economic and military spheres. Nonetheless, a certain degree of anxiety concerning the worsening of the current situation inevitably involves the moves of the next US president on environmental issues and the first signals are not encouraging. It appears that the NASA Earth Sciences Division is likely to see its funding cut in favour of space exploration. The President-elect had in fact set a goal during his presidential campaign to explore the entire solar system by the end of the century.

As often happens with the great majority of political elections, it is hard to identify specific reasons why voters decided as they did, which parts of the political programs they paid more attention to, and how they evaluated their potentially beneficial and detrimental effects in terms of the outcomes they foresaw. It is difficult to assess the importance that voters of Donald Trump gave to his anti-environmental positon, for example, his refusal to accept scientific evidence of anthropogenic climate change. While his stance might seem to us a good enough reason to vote for his opponent, it is clear that climate and environmental protection are top issues neither in his political agenda nor in the minds of those Americans who voted for him.

As always, the current issue of *Visions* offers a diverse set of papers concerning the centrality of sustainability for every aspect of the human enterprise. Each of the various contributions deals with a particular dimension of the global issues involved, concerning relationships and actions at the level of the lives of individuals or small communities, dealing with changes and choices, ethical and emotional attitudes, ways of being expressed through the interaction of genetics and socio-environmental contexts. At this micro-level it is possible to counteract the strategies adopted at the macro-level within the dimensions of politics as the exercise of power and Earth system governance. Forces operating in this macro-sphere may influence voters' choices and citizens' behaviour in the short term, but their outcomes in the longer period are more difficult to predict. In many cases, unforeseen consequences take place in such complex systems involving both individuals and communities.

We frequently risk losing awareness of what happens beyond our sight and what may happen as a result of our political and economic choices. The challenge we always face is to act with an eye to the biosphere and its myriad and multifaceted manifestations in order to pursue sustainable life trajectories, to become aware of what we lose as individuals and communities through risking a progressive detachment from nature and its living systems, its expressions and transformations, which by far transcend us. Each paper proposes a perspective which aims to help overcome the sense of anxiety, helplessness and confusion caused by macro-events and the temptation to give up, discouraged by the mainstream flows of media manipulation, and offers ways of understanding and acting directed towards the fulfilment of our fundamental needs, such as nourishment and wellbeing, developing contact with our inner and mysterious complexity, cooperating with other living beings, developing autonomy and assuming responsibility, as summarised by the Gandhian concept of *Swaraj*.

In "Life, Labor, and Value. Recreating Affective Food Ecologies Through Interspecies Cooperation", Jeffrey Baldwin explores affective ecologies within the field of of food and agriculture. He examines the concept of value in terms of the biosphere as a whole and the way in which life often produces value by finding usefulness in the by-products of other lives. The paper then proposes an idea of ecological relationships as guided by the creation of abundance and shows how cooperation can produce value synergistically and provide a basis for a socio-natural trajectory, creating more affective food ecologies.

In "Looking Back and Moving Sideways: Following the Gandhian Approach as the Underlying Thread for a Sustainable Science and Education", Laura Colucci-Gray and Elena Camino adopt the principles of Gandhi's *Sarvodaya*, or benefit for all, as guiding tools for reviewing models of knowledge and ways of learning. Gandhi's' principles point to nonviolence in human relationships with living and non-living entities. Nonviolence is the key principle for an education which promotes awareness of interdependence and the close linkages between ecology and equity.

In "Biophilia as Emotion", Giuseppe Barbiero and Chiara Marconato examine biophilia and biophobia in the context of the child's emotional development. Their conclusion is that the biophilic emotion constitutes a fundamental resource available to all human beings who are aware of their dependence upon the natural processes of this world, from which each of us draws physical, psychological and spiritual nourishment.

In "Researching the Sustainability of Teacher Professional Development", Martin Dodman explores the relationships within and between learning environments and professional profiles. He links the concepts of autopoiesis, organization and structure as a model for analysing these relationships together with those of resilience, transformability and force-field analysis as a way of investigating the sustainability of change and consequent development in individuals and communities.

In his review of Sam Kean's book, *The Violinist's Thumb,* Enzo Ferrara illustrates how vibrant storytelling can make science entertaining. The title of the book refers to Niccolò Paganini, the Italian musician whose genic shift caused him to have exceptionally flexible fingers, which both made him a master of violin and also caused pain because of the deformation of his joints. Kean blends the human histories of scientists, artists, athletes and nuclear bomb survivors with explorations of DNA, making accessible to readers the complex biological mechanisms ruling the building blocks of life and rendering science more sustainable for all.

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Life, Labor, and Value. Recreating Affective Food Ecologies Through Interspecies Cooperation

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Abstract.
As our most complex and intimate relationship with wider environments, food and agriculture provide important opportunities for exploring affective ecologies. Here I re-visit some of the ways that Modern constructs of humans as radically different from environments and of value as a function of exchange work to produce agricultural systems that are ever less affective and more problematic. In an effort to construct value in a way more applicable to the whole of our biosphere, and not only to humans, I take up an explicitly non-Modern Heraclitean perspective which conceives of all life as essentially relational. I then extend Marx's anthropocentric work to argue that all life labors to organize stocks and flows in environments which it finds useful and thus valuable. As co-adaptation illustrates, often produces value by finding usefulness in the by-products of other lives. Thus, we may understand ecological relationships as guided by the creation of abundance rather than the imposition of scarcity. From the Marxist tradition I then enlist the concepts of cooperation, which produces value synergistically, and exploitation which destroys the ability to create value, to suggest a basis for the evaluation of socio-natural trajectories, for creating more and less affective food ecologies.

Keywords: co-adaptation, mutualism, exploitation, naturalist intelligence, non-human agency

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Introduction

When deciding whether to buy produce at a farmers' market, consumers often balance two competing interests. The food is more expensive than conventionally grown produce, but it also seems better, for our health, or our environment, or for the nice people working at the market. Probably without knowing it, those who face this tension embody two dominant senses of value (Graeber 2001). A social/ethical sense of value addresses what is right, what is appropriate, what we ought to do in our interactions as individuals and as groups (Baldwin 2013). An economic sense of value focuses upon what we are willing to give to get the thing we desire is measured in dollars and operationalized in price driven markets. This sense also dominates global economies and neo-liberal governance.

On a global scale, this monetized sense of value has produced a food market which fails consumers, fails environments, and fails farmers and their communities. In the US, about 16 million people are malnourished. Another 33 million suffer from food insecurity (USDA 2014) in part because they cannot access the market, they do not have what economists call "effective demand", they do not have enough money. Worldwide, about 800 million people are under-nourished (FAO 2015b), the number of people living with insecure access to food, without enough cash to "enter the market" is far higher. It is important to note that malnourishment is not necessarily undernourishment. Over the past 40 years, agri-business firms have developed ever cheaper and more available products that threaten the health of the consumer. In 1911, beginning with the original Crisco, rich in trans fats – now due to be banned in the US – and progressing to ever more ready-to-eat foods made attractive with fats, salt, and sugar and more recently corn syrup, corporate prepared food is catalyzing epidemics in diabetes. Globally, adult type II diabetes rate is projected to increase from 2.8% (171 million cases) in 2000 to 4.4% (366 million cases) in 2030 (Shaw, Sicree, and Zimmet 2010). Adult obesity rates (BMI ≥30 kg/height in m^2) doubled from 5% of men and 8% of women in 1980 to 11% and 15% respectively in 2014 (WHO 2015; also Guthman 2011).

Modern agriculture is taking a toll on our environment as well. Driven by a moral sense of what was right and good, following World War II the United Nations along with the Ford and Rockefeller foundations, and several universities worked together to meet the needs of a rapidly expanding human population. The resultant green revolution operated through several technologies that have since degraded our biosphere. On the heels of war driven research into petroleum based chemicals, the green revolution promoted chemical fertilizers and a growing retinue of petroleum based "cides" (insecti, herbi, fungi). As Rachel Carson dramatically brought to light in *Silent Spring* (1962), these toxins degrade the health of plants and animals, including humans and especially field workers (Guthman 2004). As importantly here, these toxins have also widely degraded the soil communities that, through their life activity, make the nutrients in dead plant matter and animal waste available to plants. As a result, Modern farmers are dependent upon petroleum based fertilizers, much of which flows off fields, into streams, and causes algal over-growth and resultant hypoxic dead zones near estuaries, some of the most biotically productive and diverse areas of our biosphere. Combined with energy intensive large irrigation works, the unintended legacies of Modern farming are soil erosion, salinization, and the intentional sterilization of once vibrant fields (Brown 2012).

The green revolution and its agri-business successor have also failed farmers. First, agricultural development experts have promoted mechanization, powered by fossil fuels. As a result, fewer people are needed, i.e. can be employed in farming. New seeds have also worked to disempower farmers. Green revolution research into wheat and then corn

at CIMMYT in Mexico and at the International Rice Research Institute in the Philippines, and at public universities in other states produced high-yielding varieties of wheat and then rice and corn and then for other staple crops. Experts then taught farmers how to use these new seeds in coordination with petroleum based fertilizers to raise yields. Farmers were taught to plant extensive areas with a single strain, a technique which invited pest infestations requiring ever more pesticide application. These seeds replaced land races developed by farmers through hundreds and thousands of years of selecting and re-planting the seeds. Prior to the green revolution, farming communities had developed hundreds of varieties of corn and of potato and thousands of land races of rice, each adapted to specific growing conditions or culinary uses. These variations were generally available to any who could make use of them.

Though yields have risen, this modernization has changed the fundamental role of farmers. Through long experience working with crops and valued non-crop plants and animals, non-Modern farmers develop what Gardner calls *naturalist intelligence*, an ability to interact with food producing plants and animals in deeply knowing, caring, and sustainable ways (2006). Barbiero (2014) asserts that combined with a caring for the life in around their fields, these farmers produce *affective ecologies* – food producing socio-natural communities which, as I argue below, call forth a very different concept of value.

In a move to capture a greater share of the monetized value of agricultural production, agri-business has worked to further devalue naturalist intelligence. First by patenting the seeds that farmers must now purchase each year, Monsanto, Dow, Syngenta, and a few other transnational agri-business firms have essentially enclosed the market value of the plants that farmers grow (Acquaye and Traxler 2005). Ever more food producers now work as contract farmers. In such relationships people (not really farmers any more) are told what to grow and how to grow it, which products they must purchase from their contractors and how to apply it. As this political economy now spreads into sub-Saharan Africa, it has come to dominate meat production in the US. Increasingly the people who raise animals and now with privately held patents on seeds, people who grow crops, own neither the animals nor plants that they raise nor the value that those nonhuman beings create through their life processes.

Our food ecologies, once characterized by human families and communities engaged in profoundly knowledgeable and caring interactions with lively and productive forests, fields, streams, and seas (Altieri and Nicholls 2007; Ingold 2000) have been undone by market rationalism, supported by neo-liberal governance. Under that regime, agri-business has produced a global food/agricultural market which maximizes the market value of certain transnational firms. It has done so by enclosing revenue opportunities and externalizing costs. As a result our biosphere is degraded, rural communities are undone, and though more food is produced our health is often diminished. In short, the gesture of Modern agri-business is to undo affective communities characterized by deep caring for and extensive knowledge of local foodscapes. A liberalist concept of value underlies and rationalizes all of this.

My project here is to develop an alternative sense of value, one which empowers us to prioritize *naturalist intelligences* and a *caring for our biosphere* (Wilson 1984), *the pillars of affective ecology* (Barbiero 2014). As the readings in this special issue well demonstrate, we might pursue a variety of corrections in efforts to move us toward move vibrant relational ontologies, more caring ecologies (Bennett 2010). Each of these is further empowered by a more biospherically appropriate sense of value.

As a critical project, I first rehearse Western constructions of value across the second millennium, first as the product of Medieval bodies in intimate interaction with

agricultural fields and then as Modern monetized worth realized through market exchange. Having indicated the failings of market valuation above I then develop an alternative conceptualization of value which supports sustainable and lively human-environment interrelations. In re-conceiving a biospheric sense of value I take an explicitly non-Modern stance (Foucault 1970, Reiss 1982). Rather than drawing distinctions between humans and the rest of our biosphere, I suggest ways of understanding how we are alike through the lens of a biospheric and vibrant relational ontology. Towards that end I enlist work on alternative ontologies in the Heraclitean tradition which argue that we, that living beings generally, organize our selves and flows of useful matters in the spaces around us with the intention of extending ourselves in space and time. That we use and produce energy to build coherence around our selves as centers of caring.

I then draw upon Marx's ontological work to suggest that value, conceived as usefulness to life, arises from labor, from practical life activity. I extend that thesis and show that through co-adaptation the unintentional byproducts of life provide stocks and flows of value generally overlooked by economist and ecologists. Finally, I draw upon the development of exploitation and cooperation in the Marxist tradition to suggest a basis for the evaluation of alternative trajectories, for creating more and less affective ecologies.

Value in the western tradition

Value understood as monetized worth realized through market exchange has dominated Western discourse throughout the Modern period, However, that sense has not always been hegemonic. In the early Medieval period hermeneutic science saw value in adherence to God's plan. Poverty was seen as holy (Gurevich 1985, 8), and who had and handled money were analogized to over-stuffed intestines which "give rise to countless and incurable illnesses, and through their vices, can bring about the ruin of the body as a whole" (Policraticus quoted in LeGoff 1989, 17-18). Yet church leaders also recognized the social stability that coin represented and so defined value functionally, for what it could do, rather than as resident in coins/objects themselves (ibid, 215).

For the great majority of Medieval Europeans who made their living directly from the land, value was entwined with concepts of self that differed from Modern imaginings. People understood themselves to be among the things of the world, patterned after the divine order, and divine in one's bodily resemblance to that order. People understood themselves "caught up" in God's plan, and agency rested in a God who moved all things as He wished (Gurevich 1985, 32). Lacking individuality and agency, people imagined themselves as indistinguishable from their communities, and as intimately open to their worlds. Bahktin wrote that the leading themes of these bodies were "fertility, growth, and a brimming-over abundance. Manifestations of this life refer not to the isolated biological individual, not to the private, egotistical "economic man," but to the collective ancestral body of all the people" (1984, 19).

Bahktin explains that the body was understood as "in the act of becoming. It is never finished, never completed; it is continually built, created, and creates another body. Moreover, the body swallows the world and is itself swallowed by the world" (1984, 317). The Medieval body was understood to be:

incomplete and constantly intertwined with the earth which gives it birth and swallows it up again. The eternally renewed generic body was cosmic, universal, immortal ... The leveling of all barriers between the body and the world, the fluidity of transition between them — these are the traits of the Medieval popular culture, and, accordingly, of the popular imagination (Gurevich 1985, 53-54).

Medieval farmers understood time and their embodied being as cyclical rather than teleological. They understood that through

their labor, valued food emerged from the earth, passed through them, and through their efforts returned to the earth to emerge again.

People maintained the fertility of fields in several ways: through crop rotation, marling (Glacken 1976, 345), and through manuring, either through passive grazing on fallow fields or through the active collection and spreading of human and stock animal excrement. Indeed, human excrement became an especially potent fetish; conceived "as both a joyous and sobering matter, at the same time debasing and tender; it combined the grave and birth in their lightest, most comic, least terrifying form" (Bahktin 1984, 175-6). Excrement, and food, mediated between living bodies and regenerative earth. Through daily life, people experienced the links between their embodied product (excrement and labor), and the continuous product of land and seed. Excrement formed a link between animal life and plant life as certainly as eating linked plants' lives to those of animals (humans included). In his practical observations of daily life, Naturalist monk, Albertus Magnus (*c*. 1200-1280) understood value created through agriculture to be a reflection of the Divine. Glacken writes that he "in the need to know nature for religious and practical ends" Albertus understood the relationship between God, Man, and his environment as an unbroken "chain from theology to manuring" (1976, 351)—a very non-Modern conceptualization of value.

Prior to the resurrection of trade and urban living, through their own labor communities generally produced what they used, and used what they produced (Lefebvre 1991a, 263). As trade facilitated by money began to intermediate between production and consumption, the connection between labor and value became experientially abstracted, quantified through payment in wages rather than in things useful in and of themselves, and purchased through coin rather than something of immediate worth. Abstraction entered life through trade in money and through Modern laws and mathematics which homogenized relationships among people (Foucault 1970; Reiss 1982). As impersonal markets worked to dissolve previously personalistic relations (Ruggie 1993, 155), merchants working in an atmosphere of calculation further abstracted inter-personal relationships through flows of money and a new double accounting system (Crosby 1990, 27).

Even the basis of the value of precious things changed. By Medieval hermeneutic reckoning, jewels and coins made of precious metal were valuable for their likeness to the Godly and glittering stars of the heavens (Gurevich 1984, 217). This basis of value shifted and by the sixteenth century economists argued that coinage made of precious metals was prized for its ability to *represent* value which could be gotten with it through purchases (Foucault 1970, 169).

Thus, as burghers began to quantify time, individuate themselves, and compete in urban market economies, new concepts self as agent and of scarcity and finitude of time and life became dominant. As Foucault put it, by the nineteenth century:

what made economics possible, and necessary, then, is a perpetual and fundamental situation of scarcity… it designates in labor, and in the very hardship of labor, the only means of overcoming insufficiency of nature and of triumphing for an instant over death. … homo oeconomicus … is the human being who spends, wears out, and wastes his life in evading the imminence of death (1970, 256-257).

Scarcity among certain classes, and its management and elimination became a primary concern of Modern economics, particularly amongst liberalists.

Concerned to understand value as a function of trade and markets, Adam Smith's work proved canonical. In 1776, he argued that scarcity is not always endemic; however, exchange or market value can be realized by *creating* scarcity. Smith observed that "things we desire and are held commonly and in abundance, such as air, have no value. However, if a "*product in demand can be appropriated and enjoyed by a number of*

persons to the exclusion of others," it takes on value which can be realized through exchanges in markets (1828, 4: 82, italics in original). Thus constructing monopolies of access to the products of nature, i.e. commoditizing matters once commonly available, is understood to be a means of creating value where none was before. Yet clearly that condition may not lead to a greater abundance of the valued thing, and prohibits access to those unable to purchase the desired matter.

The environmental consequences of value so conceived are writ large across our biosphere. Through enclosure movements in Europe (rationalize by Locke 1988, 2: 19-34) and the dispossessions of lands in colonial and post-colonial spaces, elites have worked to create monopolies over access to land and land-products.[i] More recently, globalizing agri-businesses have created scarcity through their control of seeds and associated chemicals, and through wholesaler collusion to drive down farmers' profit margins. In response farmers must work ever more acreage and where possible are driven to clear more land. Small farmers, who still produce as much as one-half of the world's food (Maass Wolfenson 2013), are being driven out of business or forced into mechanistic contract farming.

As Weber (2013) explains, this Modern construct of scarcity as an organizing principle also pervades ecology, a second Modern science central to this essay. Darwin's thesis that scarcity, as the normal condition drives evolution clearly reflects Malthus's essay (1966 [1798]) predicting that famines would result from rapid population growth. Today the imprint of scarcity is seen clearly in energy focused ecologies which fixate upon trophic chains (1,000 kg of plants => 100 kg of herbivore => 10 kg of primary predator> = 1 kg of top predator). These imagine life as wasteful, but at the same time driven to efficiency by endemic scarcity. Following Darwin's scarcity thesis, evolutionary biology has organized itself around an assumption of poverty as a natural and virtuous driver of adaptation. Yet as Weber (2013) points out, Darwin never observed speciation occurring as the result of scarcity.

Smith's argument that matters as useful as air would have no value suggests a certain poverty of thought, and certainly does not describe life, human or otherwise, beyond markets. And so I suggest an explicitly non-Modern reconceptualization of value and of self which addresses what life does, and so allows consideration of our biosphere as imbued with vibrant agency. I seek a concept of value that encompasses the processes through which life finds and produces both value, and its antithesis for which we do not have a word – matters and processes that degrade value. Above all, this discussion views life through a lens of vibrant relational ontology (Bennett 2010), a position which begins with the non-Modern understanding that all beings exist through interactions with the bodies, products, and projects of other beings whose first and shared motive is to live.

Finding biospheric common ground

Modernity is marked by binary categorizations founded in difference, rather than inter-relation (Foucault 1970, Reiss 1982, Fracchia 1999). Such categories arise when different matters are compared along single axes of difference: e.g. sentient ⇔ insentient. Longhurst (1997, 490) explains that categories so constructed form mutually exclusive and mutually exhaustive poles. And because axes of comparison carry an implied normative quality, as either 'good' or 'bad,' our orderings are ethically hierarchical and so "describe systems of domination" (Grosz 1989, xvi).

Western categorizations of humans and nature thus construct humans as Godlike and Others the rest of life as lacking in such virtues (sentience, language, intent, value production or appreciation). As I develop in the discussion of (un)intentionality and value

below, this categorization scheme supports logics which find appropriateness in dumping waste such as greenhouse gases, pesticides, and waste into our global commons, so long as there is no monetized cost incurred. I join many others in suggesting ways to think differently about ourselves, to undo this human-environment binary. Towards that end I begin with the very non-Modern questions, how are humans *like* all other life, and how is life essentially different from non-living matter?

In seeking commonalities between human and nonhuman beings, in identifying what *life* does to continue itself, it is useful to contrast the most basic reaction separating living beings from non-living things. That difference is made clear in the absorption of solar energy by living plants and nonliving matters. Photons, the energetic waves in sunlight, change atoms that absorb them. Absent photosynthesis, atoms absorb and hold that energy for only one ten millionth of a second before re-radiating the energy at a lower frequency (Ho 1993). The energy is transformed but, in accordance with entropy, is released in a lower and "less useful" form (usefulness is poorly described here). In abiotic processes actions are impelled by what we understand as physical and chemical properties such as gravity, thermodynamics, and quantum mechanics (McDaniel 1983). Photosynthetic plants do something very different. Ho writes that "life has learned to catch the electron in the excited state, uncouple it from its [electron] partner and let it drop back to the ground state … utilizing its excess energy for life processes" (ibid, 56). Indeed, Lefebvre asserts that life normally produces surpluses of energy:

The living organism may be defined as an apparatus which … captures energies active in its vicinity. … It also, as a 'normal' thing, retains and stocks a surplus of available energy over and above what it needs …. This superfluity of energy is what distinguishes life from survival (1991, 176).

All healthy life obtains energy from its environments and processes that into stores for later use. Non-living matters do not do this. Their energetic interactivity is described by entropy. Living beings gather energy and then direct the expenditure of those energies to fuel its efforts to extend itself in time and in space.

Intention

Such self-directedness is a central point here. Humanists have long held that intentionality constitutes a central axis differentiating human from nonhuman life. This human exceptionalism is difficult to escape. Even among posthumanists who argue that human subjectivity is essentially a self-world hybridization (Badmington, 2000), non-representationalist conceptions of intent tend to still place human awareness at the center of networks/hybrids/*collectifs*. This persistent anthropocentrism is evident in Latour's (2004) representative example of nonhuman agency recounts how snail darters, a small fish native to the Little Tennessee River stopped a major dam project in 1973. However, as Latour explains, it was the new consciousness of the threatened species among anti-dam activists who then sued and stopped the dam project (see also Lorimer 2006 and Braun 2008a, 673). The snail darters in fact *did nothing* to stop the dam but exist. However, *collectifs* may be very intentional without the central participation of humans.

One cannot use human language to ask a plant about whether efforts on its own behalf are intentional; however, directedness may be understood as the performance of intention. Even bacteria employ tens of receptors to identify matters they can use and then work to move to and stay near favored food molecules (Mortensen 1987, 127). Working from an ontologically relational feminist perspective, Massey (2005) points out that all living beings author their own trajectories and negotiate the trajectories of others. All life works to sustain and continue itself through directed efforts. In the same vein Plumwood observes that in so doing life performs intention:

To a more sensitive and less human centered view, the plant world includes fully intentional others whose strivings, interactions, and differences in life strategy are intricate, amazing and mysterious. … To all living creatures we may clearly ascribe a teleology or overall life-goal…. Trees appear as self-directed beings with an overall 'good' or interest and a capacity for choice in response to their conditions of life (1993, 134-135).

The intention of life is to live. That intent is manifested in living entities' efforts to produce themselves and their space. In those efforts life is directed and intentful (see Sterelny 2001). Keystone species, such as beaver clearly co-direct projects and with nonhuman others in ways that can significantly alter landscapes.

Behavioral scientists continue to provide new evidence that nonhuman beings are intentful. Even bacteria move decidedly towards food (Mortensen, 1987, 127). That beaver and other species choose optimal sites for their dwellings (Naiman et al. 1988), and that animals such as Satin Bowerbirds incorporate colorful themes, such as plastic bottle tops all of the same color (Milius 2000) in their flamboyant nests provides evidence that such behavior is not solely instinctual. That plants, animals, and even communities generally prefer (choose) behaviors that lead to their enrichment and persistence rather than to their impoverishment and death further demonstrates intent. This intentful preference begins to suggest a sense of biotic valuing.

Autopoeiesis

Grobstein asserted that life is uniquely "characterized by replication, metabolic turnover, and exquisite regulation of energy flow constitutes a spreading center of order in a less ordered universe" (1964, 1). Unlike non-living matters, living beings are self-organizing, they are "materially embodied processes that bring forth themselves" (Weber 2013, 30). Thinking about life in terms of process rather than object, evolutionary biologist Ho suggests that living beings may be understood as fields of coherent activity (1993, 178). She asserts that in their metabolism living beings:

[C]an mobilize the whole spectrum of energies for work …[Life activity] has not so much to do with free energy…, but with the way energy is trapped, stored and mobilized within the living system. Energy is trapped directly at the electronic level. It is stored not only as electronic bond energies, but also in the structure of the system; in gradients, fields and flow patterns…. All this in turn enables organisms to mobilize their energies coherently (ibid, 71).

Understood as consistency, connection, or contiguity arising from some common principle or relationship, *coherence* allows us to think in terms of caring selves who organize spatial flows in dialectic with active and inactive others. It allows one to imagine unbounded selves, centered in concern for their own life; all constituted by flows which circulate through environments and bodies. Coherence works to undo self/world dichotomies without annihilating the individual. Coherence allows one to address what life does, rather than what humans do and what nonhumans do not do.

The dialectic aspect of coherence also serves to challenge mechanistic metaphors for living beings. Genetic determinists still entranced by the life-as-mechanism metaphor attribute such activity to DNA structures; however, that inherited information only guides or constrains spatial form and behavior. This is well demonstrated by an experiment conducted by a group of scientists from Stanford University in the 1930s in which clonal starts were cut from a single plant and replanted in various California climates (Lewontin 2001). Though genetically identical, the plants grew in ways that reflected their new surroundings, each with distinct forms. Indeed, since 2006 the peer reviewed journal *Plant Signaling and Behavior* has offered good evidence of plants' ability to interact, to learn, to remember, and to adapt their somatic form to be appropriate with their environment (see also Trewavas 2014).

Socio-spatial being

As organisms adapt their bodies to environments, they also work to adapt environments to their needs. In accord with Greek philosopher Heraclitus, Serres (1982) characterizes living bodies through *diarrhesis*, as forms through which environments flow. Moderns, fixated upon Leibnitzian atomism, understand living bodies as clearly bounded objects. However, our bodies may also be understood as processes (Martin 1998). Dossey observes that

When we view our physical boundaries with pinpoint accuracy, they are so fuzzy as to be nonexistent. With each bodily movement, we trail such a haze of chemicals, vapors, and gases behind us that we resemble out of focus images. … Not only are we constantly blending physically into the world and our environment, we are blending into each other. … Many of the elements that comprise our bodies were not born on Earth but were recycled through lifetimes of several stars before becoming localized on our planet. Thus, not only are our roots in each other, they are also in the stars. We are literally star stuff (1990, 79).

Thus, living bodies are reasonably consistent in form, but dynamic in substance. Even the molecules that make up our bones stay with us only for about ten years.

As we organize our bodies, as living beings we also work to organize the flows of matters which we value and add value to. In so doing we produce certain spaces. I do not mean to say that life produces space itself, but that it produces particularities of space, it affects space. Through our life activities we transform what is there into something it was not before. As Lefebvre observes, "The release of energy always gives rise to an effect, to damage, to a change in reality. It modifies space or generates a new space" (1991a, 176). Serres (1982) explains that life is not only constituted by coherent flows, life works to create and organize those flows, a process he calls *syrrhesis*, or flowing together. From an evolutionary perspective Grobstein observed that for all life "Among the mechanisms that have proved successful are those that that extend *into the environment* the homeostatic consistency of the organism (1964, 111).

Agency

From a posthumanist perspective, a more-than-human sense of agency suggests that coherence is an essentially inter-relational process (Braun, 2004a). Hinchliffe (2007) and Braun (2008a) explain that in the Western tradition agency has been located in particularly qualified and very specific human bodies (Callon and Law 1995). Network and hybridity theorists (e.g. Whatmore 2002; Latour 1993; Haraway, 1992) argue that agency is manifested through relations with and between humans and nonhumans. Hinchliffe enlists Law's (2004) conceptualization of *agencement* to argue that agency arises through "a suite of stories, practices, technologies, animals and people … an active combination of technologies, ways of proceeding, their arrangements and their ongoing, unfolding nature" (2007, page 38). Agency in this sense is still/always in the act of unfolding, becoming, emerging.

Graeber (2001) goes so far as to argue that value itself rests in relationships, in process. I disagree and suggest that this reproduces a Modern either/or trap. In response to such polar thinking Lefebvre observed that while "Around the living organism, both those energies which it captures and those which threaten it are *mobile*: they are 'currents' or 'flows.' By contrast, in order to capture available energies the organism must have at its disposal apparatuses which are *stable*" (1991, 176). Just as we are both ontologically stable and dynamic, matters that are useful to us are both object and process, often simultaneously. The seed of a corn plant bred to grow well in volcanic soils at elevation with full sun is a thing, co-produced by people before me in concert with the plants and the specific environments they've adapted to over many generations. It is a thing, it is also a process, and it is also the configuration of many relationships.

This inessential and extra-categorical nature of value is captured in Callon and Law's

argument that "by themselves, things don't act. Indeed, that there are no things 'by themselves.' That instead, there are relations, relations which (sometimes) make things" (1995, page 497). They suggest that agency is performed by *collectifs*, emergent effects "created by the interaction of the heterogeneous parts that make it up" (ibid). Thus, agency rests in the affective relationship itself, rather than in specific actors. But value may rest in relations, *or* in the things they make.

The next question then is how do we understand life to do this, to access matters it needs and create matters of greater worth? How does life create value? Marx's ontological theorization of labor and value provide insights.

Value as usefulness created through labor

Throughout Modern history, certain economists have attended to the role of labor in creating value. In the eighteenth century the French physiocratic school argued that the value produced by labor was equal to the cost of labor, and that surplus value arose not from labor but from the productivity of nature (Foucault 1970, 193), what we call ecosystem services today. Along similar lines Smith argued that in manufacturing labor was simply paid for the value it added, and that profit arose from market conditions and scarcity (1828, 2: 93). Alternatively, in the early nineteenth century Ricardo argued that the value of a commodity was in fact the result of and measured by the labor contained in a commodity.

As Marx laid out his relational and materialist ontology, he argued a rather different relationship between labor and value. In the opening pages of *Capital* (1976, 126) Marx, citing Locke (ibid fn 4), asserts that value lies in usefulness and writes that: "The natural worth of anything consists in its fitness to supply the necessities or serve the conveniences of human life." In this sense, value lies in usefulness. In the thrall of Modern human-exceptionalist constructs, Marx insists that value and usefulness are co-produced by uniquely human sensibilities. Here I dismiss that historical affect and suggest that this is true for all life.

Marx worked to construct people as essentially material and relational beings. He reasoned that we were fundamentally engaged in dialectic relations with other people and with our environments. In his *German Ideology* he observed that we produce value by mixing matters "from nature" with our "practical human activity" (1972b, 74; also 1967, 177). This fundamental process provides a fruitful basis for reconceiving value. It suggests that one might understand value as a functional rather than an essential category; a category based upon what things do, rather than what they are. Functionally, value lies in things, relationships, processes, environmental qualities in which life finds usefulness as it pursues its various projects and trajectories.

Consistent with the idea of syrrhesis, Marx also argued that through mixing matters of the world with our labor we also invest labor and so value into nature/space. In so doing we alter, we enrich, we invest value in biospheric spaces (1972b 145-160). He explained:

Animals and plants which we are accustomed to consider as products of nature, may be, in their present form, not only products of, say, last year's labour, but the result of the gradual transformation continued through many generations under human control, and through the agency of human labour (Marx 1976, 287-288; and earlier in 1972a, 116).

Thus, value may be produced in excess of the producers' need. And in a self-actualizing socio-ecology the results of other's labors are available to us in biospheric spaces. Thus, we, and life more generally can be understood to act both autonomously and interdependently (Weber (2013). Organisms are autonomous in their self-caring, and they are dependent upon the products, the valued matters made by others. In breeding a plant better adapted

to wet soils, for example, we create value not only for ourselves, but for others who might also benefit. As a result, the matters we work upon are themselves often the products of the labors of other beings.

(Un)Intentionality and value

Thus, through labor, i.e. practical life-activity, organisms alter biospheric spaces and effect relationships. The intended result is to create value for the organism and/or for others that it cares for or about. But life also finds value and harm in the unintended byproducts and waste that laboring organisms also produce. A market focus directs attention away from these externalities. Yet as I detail in the introduction, those effects can cause very real harm.

Williams addresses the resultant myopia with regards to the by-products of human industrial activity. He explains that because we have imagined ourselves separate from 'nature,' that is where we project our "unacknowledged activities and consequences" (1980, 81). This would not be such a problem, Williams asserts, if we were not in fact so profoundly inter-related with nature, with "the environment". He writes that:

we find it very difficult to recognize all the products of our own activities. We recognize some of the products, and call all of the others by-products; but the slagheap is as real a product as the coal, just as the river stinking with sewage and detergent is as much our product as the reservoir. … Furthermore, we ourselves are in a sense products: the pollution of industrial society is to be found not only in the water and in the air but in the slums, the traffic jams, and not these only as physical objects but as ourselves in them and in relation to them (ibid, 83).

Though unintended, byproducts are no less effective.

Byproducts may also be very useful. Amongst ecologists, those focused upon energy exchange may miss unintended yet valued spatial amenities, and those focused upon scarcity may miss the abundance the byproducts may create (Weber 2013). Examples abound. Native to Northern India, neem trees follow their own life trajectories and projects (Massey 2005; Plumwood 1993): their roots grow towards water, their branched grow toward full sun where their leaves produce nutrients through photosynthesis, the resulting carbohydrates are metabolized to produce biomass, and they produce an excess of seeds for their own reproduction. The trees also produce and invest chemicals in those seeds which interfere with molting, reproduction, and digestion among over 200 insects. Thus the trees inhibit populations of organisms that might harm or kill them. These are some of the 'intended' objects produced by the trees for their own use (ibid, 134-135).

The trees also produce potentially matters useful to others, but not to itself. Nearby plants and animals may also benefit from the trees' insect repressing matters. The trees also produce byproducts in the form of shade which cools nearby terrestrial and aquatic environments. Their branches provide living spaces and shelter for birds, insects, reptiles, small mammals, and other plants. The trees produce an excess of nuts which are edible to mammals, and spent leaves fall to earth and become food for soil communities. All of these values are enjoyed by others able to adapt to use them with little or no cost to the tree. This facilitation becomes mutualism when partner species produce matters valued by the trees. Animals defecate or die near the tree and so provide nearby soil communities with matters from which they make phosphorus and other nutrients available to the tree itself. Other co-inhabitants eat organisms that might diminish the trees' vitality. Still others help disperse the trees' seeds away from the parent assisting the trees' population continuance in time and space. Such cooperative mutualism increases as populations co-adapt to find usefulness in the byproducts of their neighbors.

Abundance

Though scarcity has long been a foundational concept in both liberal economics and evolutionary ecology, it seems that life may

be better described through abundance, through a surplus of value. Neem trees produce far more seeds than is required to reproduce themselves. Indeed, most plants and many aquatic and marine species produce thousands and even millions of seeds and eggs even though the populations of all non-threatened species are far larger than necessary for species continuance. Weber (2013) goes so far as to argue that life is normally inefficient, at once benefitting from abundance of value while also creating that abundance of matters, of bodies, of relationships, of species. Lefebvre observes that surplus production of value is the norm and that an economics based in scarcity "is biologically or 'biomorphically' inadequate. It is a low-level principle applied only to situations where a short supply of energy calls for restrictions on expenditure. It applies, in other words, only at the level of survival" (1991, 176).

Ecologically, scarcity is not the normal state. Rather it describes only spaces deficient in critically valuable matters such as water, sun, nutrients. Absent those constraints, given time life proliferates as it embodies value, invests value into environmental spaces, and organizes flows of value, all through labor conducted out of caring for self and others. Economically, scarcity is the normal state only where markets prevail. Though capital endeavors to colonize everyday relations (Lefebvre 1991), Gibson-Graham's *oeuvre* has focused upon the limits of capitalism and the depth and breadth of economies that operate out of caring: creating family, building community, mentoring, all the value-creating things we do to produce abundant and vibrant material/relational human life.

Models for less and more lively food production

Exploitation

In a Marxist sense, biospheric relations may be understood as more exploitative or more cooperative. Though Marx himself became focused upon exploitation as it affects human labor, Young (1990) provides a more widely useful formulation of the concept. She asserts that exploitation occurs when more value is taken than is returned. The one-sided appropriation of matters produced and valued by nonhuman beings from biospheric spaces has been a central gesture of capital. This is the root of primitive accumulation (Harvey 2003), wealth accumulation through the enclosure and dispossession of spaces laden with values that can be stripped and sold in markets. In many cases this exploitation has degraded or destroyed locally valued biospheric processes, now often referred to as ecosystem services (Costanza et al, 1998).

Perversely, in many cases where industrial byproducts have degraded or destroyed ecosystem services, capital often steps in to replace the lost flows of value. Thus capital circulation expands through the destruction of ecosystem services. The agro-industries that produced the chemicals that killed soil communities are the same that then produced and sold fertilizers. Modern agriculture is foundationally exploitative.

Cooperation

Marx argued that communities are self-actualized by doing the opposite (1972b). Rather than taking more value than given, successful societies produce surplus values and share them cooperatively, taking no more than is given, and often contributing more value than is consumed. What Marx held to be true for human communities is equally applicable to biospheric communities. Life is life, value is value, and labor is labor. Human integration with wider biospheric flows of value are nowhere more immediate than in agricultural production.

Human cultivation and caring for the value produced by nonhuman partners is hardly a recent innovation amongst agriculturalists (Rosset et al 2011). Many non-Modern cultures value the excess, byproducts, and waste produced by partners in agricultural ecologies. Such partnerships are evident in

the extensive dark soils in and Amazon basin produced by Neolithic farmers (Glaser et al 2000), among wet rice paddies in Southeast Asia which have been in continuous production for hundreds of years without off-farm inputs, by pre-Modern three field rotational farmers in northern Europe, by shifting cultivators who have exquisitely managed fertility and production in wet tropical environments.

Amongst contemporary Western farmers, agro-ecology techniques mimic and extend these trans-species cooperative practices (Altieri 1995). Many agro-ecology efforts build upon four themes (Pretty 2008; Altieri and Nicholls 2012). Bio-control, also called integrated pest management has farmers enlist certain insect, plant, and vertebrate populations which control, but do not eliminate other problematic (pest) populations. Intercropping both provides a variety of habitat for insect, bird, and microorganism partners and decreases infestation risks by avoiding monocropping (a farmer in Matanzas, Cuba told me that biodiversity was his best pest control). Agro-forestry maintains soil moisture and habitat-rich forest structures while also producing food, richer soils, and providing resilience following storms (Holt-Giménez 2002).

Composting and vermiculture actively partner with micro-organisms and invertebrates to convert waste into fertile soil amendments. In a review of the efficacy of these techniques, Pretty et al (2013) find that among 40 different projects in 19 sub-Saharan countries, across 11.3 million hectares, and over the course of 3-10 years, small holders more than doubled their annual production. Over the past several decades geographers and anthropologists have further documented what is often called indigenous technical knowledge, naturalist intelligence that allows pre-Modern farmers to manage often very difficult conditions while farming in modes that are sustainable and actually cultivate biodiversity and resilience (Tsing 2005; Hecht and Cockburn 1989; Dove 1985).

In the US, the hearth of highly exploitative commercial agriculture, even conventional farmers are beginning to appreciate the benefits of allowing non-crop life in their fields. In 2014, about 35 percent of all crops were planted using conservation tillage techniques. These modes of planting seeds leave soil communities and some cover vegetation in place and so decrease erosion and increase soil nutrient content and moisture retention. While Natural Resources Conservation Service agronomist Ray Archuleta referred to this as a "massive paradigm shift" (in Goode, 2105), Texan farmer Terry McAlister more closely reflects findings of research into conventional farming adaptation to climate change in California (Jackson et al 2011 and 2009): "My goal is to improve my soil so I can grow a better crop so I can make more money … If I can help the environment in the process, fine, but that's not my goal" (ibid).

Paradigm shifts

Like most farmers in North America, Mr. McAlister remains enrapt in a Modern sense of value and self. He understands "his soil" and his land as something different from "the environment", something that he does not particularly care about. Like most Modern farmers he has become a knowledge receiver instead of a creator – he is told that if he does not turn his soil and otherwise destroy the communities that produce fertile soil, he will be able to spend less on chemical fertilizer and cut costs.

Does conservation tillage allow livelier and so more resilient agriculture? Clearly it does. But a shift to conservation tillage does not constitute the re-establishment of affective food ecologies. And the political economic structures that work to the benefit of agri-business remain in place. Under market logics, anytime yields increase, from conservation tillage in this case, farm-gate prices drop. Mr. McAlister and his peers will continue to face ever decreasing monetary returns per acre, and monocropped farms

will have to expand. To become more efficient (i.e. to cut expenses), farmers will continue to externalize costs. Farms unable to expand will perish, and often communities with them. Surviving communities will be harmed by some of the toxic externalities. Processed food manufacturers will continue to find new ways to market (i.e. to create desire for and access to) the increasing supplies of soy, corn, and palm oil in the form of tasty, faddish, obesity and diabetes engendering foods.

If we, farmers and consumers alike, were to think about value as I develop it here, we might expect a different result. When we think of value as what is useful to life and truly respect the lives of others, if we were to see ourselves as essentially vibrantly interdependent upon our biospheric partners, if we were to eschew harmful externalities because we get that "the environment" flows through us too, if we were to champion affective food ecologies, agriculture might look very different.

This isn't conjecture. Agricultural systems which work through alternative and often affective ecologies are not a fringe movement. Thousands of communities and millions of households now live in accord with this ethic. Some estimate that over one half of the global food supply is produced on small farms (Maass Wolfenson 2013). Many of these farmers have deep knowledge of and caring for their nonhuman and human communities. Programs sponsored by the UN Food and Agriculture Organization (FAO 2015a), government extension services, and numerous non-profits are helping farmers regain lost naturalist knowledge and re-vivify agro-ecological modes of food production, often using traditional cultivars. Through efforts like their *campesino-á-campesino* program in which farmers share their growing naturalist intelligence, La Via Campesina has become the largest civil society organization in the world (Rosset 2008; Desmarais 2012). And these affective ecologies continue to face challenges agri-business, from development programs, from government initiatives, and from corporate land grabs.

We *can* think differently. We can change our notion of value as the West did in its transition from Medieval to Modern frames. Understanding value as the product of lively labor whose surpluses infuse our shared spaces works to undo scarcity, to undo the logics supporting agri-business. It also suggests what one ought to do if interested in restoring biospheric vitality and resilience—work to decrease exploitation and increase cooperation manifested in biospheric liveliness.

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[i] In his *Second Treatise on Government* Locke argued that "God gave the World to Men in Common; but since he gave it to them for their benefit, … it cannot be supposed that he meant it should always remain common and uncultivated. He gave it to the use of the industrious and Rational, (and *Labour* was to be *his Title* to it;)" (1988 2.34).

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Looking Back and Moving Sideways: Following the Gandhian Approach as the Underlying Thread for a Sustainable Science and Education.

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Abstract.

In his 'Constructive Program', Gandhi proposed a re-thinking of social and economic structures, including educational processes, to achieve 'Sarvodaya, or 'benefit for all'. The pillars of Gandhi's vision were self-sufficiency, nonviolence and unity in a community which is first, and foremost a community of all living forms. In this contribution, we draw upon our encounters with some of the people who embraced and enacted Gandhi's ideals in rural communities in Southern India, to engage in a process of epistemological inquiry and reflection on the nature of knowledge and implications for pedagogical practice in science education. The key dimensions of community learning, multiplicity of perspectives and creativity in practical work set the basis for a science education which sustains the social, emotional, and spiritual as well as cognitive development of all students. Examples of activities with students at different levels of education are described as part of an ongoing, dialogical inquiry - guided by Gandhi's insights – aimed at developing reflexivity about one' s position in the global, ecological web. Reflection (or looking back) was taken as a central tenet of a process of research seeking to dialogue with other cultures and traditions to disclose opportunities for stepping sideways, diverting from established assumptions, and including science education within a sustainability view.

Keywords. Nonviolence; Gandhi; science education; techno-science; participatory processes.

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***Perspective**: Theoretical and educational visions*

***Fields**: Social processes and structures, Human Sciences*

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Introduction

The fundamental concept of Sarvodaya described in 1942 by M.K. Gandhi in Hind Swaraj was the benefit of all, achievable through the autonomy of development for every Indian village: *"independent of its neighbours for its own vital wants and yet interdependent for many others in which dependence is necessary*" (Kumar, 2002, p. 109). Each village should be self-reliant, making provision for all necessities of life - food, clothing, clean water, sanitation, housing, education and so on, including all socially useful amenities required by a community. At the time of Gandhi's writing, when the Indian sub-continent was still under the British rule, words such as autonomy - *swaraj* - and *swadeshi*- independence would naturally resonate with nationalist aspirations. However, fundamental to Gandhi's idea of 'autonomy' or swaraj, was the desire to achieve self-reliance, for an autonomous being is self-sufficient, integrated with others but can provide for itself. As Johan Galtung recalled in a recent essay, then, as they are now, these were revolutionary ideas which effectively pointed to 'two civilizations', branching out from the core of the same land (Galtung, 2016). When India was setting off on the road of modernity, with its booming cities, militarization and unlimited trade, Gandhi's approach was focussed on needs, pointing to spiritual rather than material growth, with the provision of practical and lived-in examples (Harris, 1987). The two principles of swaraj and swadeshi were integral aspects of the practice of nonviolence, or *ahimsa;* non-duality, mind and spirit, human and non-humans, diversity and interdependency.

Amid the turmoil of 21st century, the expanding net of poverty, social deprivation, and environmental conflicts, affecting people and communities struggling to meet their basic needs every day around the globe, we wish to turn to Hind Swaraj with renewed attention. The process of globalization of goods which held the promise of raising standards of living and material satisfaction for everyone, has brought forward its inherent contradictions; the production of wealth at global scale can only be achieved for some, at the expenses of others. Connected to this, the concentration of scientific, economic, and political power in the hands of a few people is now constituted as the single, biggest threat to plurality and diversity in human communities (Martinez-Alier, 2002). In this scenario, Gandhi's thought has resonated at times explicitly, and other times implicitly, with debates on the contested relationships between science, technology, and social values (Ninan, 2009; Shah, 2012). Similarly, in the realm of our practice, Gandhi's ideas guided us through a process of re-examination of the nature of knowledge and more specifically, the role of science education in shaping models of development and views of the future. As we will explore further in this article, models of expertise were questioned and revisited in the light of ideas of community and participation. Recognition of our total dependence on the natural systems underpinned a process of mutual and personal inquiry with students, exploring a relational way of knowing.

A Dialogical and Reflective Inquiry

In this contribution, we wish to illustrate and re-tell some of our experiences of engaging with Gandhian thought in our educational practice. We will embark on this enterprise in the manner of what characterizes an *essai* (in the sense of the original French), as somebody who *tries* and an *attempt*. It is a choice of medium that as described by Pirrie (2015) develops dialogically, as a form of reflective conversation between writers and readers. It is a way of writing which we feel is akin to the way we gradually entered in contact and 'in dialogue' with Gandhi's ideas, by meeting and working directly with people who are providing "lived-in" examples of his practice. These encounters exposed us to a way of thinking and being in the world that was very different from our own. In our

practice, this was translated into the sustained effort of listening and entering into dialogue with our students, to involve them, literally, as the English word suggests, to *turn in*, become one with and part of the learning process. We were guided by Gandhi's ideas of Swaraj, as the development of the sense of self, in its multiple dimensions, which can only take place as part of active participation within a community (Sterling, 2009; Camino, 2011).

With this notion in mind, in this article we invite the reader also to be part of the unfolding dialogues, and to become witness to - rather than scrutiniser of - the works of a community of people searching together, in the manner of a collective inquiry. Initially and for several years afterwards, we worked together in Italy. More recently, we have come together to share feedbacks from parallel experiences that each one of us conducted in a different geographical context, respectively in Italy and Scotland. This long-term conversation between us supported our practice with the students and it enabled us to go deeper into the reforming educational value of the works of Gandhi and his followers. In this process, we also discovered affiliations with other authors and thinkers who, at different points in history and from different disciplines, have questioned the nature of knowledge and associated models of development. These ideas align with the advancement of a systemic perspective of the world (Volk, 1998), which is accompanied by a profound awareness of human knowledge and human existence as totally embedded activities, inextricably dependent upon natural systems.

In what follows, we narrate the progressive interlinking of epistemological reflections and educational practice which has characterized our activity in science education.

Witnessing Gandhi's Ideas of Knowledge, Technology and Education in Practice

Our encounter with Gandhi's ideas can be traced back to our involvement in activities of international cooperation with the Association for Sarva Serva Farms (ASSEFA) and the Land for Tillers' Freedom (LAFTI), which we had the opportunity to get to know and to appreciate for many years. Both organisations find their roots in the Bhoodan movement, established by Vinoba Bhave, in 1951, with the aim of securing an equitable distribution of the land as a basis for both social and economic development in rural areas (Bhave, 1955). Amongst Gandhi's followers, the writings of the economist J.C. Kumarappa were influential in raising awareness of the problematic linkages between human wellbeing and the large-scale, industrial development of the fifties. Driven by his vision of establishing a nonviolent basis for social organisation, Kumarappa recognised the early signs of the social and ecological disruption promoted by the capitalist system of production and consumption. At the time of the 'great technological acceleration' at the start of the twentieth century, Kumarappa perceived the inevitable consequences of spurring competitive production, which created false needs and demands: "*extension of markets in their turn call for the Army, Navy and the Air Force to control them in the interests of particular nations*" (Kumarappa, 1947, cited in Govindu and Malghan, 2005). Thus, for Kumarappa, wars were not simply a means to an end but a structural component of the global economic process, rooted within the disequilibria engendered by industrial, large-scale production (Kumarappa, 1938).

Many years have passed since Kumarappa first wrote about the critical interrelationships between science, technology, and economic power. Yet it is possible to find resonance between his earlier critiques and current debates on science and technology, and their role in promoting sustainability and development for all. At the start of the nineties, complex and controversial socio-environmental issues, such as the construction of nuclear power

plants, the problems of waste disposal, the risks and unknowns of genetic modifications called for greater debate on the very idea of development in western societies. The prospect of an increasingly technological future was confronted with mounting social inequalities and environmental instabilities; a situation calling for more awareness of the limits of the Biosphere and humanity's dependence on the natural systems.

In that same period, it was the year 2000, we were made aware of a controversy which involved local populations in Tamil Nadu and the owners of industrial prawn farms. The controversy was rooted in an intervention supported by the International Monetary Fund, the World Bank and the Food and Agricultural Organisation, which, upon advice of their scientific experts, sought to introduce a new farming activity that would revolutionise food production in Southern India. Tiger prawns reared intensively in aquaculture ponds were set to bring international trade and global economic growth. At the time, the issue became known to us through the actions of a Gandhian activist and member of LAFTI, Sri Jeganatthan, who brought the case of the social inequities and the environmental pollution caused by prawn farming to a hearing before the Indian Supreme Court in 1998. Jeganatthan involved people from the rural villages in nonviolent marches and rallies to expose the social injustices arising from the indiscriminate use of natural resources. The issue reached international attention and its analysis became a case study in context which helped us to reflect on a set of interrelated dynamics which appeared to be common to many cases of eco-injustices around the world (e.g. Martinez-Alier, 2002). The controversy involving indigenous people and the Government supporting oil extraction in Canada; local communities protecting their land from devastation caused by the mining company Vedanta in India, to name only two of many, are living examples of the struggles of people living in close contact with natural systems and who are seeing their ways of living eroded by the energy-hungry, ever-expanding forces of the global economy. Such instances brought us to reflect more critically on deeply seated conceptions of science as a way of knowing. Several questions guided our inquiry over the course of the years:

- How can we develop a way of knowing and acting in the world which enhances the sustainability of different ways of being and inhabiting the world?
- How can we develop educational contexts which enable the connection of knowledge to contexts and to the lives of people, in a process of creative and critical inquiry?

Such questions led us to explore the writings of Gandhi in dialogue with other authors who supported our reflection on the nature of science and technology, the role of the 'experts', the linkages between cognition and nature. Central to this inquiry was the dimension of power, cross-cutting human relationships with other living and non-living entities. We will explore this dimension first from an epistemological point of view. Then in the second part of the article we will introduce our methodological approach exploring the role of education in promoting more equitable and nonviolent ways of being.

Understanding Science and Technology from a Reflective Perspective - Epistemological and Ethical Aspects

Several commentators have referred to the nineties as a watershed moment in the philosophy of science (Turnpenny et al., 2010) with many writers devoting attention to the changing relationships between science and society. Funtowicz and Ravetz (1993) and Ravetz (1999, 2006a, 2006b) attracted our attention as careful observers and critics of the academic view of science as a 'truthful' description of the world. In their conceptualisation of *post-normal* science, Funtowicz and Ravetz (1993) drew attention

to the dimensions of complexity, uncertainty and unpredictability which characterise human actions in the environment. Socio-environmental problems akin to 'wicked problems' do not allow for simple solutions. Rather, they call for dialogue, between a multiplicity of legitimate perspectives.

The pluralist epistemology which accompanies the insights of post-normal science resonated with the contributions of other theorists from a range of diverse fields, from science studies, to anthropology, law, psychology, and neurosciences, all seeking to understand the changing conceptions of science and technology in face of ecological and social change. Post-normal science posed a challenge to the idea of 'science speaking truth to power' (Collingridge and Reeve, 1986; Gluckman, 2014), opening important and more general considerations about the nature of knowledge and how it can be more commensurate with the complexity of the world but also with the experiences and the needs of people (Saltelli and Funtowicz, 2014). To this regard, interesting contributions were also drawn from the fields of philosophy of technology and anthropology studies. Ihde (2009) pointed to the significant epistemological shift involved in recognising that science as we experience it in everyday life is effectively 'techno-science'. Differently from the idea of science as abstract knowledge, techno-science stems from the combination of scientific research and material networks, enabling real-time transformations of natural resources and services (i.e. Lenk, 2007). Like all technologies, techno-science operates as an extension of the body in the environment and in so doing, it operates as a medium through which human beings *relate with* and experience the world: "*concepts are created and manipulated in culturally organised practices of moving and experiencing the body*" (Hutchins, 2014, p. 429).

Differently from basic technological tools however, techno-science involves a large network of stakeholders and sets of super-systems operating at a large scale; its activity relies on conspicuous political and financial support (Lenk, 2007). In this sense, power becomes a significant dimension of techno-science. The power to move large fluxes of materials, energy and money, for example as it is the case for the construction of a transnational oil pipeline (Camino, 2016) or a nuclear power plant (Colucci and Camino, 2016); the power to affect communities and systems which are very distant both in space and in time. Techno-scientific operations are extensive and penetrate the deepest infrastructure of the biological and material world. Risks and uncertainties are part of the fabric of techno-science and while these dimensions are quasi-celebrated as 'pioneering', 'venture' and 'frontier' operations (Shah, 2012), some important ethical issues arise. A significant gap exists between the few who manipulate and to some extent, benefit from techno-scientific tools, and the many who bear the costs.

As reported by Galtung (1998; 2002) a contemporary Gandhian philosopher, energy-hungry techno-scientific activities bring forth models of economic, scientific, and social development based on power hierarchies and verticality, which separate people from communities, and human communities from nature. From a vertical point of view, nature, matter, and other people (!) will appear as inert, passive substances to be moulded by the superior human, scientific intellect. Conversely, as Galtung (2002) argued, a nonviolent approach would pursue horizontal, equitable relations based on empathy, affiliation with one another and dialogue. The way of nonviolence brings forth a corresponding ontological shift, whereby nature is re-framed as a space for co-existence and co-construction. Most importantly, the relational nature of nonviolence is founded upon the idea of continuity between oneself and the environment, a horizontal connection, as indicated by Galtung (2002).

Ethical and ecological behaviour will thus arise from direct and tangible experiences of nature, as it is "*natural affordances that will afford particular behaviours*" (Blok, 2015, p. 929). With the word 'affordances' from the Latin verb *ab-fero* - to bring something over towards oneself – the environment can take an active connotation. Affordances are not submissive and disposable in the eye of an onlooker. Rather they appear in their being at the point of encounter, when a stone can be a step to lift oneself upward, and a cover for a rabbit's hole. In this sense, affordances have the power to affect and being affected, in a web of interrelations, which are psychological, emotional, and bio-physical. Looking ahead, and filling the gap that exists between personal actions and ecological outcomes is by no means an exercise of predictive power but occurs through the development of an ethical position, the ability to feel and see oneself in somebody else's shoes, as *ahimsa,* "*Nonviolence, which is the quality of the heart, cannot come by an appeal to the brain"* (M.K. Gandhi, in Merton, 1964, p. 39).

So, key features of a way of knowing which recognises nonviolence and sustainability as central, epistemological tenets include: the interplay between mind and body, language and context, emotions and cognition, dialogue among people, and awareness of the interposition of exo-somatic tools.

Science, Technology, and Gandhi's Constructive Programme

Returning to Gandhi, we can see how the recognition of a mutual relationships between humans and nature aligns with the relevance of 'Swa' - or sense of itself – advanced by Gandhi in the Constructive programme (Gandhi, 1910; 1941). The autonomy of the self as in swadeshi, is expressed through the ability to act; however, action or agency are not simply psychological features or inner qualities of the organism, they arise in-relationship. Autonomy comes with responsibility, the ability to account for one's own actions within a community.

Moreover, Gandhi extended the idea of knowledge by emphasizing the value of 'working with the hands' as a form of education that was at the same time both for fulfilling human needs and for acquiring knowledge. Gandhi's early writings on the mechanization of society were anticipatory of the social and humanistic implications of contemporary philosophical critiques of techno-science, pointing to the impact that modern industry was having on humans' abilities to *understand* themselves and their own actions. By its very nature and definition, the industrial society aimed to significantly separate human beings from direct and purposeful engagement with resources and materials, reducing such engagement to the operation of machines housed in factories. Such separation becomes even greater today as the manipulation of technological/digital devices is directly connected to the global flows of extraction and consumption of resources, along vertical trajectories of political and financial power.

So, for young people today, who are increasingly urbanised and technologically connected through exo-somatic links with the world, promoting awareness of the increasing dependence of our knowledge on technological filters is of vital importance. In line with the suggestions provided by post-normal science, dialogue between a multiplicity of perspectives may be essentially encouraged to generate awareness of how different technologies shape the way in which we perceive and talk about problems and their solutions, and moreover, to acknowledge issues of power. In a similar way, in education, we were made aware of the necessity to introduce students to a much more dynamic view of scientific knowledge: no longer a series of well-organized, disciplinary-bounded truths about the world, but a dynamic and socially contingent interpretation of human relationships with the natural systems, encompassing controversial and conflicting positions.

Pedagogical Interlude: The Crucial Interactions Between Science, Values and Learning

Revisiting, and deconstructing the consolidated idea of science as an objective and neutral body of facts stimulated further reflection on the connections between science and values and particularly on the responsibilities of both scientists and teachers towards civil society. Science teachers play a crucial role in supporting the process of maturation of their students, who are already active players in their community. What 'narratives' of science education should be proposed when confronted with a scenario in which mainstream ideas of science are increasingly aligned and connected with images of technological progress and economic growth?

Nonviolence was offered to us as a reflective frame for our practice, highlighting the nature of the relationships between humans and other living and non-living things, with a view to transforming mainstream, often violent, paradigms of separation and control (which permeate and feature various fields of human activity) into a respectful and inclusive worldview, aimed at achieving Sarvodaya, or benefit for all.

In this respect, a nonviolent approach is rooted within the awareness of violence as a cultural dimension embedded in our infrastructures and institutions, from the design of our cities to the layout of our living and educational spaces. The ways in which our body moves and perceives give rise to linguistic and mental frames, which, in turn, influence how we think about others and the world. To this regard, the collaboration with a linguist, Martin Dodman (2014a, 2014b), was central to developing educational approaches recognising the centrality of language in building and shaping the ideas we hold but also as a means for developing reflexivity[1]. This recognition prompted us to explore the value of language not simply as a tool for externalising one's knowledge or ideas but most importantly, as a tool for occasioning reflection and developing new constructs. Awareness of language provides insights into the varied and transitory nature of ideas and views within each society (Camino and Dodman, 2009; Colucci-Gray et al. 2013). In science in particular, it helps to take cognisance of science and scientists as deeply embedded within the complex, evolving, and limited contextual reality on which we completely depend (Bateson 1980). It is through linguistic exchanges that young people become active participants in the process of learning However such process must not be simply focussed on the transfer of information - learning 'what' - but include all opportunities to explore issues and questions, looking at the "how" and "why" of current affairs, requiring everybody to take a stance and participate in making decisions (Colucci-Gray and Camino, 2014).

Thus, taking a global view of our experiences with students in educational contexts, we have become increasingly more aware of the opportunity to draw stronger links between our professional practice as educators and the practices of our colleagues in India - leaders of the Gandhian movements in various communities. They do not operate as chiefs or heads but more as facilitators and 'animators' in the way they would bring people together to engender personal reflection on their conditions and to sustain collective and constructive actions. Similarly, in the realm of our educational contexts, our effort was not so much that of imparting knowledge but to involve people in the complexity of their experiences, perceptions and sensibilities. Our choice of pedagogy was designed to stimulate the learning process, by

[1] We recognise here some similarities and alignment with Lev Vygotsky's ideas of language as a tool for sense-making and the notion of knowledge construction as a culturally mediated and situated process. Within the limitations of this article, we do not wish to further elaborate on this but we retain the core idea of learning as being both an individual and collective process. Thus language becomes a powerful tool for reflecting on the critical interface between individual expression and cultural discourses.

putting students in the role of active participants and sustaining ongoing reflection on our respective roles as people with different experiences involved in a communal search. Involving people in their biological, cultural and spiritual complexity, we sought to engender reflexivity and dialogue, with the power to influence existing modes of being and thinking in the educational system.

In line with the philosophical premises of our educational approach, also our mode of approaching research needed to be responsive to the overall aim of Swaraj. Our activities were informed by interdisciplinary literature but they were not designed to measure impact or assess an effect that was set a priori. Rather, the activities were conceived of as stimuli to create involvement and generate feedbacks for further reflection, encouraging participants - ourselves included – to explore problematic aspects and new questions arising from the discussion. In this regard, our research was mainly conceived as a form of reflective inquiry, supported by a range of tools which we applied in the process of learning and teaching to engender an interruption of normal perception, problematise everyday experiences, to support dialogue and further practice. In what follows, we will not be focusing on 'results' derived from an intervention, but we will articulate how feedbacks from participants supported new activities with a view of activating deeper levels of understanding and participation.

Experiences and Activities

From the beginning of our research and educational activity we were interested in an interdisciplinary approach to science education which promoted students' participation in knowledge building (Colucci and Camino, 1999). As we mentioned earlier, thanks to the personal acquaintance that we developed with Gandhian leaders, working 'in the field' with rural communities, we sought to formulate an approach to teaching and learning scientific topics which considered the epistemological elements highlighted earlier, namely, dialogue across a multiplicity of perspectives to generate participation, emotional involvement, and awareness of the limits of our knowledge and the limits of the biosphere. We worked together with students and teachers in a variety of different educational contexts: university students, including student teachers, as well as in-service teachers and school pupils at primary and secondary levels. Gradually, a number of new initiatives arose and developed, with reflections and experiences coming out of two different, but interacting, realms: 1. Dialogue between a multiplicity of perspectives centred on world issues around us; 2. Experiences in outdoor contexts, as essential components of a balanced development, especially for children, many of whom are currently deprived of direct contact with Nature. Here we provide some examples of our activities.

1. Dialogues Within a Multiplicity of Perspectives Centred on World Issues

The activities described in this section were developed largely with university students involved in the Degree course in Natural Sciences and in the Teacher Education Programme for Secondary teachers, both held at the University of Turin, in Italy. Participating students would either have science as a main subject in their preparation or would have graduated with a degree in a scientific discipline. The activities were introduced as part of courses designed to introduce them to debates on sustainability.

Perspective-taking and role-plays

As reported earlier, the nineties signaled an explosion of socio-environmental issues connected to scientific and technological interventions. Such issues were characterized by lack of agreement among experts holding different views, and clashes, sometimes with the explosion of violent conflicts, between different social groups. Martinez-Alier (2002) talked about the globalization of the poor to

describe the hardship experienced by many populations resulting from the intensive use and displacement of resources and environmental services. The complexity of the real world, along with the complexity of the multiple views held by the many actors involved (local communities, experts, politicians, but also other living beings!), led to controversies in which the multiplication of voices made it increasingly difficult not only to find the 'right' solution but also to put decision-making processes in place which would involve all stakeholders.

Drawing on the methodological premises of drama, we devised the position and experiences (including age, gender, background and interests) of characters who were involved as stakeholders in a range of such controversies (Colucci-Gray, Camino, Barbiero and Gray, 2006). One such case concerned the intensive production of prawns in aquaculture ponds and it involved Sri Jeganatthan and local farming communities in Tamilnadu, which we have reported extensively in other publications (see for example, Colucci-Gray, 2009). By taking part in the dramatized activity, students were 'involved' in a dynamic activity of participatory research, collating and sharing scientific, economic, and sociological data, discussing different options and listening to different points of view, in line with the process of nonviolent conflict transformation (Galtung, 1996; Colucci, Camino and Perazzone, 2001). The diagram presented in Figure 1 illustrates the range of educational opportunities offered by this type of trans-disciplinary activity.

As indicated in the diagram, the three levels of individual, small group and societal interactions are interdependent. If knowledge is not an abstract product but a process of ongoing interaction, involving the entire self, in its becoming in the world, it also means that knowing is directly linked to the webs of energy and materials crossing our body within the biosphere.

We can no longer perceive ourselves as singular individuals set against a context but we are organic forms arising from the nexuses of energy and material flows: "*the biological, environmental and social are thereby integrated within a unified framework of analysis*" (Marchand, 2010, p. 13). In this view, the enactment of a perspective in-role enabled people to share their knowledge while being exposed to a felt awareness of different ways of *inhabiting, being in* the world.

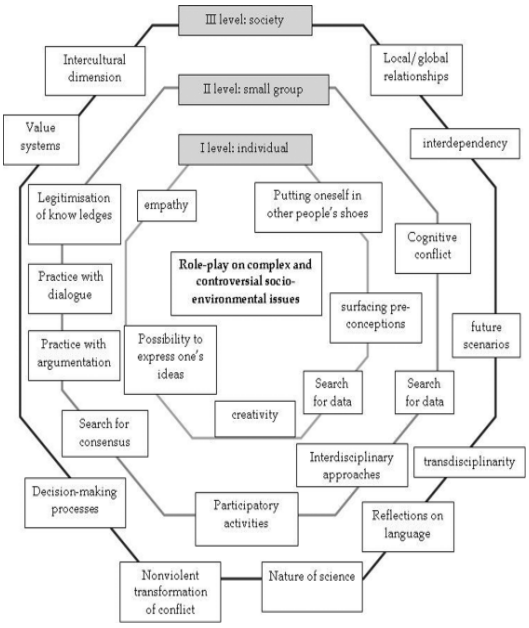

Figure 1 Multiple educational opportunities offered by role-play (from Colucci-Gray, 2009).

In the role-play activity illustrated above, students 'in role' used language to give meaning to their different experiences. The controversy was played out at different levels, because during the drama the students were 'inhabiting' their own local world as part of the wider sets of global interconnections which bring together – into the same view - different individuals and populations which are apparently very distant and very different. This process of learning was aimed at recognising ecological and economic interdependences within a

finite ecosystem, but it was also aimed at uncovering fundamental human needs, such as security, community, and shelter, which are shared across the living world. Achieving and integrating those concepts from 'inside'- through the simulated experience - may help students to intuitively grasp the reasons why Gandhi and Kumarappa thought that large-scale mechanized activities would lead to inequalities and inequities.

Knowing as 'crossing' the living world

Acknowledging the role of an individual's embodied experience during the process of knowing, or more widely, *acting* and *being* in the world, is to allow for individuals to 'join in', to self-direct, to formulate their own meanings. This way of knowing is more akin to Gandhi's view of seeking truth, not so much as finding the end-point, the ultimate resolution, but rather as the ongoing process of self-disclosure and acknowledgement of one's inherent dependence upon others and the world. From this perspective, becoming knowledgeable is not a matter of assembling information, looking for the ultimate proof of evidence, but a form of dynamic action, as knowledge is being formed in everyday activities, knowing being co-terminous with our movement *through* the world… the life-giving ground, the paths along which wayfarers move, and the medium of air, wind, and weather in which we exist (Ingold, 2010). Returning to earlier discussion on the embodied nature of cognition and the knowledge we gain through different technologies, we can re-appraise our position towards the natural world, dramatically shifting from a state of 'by-stander' to a state of 'inhabitants' or 'participants' who share in the life-paths of others.

In this respect, also some of the common words we associate with our knowledge activities can be re-thought so as to account for the biological and enacted dimension of knowing. For example, one such important concept is that of 'seeing', a word that we commonly associated with knowing as we see 'somebody's point of view' and as primates evolving in what is a mainly visual world, it is through 'seeing' that we communicate and know. So, 'to see' is sometimes used to describe the act of focusing on something or framing something, which can be thought of as the physiological and psychological capturing of the reality within one's own field of vision. Seeing is about what is right there, in front of the onlooker. Another way of seeing however is 'seeing as valuing', where the act of seeing is dependent on *what* is seen and is a psychological capturing affected by prior knowledge and personal attitudes. In this form of seeing we are discussing what is and what is not noticed, how prominence might be given by the *seer* to certain things and downplayed in the case of others. Seeing can also be interpreted as an empathetic capability, where we might talk of seeing someone else's point of view, or taking someone else's bio-physical and value perspective.

From the field of arts and design, Hirst (2013) stresses the importance of "thinking more complexly about visibility' (p. 41). He explains the importance of this lesson as relating to four key understandings:

- That vision is more than a physical or sensory function.
- Learning how vision and thought affect our seeing and understanding is indispensable for a student of art and design, as it would be for a student of science and any other problem solving discipline.
- The need to highlight the distinction between collections of visual materials (how we visually select, simplify, and compare elements) and its context (including placement and memory).
- The importance of emphasising that to see clearly, we must not only look more closely at visual objects and images, but also learn to imagine and interpret what's not visible. (microscopic to cosmic)

On this basis, the act of drawing becomes a means for understanding how the student's own way of seeing is mapping their thinking, an insight into their perspectives (Hirst, 2013). Thus, seeing is to observe what is there in a new way, and seeing is also recognising the way in which things are seen by others. However, as Masschelin warns, to see (or in his term gaze) is not about arriving at a liberated or critical view, but about liberating or displacing our view, *'it is not simply about becoming conscious or aware but becoming attentive, paying attention'* (Masschelin 2010 p.2), displacing one's gaze. These reflections allowed us to explore further the power of perspective-taking introduced in the role-play by drawing on visual methods as a means for increasing students' awareness of their own framing and their own thinking. A new set of activities was devised to enable participants to explore and to draw connections across new and possibly unanticipated dimensions of the problems and to apply new concepts, as in the following examples.

Interlinked ecosystems

Vignettes prove particularly effective in generating open questions and engaging students in shared inquiry about the multiple-meanings conveyed by different ways of seeing. The cartoon of Fig. 2, for example, was presented to all students at the beginning of a lesson as the basis of a task inviting them to '*give a title, write a caption and list some topics of the life sciences which have relevance for the depicted scene*'. The stimulus provided by the iconic message of the vignette elicited a variety of interpretations from participants.

In the analysis, the richness of students' explanations and contributions provided cues on underlying views and value systems (e.g.: 'natural world against modern world'; 'equilibrium between production and consumption'; "North and South"). With regards to this vignette, interpretations which appeared to be in opposition with one another were also selected and shared with participants. This way of working made an impact on the participants by raising their awareness of a multiplicity of alternative views and by fostering their interest in listening to the voices of others. It is important to note that this activity was not to be taken as a premise for stimulating counter-oppositions and argumentation aimed at selecting the most convincing and/or truthful statement. Rather it was introduced to stimulate an initial awareness of the limitations of any single interpretation. We refer here to the power of humour, as proposed by Bateson (1980) to uncover one's own cultural framings and thus to generate learning potential from the process of enacting dialogue between a plurality of ways of seeing to recognize, in line with Hirst (2013), what is not visible, the unspoken, the unsaid, the assumed and the accepted. Stimuli from the vignettes encouraged students to think about the puppeteer as a metaphor for power: the power of those who can move large-scale flows of materials around the world; but also the power of the students who become aware of themselves and their role as consumers and inhabitants of the living web.

Figure 2 Interlinked ecosystems. Courtesy of Massimo Battaglia

Following a similar approach, the following activity was aimed at taking a reflexive stance towards the flows of energy and matter in the ecosystems involved.

Oil Eaters

Some authors maintain that we—as inhabitants of modern industrial societies—can be defined as "oil eaters." Why? In your opinion, is the sentence to be interpreted literally or figuratively?

This activity is part of a research strand that we have been pursuing for many years, raising awareness of the role of science teachers in promoting understanding of socio-environmental problems (Camino, Barbiero & Marchetti, 2009). Thinking in terms of energy flows and matter transformations (e.g. Smil, 2008) in following the chain of processes of food production and consumption can be very useful for understanding that the consequences of the energy crisis are not only manifested in the transport and industry sectors (Jones, 2001).

By reflecting with students on the energy flows and matter transformations connected to food production, it gradually emerges that it takes energy not only to transform matter, but also to acquire, transport, store and even use energy. Such invested energy may be compared to "returned energy," and a powerful conceptual tool can be applied to address the problem in terms of quantities: EROI (Energy Return On Investment) is the ratio between the energy delivered by a process (for example, the calories of a given food) and the energy that is being used directly and indirectly in that process (to grow, harvest, transform, transport the food product, as delineated by Cutler, 2004). This activity has the potential to trigger further reflections on the 'hidden energy costs' involved in human production and consumption activities and which give rise to depletion of resources in places which may be geographically remote or outside the realm of one's consciousness.

The activities described so far place emphasis on the power of interactive pedagogies which harness prior knowledge, memories, and collective frames to stimulate new ways of seeing and to integrate differential experiences and perceptions. The activities, however, were also indicating the effort required to displace one's gaze from 'the nature out there' as an abstract concept, removed from us, to 'the nature within', to recognise our inherently 'grounded' biological position within the biosphere.

In the following set of examples, we aimed to explore more closely the role of the body in enabling participants to recognise themselves as part of the natural world and in mutual interdependence with other living forms. In line with the ideas expressed earlier on embodied cognition, multiplicity of perspectives and awareness of the filters we pose upon perception, the following set of activities illustrates the power of knowing through the body to develop awareness of one's affiliations and complex, bio-physical entanglements with the natural world.

2. Childhood Memories and Experiences in Natural Contexts

Retrieving Memories of Childhood

It is common for young people to develop a perception of scientific knowledge as the knowledge of *something,* rather than knowledge that is socially constructed and negotiated. Teaching strategies that are heavily reliant on explanation and demonstration contribute to *"thingifying"* views of science (and of the world itself), often generating a sense of alienation, if not fear, toward nature. However, the emotional dimension of knowing nature plays an important role that, perhaps, has been underestimated in our increasingly urbanized society. We mention here briefly an activity that we have been proposing for many years to future secondary school teachers and which has provided outcomes that continue to move and encourage us in our educational work.

After a short moment of silent concentration, we ask student teachers to write down a vivid recollection from childhood that is connected to nature and to explain why it has remained

so strongly impressed in their memory. What follows are two examples of their comments.

- *Afternoons spent at my uncle and aunt's country house in Sicily. A swing made of a wooden board and hanging from a tree—the wild asparaguses, the places where I was running.*
- *The colour of the bluebottles, which I have never seen any more in the fields. I was going looking for them on my bicycle.*

What is remembered is generally associated with complex experiences, an element of intense sensory perception (colours, smells), a human presence (children, friends, and grandparents) and a dimension of doing (running, building, hiding, rolling). Such memories trigger strong emotions, a sense of astonishment for having temporarily forgotten about them and a desire to narrate and to share.

Triggering memories of nature points to the importance of engaging the senses but also to recognise how learning as a process is also a profoundly embodied experience. Unfortunately, the *thingifying* experience of learning science (Colucci-Gray and Camino, 1999) is also a means for *thingifying* the body, described as an accumulation of parts, and static. With a view to formulating an understanding of sustainability as a process of actions in the world, in the manner of Gandhi's Constructive, action-orientated programme, a renewed understanding of the body in action was also required.

We, human bodies

The literature which asserts our profound relationship with the natural world and the fundamental role played by nature in our ability to express ourselves as social and creative beings is extensive and ever-growing. Within the realm of sustainability studies, some authors give great importance to the competences that can be developed through direct contact with nature, through sensorial awareness, without the mediation and cultural transfer of information (Boeckel, 2013). In this respect, Arne Naess was a great anticipator of these ideas and recognised the mutuality of affiliation between human self and nature for loving ourselves is inextricably linked to loving and valuing that which we believe should support us. As recalled by Thomas Weber (1999), the new environmentalism in the form of deep ecology very closely mirrors Gandhi's philosophy.

Through science, however, we have become accustomed to adopt as much as possible an objective and neutral approach towards what we set out to know. 'The human body' is no exception and it is through the objective and 'clinical' attitude that both scientists and doctors relate to the body, as an object set against a background, a part isolated from the rest. It is also through the same approach that the body is often considered in school, however much we – and each one of us as human beings – know the body in many other ways because of the experience we have of it as subjects. The adoption of a reflexive approach, as a way of looking directed towards oneself, has produced sophisticated understandings of the 'essence' of the body in other cultures. Particularly the Hindu and Buddhist traditions over the course of millennia have elaborated inquiry techniques and practices of control of the body leading to a rich set of 'first person' knowledge (Wallace, 2000). As indicated by Ricard (2003), a French biologist who became a Buddhist monk - "*the texts of Buddhist contemplative science are precise, clear and coherent. […] Their methodology is rigorous, and their findings corroborate those of others and stand up with just as much strength as any mathematical reasoning."* (p. 231)

In our educational practice, we try to involve students not only and not so much at the level of content (which we draw upon to provide examples, summary diagrams and further readings) but at the level of their own interpretive schemas. We encourage them to view and to interpret the body in many different ways and to integrate the different approaches to build a rich and complex view

in which their creative and personal experience plays a central part. An interesting challenge for educators is to help students to 'recompose' their own 'ecological self' by developing the insights provided by scholars. For example, Joanna Macy, in the early nineties, proposed to extend the boundaries of one's own body, which [*...] is being replaced by wider constructs of identity and self-interest-by what you might call the ecological self or the eco-self, co-extensive with other beings and the life of our planet. It is what I will call "the greening of the self"* (Macy, 1990, p. 53).

As Thomashow puts it *(*1996, p. 3), *ecological identity refers to all the different ways people construe themselves in relationship to the earth as manifested in personality, values, actions, and sense of self. [...] The interpretation of life experience transcends social and cultural interactions. It also includes a person's connection to the earth, perception of the ecosystem, and direct experience of nature.*

In this light, our 'lessons' on the human body are structured in such a way to involve and to include everyone and to offer the possibility for everybody to play a part so that 'a plurality of legitimate perspectives' can be gathered. This kind of approach is interdisciplinary by its very nature, in that it draws upon and makes connections between physics, biology, chemistry, but also linguistic insight and philosophical reflection.

In the following section, we will outline some of the sequences that we have tried out with university students (and which are variably connected with one another):

- language and ideas of the body
- embodied cognition

Language and ideas of the body

Researching the metaphors which are used to describe and explain the human body can help to uncover underlying paradigms and worldviews. Thus, the body can appear to us, from time to time, in different ways (with some important consequences):

Table 1 Metaphors for understanding the body

container (with 'parts' contained within)
machine (requiring 'fuel' – food – in order to 'perform', through movement, sport etc.)
slave (executive the commands of the mind)
chemical factory (transforming matter through metabolic processes)
river (a dynamic reality, crossed through by flows of energy and matter)
system (made of different organizational levels which are mutually interacting)
manifestation of uniqueness (expression of a unique package of genes)
witness (of a family history)
treasure box (containing traces of an ancient evolutionary process)
cluster (of cells)
ecosystem (inhabited by billions of other creatures)
opportunity for expression (through dance, sport, music, singing ...)
autopoietic machine (able to self-construct by drawing upon resources in the external environment)
multi-layered structure (according to yoga tradition: thin, causal, coarse body)

Some numerical data can help us to understand our complexity, which is derived from multiple organisational levels, from molecules to cells and apparatuses, but also from the co-existence and exchanges with our own 'guests' *(*Giordan, 1999): "*A billion of living things, far larger than the number of body cells, inhabit our body... each one of us is hosting a large variety of species (more than 50.000): a real zoo indeed! Some of them are strolling freely over the surface of our skin, others are more 'integrated' within the*

intestine and the mucosae. In 99, 99% of cases, cohabitation is peaceful…"[2]

'Feeling' and recognising ourselves as ecosystems is a helpful way to learn to 'decentre', to develop an 'eco-centric' view. This is an additional view of our own body, which becomes part of the repertoire of views we already hold. While the activity was originally conducted with university students and prospective teachers, the same activity can be proposed to secondary school students, interpreting the list of metaphors, and enriching the list with some of their own. In this way, the plurality of legitimate views becomes richer.

Embodied cognition

From the activities conducted with the students on their understanding of the body, we moved into the realm of primary education, working with a schoolteacher and her class. One of the obstacles to learning which is increasingly expressed by teachers in recent years is the difficulty of students to 'focus' attention. Young people are lively, intelligent, and they generally bring to school a wider set of information and cognitive skills as compared to those shown by their older siblings. Yet, they struggle with concentrating, they are restless. To deal with this problem creatively, we have directed our attention towards the interaction between mind and body. Silence was the threading theme of a series of activities proposed by a primary teacher to help her pupils (9-year-old children) to achieve serenity, develop attention, and entering contact with the natural environment. As part of the activity, the children periodically met Dida, a Zen monk, for a few weeks. No reference was made to religious views, only the suggestion to encounter 'silence'. *"Sitting still with a correct body posture (this posture enables us to keep still so that there is time for experiencing a deeper contact) our breathing is calmer; by breathing calmingly also the mind is calmer; and here it is, in the quiet space of body-mind-breathing, in a natural and spontaneous way, serene attention emerges, observant and open participant in the non-separation of phenomena of which we are integral part"* (Ferrando et al, 2005).

Here is the comment - one of many - of a girl, Rachida, who writes: *"... to me silence means that when I put my left hand over the right hand and the two thumbs get closer I feel that I am 'holding' silence. Hence for me it is as if I was 'praying' that silence that I hold in my hands. When I sit to being in silence I feel all concentrated, as if I was a tree, with the feet on the ground and the head in the sky..."*

Multiple relations and relations everywhere

Drawing on the insights offered by Gregory Bateson, the process of learning cannot be disentangled from the ecosystem of relationships that are material, social, biological, genetic, and evolutionary and in which we are immersed. In his book, Mind and Nature, Gregory Bateson (1980) asks us to consider: "*What pattern connects the crab to the lobster and the orchid to the primrose and all four of them to me? And me to you?"* (p.8). Bateson's insights into 'thinking relationally' invite us to carefully consider patterns of relationships across time and across space, as occasions to develop our awareness of being part of a system of mutual relationships that we define and by which we are continuously defined. Through the development of a set of cards, we drew on the opportunities offered by a flexible tool for encouraging students to think about the multiplicity of roles performed by living things in the ecosystems (Figure 3). As we illustrated earlier, however, being in-role also means being part of a web of relationships, exchanges, and interdependences. This activity was first developed in Italy, by Elena Camino, as a stimulus for teachers reflecting on the limitations of classifications as tools for gaining knowledge of the world. It was then adapted by Laura Colucci-Gray, in a science education course offered to future primary teachers in Scotland. The aim was to encourage participants to acquire

[2] Authors' translation from the original French.

consciousness of the limitations of description, and the tendency of formal school science education to 'thingify' the world with crystallized concepts. Abstract knowledge, provided as a set of consolidated notions, is disconnected from real experiences and most importantly from the nature of living processes, which are always in ongoing and dynamic flux. The first activity "What relationships?" asked students to identify relationships connecting the pictures on the two sides of the sheet (Fig. 3).

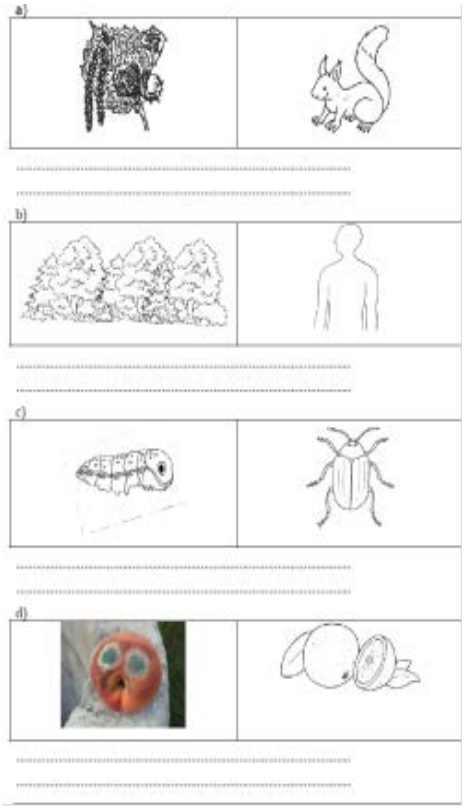

Figure 3 Relationships everywhere

The activity proved challenging for participants who were not used to thinking about the interactions that exist - in time and in place - between organisms which are normally conceived of being separate as they are placed in different categories (i.e. plant/animal). Also, when thinking about ecological relationships, students tend to be more accustomed to identify 'feeding relationships' (the nut eaten by the squirrel) while they were less familiar with thinking about behavioural patterns, e.g. competition, collaboration, support or companionship, such as the case of the beetle and the bug, or transformations occurring over time (ripening and rotting of fruits).

This activity was planned as a springboard for students' creativity, to encourage them to explore new ways of seeing, as commented below:

- *I realised that different organisms are a lot more related than I thought;*
- *I enjoyed the irony of fir and fur. It means the same thing for different things.*
- *I enjoyed thinking about the different animals in details; I found it difficult to think of non-obvious relations; I realised that even the most dissimilar things relate.*

Further to this activity, Scottish students were encouraged to extend their 'relational view' to include themselves within the web of relationships, through their bodies, in the living world. The activity with cards became an organising tool for the facilitator to connect ecological concepts which are normally covered in science, with learning outdoors, as a new curricular area in the Scottish primary curriculum. So, students were invited to go outside to undertake a series of experiential tasks (Fig. 4), which are reminiscent of some of the activities described earlier, recognising the body as a system and becoming aware of the flows of energy and materials crossing the body at all times. Their body became an instrument for building new knowledge about the world and their own position within it.

1. Stretching and warming up
2. Looking for evidence of existing relationships
3. Myself in relationship: walk around a tree for 1 minute
4. Stand up against a tree for 1 minute
5. Push against a tree as strongly as you can…
6. Open your mouth and breathe the air…
7. Stand still…
8. Playing hide and seek…

… and respond to the question: what relationships?

Figure 4 Experiential tasks to perform outside

Throughout the course of the activity students commented on their knowledge, sensations, and surprises derived from direct exposure to the environment:

> *I discovered there was a relationship between the air and the fumes from the road. I could taste the chemicals;*
>
> *I discovered that when you take the time to observe with your senses you see things you do not normally see;*
>
> *…energised! Fresh air is so good for you! You are closer to nature than you think. You just choose to ignore it.*
>
> *I discovered that if you taste the air and think about it then you can actually distinguish the air.*

Conclusions

Ideas about knowledge

The fierce critique by Gandhi of Western society[3] is widely known to many people, as is that of modern science and technology expressed from the beginning of the nineteenth century in the text *Hind Swaraj* (Gandhi, 1909). Less known, and only recently acknowledged (Diwan & Lutz, 1985; Visvanathan, 1997; Prasad, 2001; Anup San Ninan, 2009), are the numerous arguments proposed by Gandhi and by those following in his footsteps, such as Kumarappa and others, which highlight the close interconnections between science, economics, social relationships and education in the rapidly developing technological society.

One of the scholars who took on the task of extending the field of 'Knowledge Swaraj'(KICS, 2009) - Amit Basole – refers back to the concept of lokavidya (loka = folk; lore = knowledge), a term pointing to the body of knowledge held by a society. It is not only, nor principally, an abstract body of consolidated knowledge, but rather the knowledge which is implicitly held by the community, extensively drawn upon for practical activities that are often considered to be of marginal importance. It is a body of dynamic knowledge which enables people to adapt to new and changing life circumstances: *"The lokavidya perspective recognizes that ordinary life is a centre of knowledge production and not merely an 'implementation' of knowledge generated elsewhere"* (Basole, 2009, p. 10).

With their holistic view, Gandhi and his followers were precursors of many of the considerations expressed throughout the nineteenth century by individual Western thinkers, who were often isolated and 'working against the current' (e.g. Bateson, 1980; Illich, 1973, 1981; Martin, 1979, 2005; Sachs, 1987; Schumacher, 1998). As pointed out by Ravetz in a recent essay*:*

"In the present period, Gandhi's message has (so far) been less diluted than some of the others. Let us make a list of the attributes of a science based on Satyagraha, focused on ourselves. These include awareness: of one's own ignorance and propensity to error; of the readiness to learn from anyone, be they a student or a citizen; of responsibility for the unanticipated consequences of one's discovery

[3] This civilization is such that one has only to be patient and it will be self-destroyed (Gandhi, 1909)

or invention; of the possibility of doing evil in the name of good; and of the contradictions that afflict anyone who faces the corrupting pressures of power or responsibility" (Ravetz, 2006 a, p. 16).

In this view, the project of Swaraj brings together ideas of humility, uncertainty, collective dialogue and self-emancipation within a view of economic development which takes account of change and respect for others:

"The process of integrating non-academic actors in knowledge production for attaining social goals is central […] reflexivity and social accountability refer to both researchers and involved stakeholders, and to the interactions between them. This type of reciprocal and critical reflexivity can only occur through mutual learning". (Polk & Knutsson, 2008, p. 645)

Educational practices

As we tried to illustrate in the course of this article, the ideas of Gandhi and his followers made an important contribution to educational practice. As Prasad (2001) underlines, the popularisation of science, according to Gandhi, was not a linear transfer of knowledge from the expert to the layperson, but had to be necessarily a collaborative effort, in a process of mutual benefit for all involved: "It *is clear that in Gandhi's Nai Talim, science education was not to proceed by pursuing islands of excellence in a sea of mediocrity. Work was to be done on the base of education so that no hierarchies of knowledge were created between the scientists as experts and the people. He wanted a proliferation of scientists and engineers in the villages, an increase in India's scientific manpower that would not be measured by the number of university degrees in science, but in creating scientists who would be true servants of the nation" (*Prasad, 2001).

Central to the educational programme outlined by Gandhi is manual, practical work[4]. In Gandhi's anthropological and pedagogical conception, the spinner (*charkha*) is the symbol of nonviolent practice, the spearhead of a slow, silent and peaceful revolution, and yet gifted with an irresistible power of casting songs of hope for humanity's future in its advancing. From a strictly educational point of view, manual activity is proposed as a component of teaching and learning that goes - hand in hand - with all other disciplines, providing a solid structure for developing every process of knowing. From this, an innovative and fascinating approach emerges, which proposes teaching elements of history, geography, numeracy and geometry by means of embodied experiences and practical work. It is through practical work that people can become aware of the entanglement of time, activity and resources as it can be experienced through different modes of living. It is also through practical work that people can find opportunities to create something new from what is already there and existing, gaining fulfilment and self-actualisation.

The Gandhian approach to scientific research and science education can also be recognized in the thoughts of a leading western researcher, Brian Goodwin, who made key contributions to the foundations of bio-mathematics, complex systems and generative models in developmental biology. He was one of the prominent scientists who suggested that a reductionist view of nature will fail to explain complex features: *"[…] the university concept will have to be radically rethought in terms of an education process that provides people with the practical skills needed to support their local community as well as an understanding of the cultural history that has brought us to the present moment of transition. […] there will be a*

[4] *"Our education has got to be revolutionized. The brain must be educated through the hand. If I were a poet, I would write poetry on the possibilities of five fingers. Those who do not train their hands, who go through the ordinary rut of education, lack music in their life." M.K. Gandhi, Harijan, 18-2 '39, p.14-15*

diversity of learning possibilities within this system, appropriate to different individual interests, but they will all be grounded in a common understanding of ecological and cultural principles as expressions of a creative process in which everything is engaged, human and non-human, animate and inanimate" (Goodwin, 2007, p. 337).

Practical skills, diversity of learning possibilities, an understanding of ecological and cultural principles, creative process, cooperative dimension… these are the principles which guided our practice. These are also the key terms of an approach that – stemming from Gandhian thought – we wish to encourage and promote so that it can spread - sideways - within our globalized societies.

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Biophilia as Emotion

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Abstract.
Biophilia is defined as the innate human tendency to experience a bond or deep connection with other forms of life. It is innate, but not instinctive, and it is based on a set of learning rules that appear to be genetically determined. The ways through which biophilia is manifested strongly suggest that would be best described as an emotion, intended as an immediate and consequent reaction to a natural stimulus, which may be positive (biophilia, *sensu strictu*) or negative (biophobia). In this article, we will attempt to contextualise biophilia and biophobia within the two principle theories of emotional development in the child: the Socioemotional Development Model by L.A. Sroufe and the Differential Emotion Theory by C.E. Izard. Whatever the origin and ontological development of biophilia may be, it seems clear that the biophilic emotion constitutes a fundamental resource available to all human beings who are aware of their dependence upon the natural processes of this world, from which each of us draws physical, psychological and spiritual nourishment.

Key words. Biophilia, emotional development, affiliation

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***Perspective**: Theoretical visions*

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Biophilia and biophobia as emotions

Emotions are complex subjective states in which biological, cognitive and social components are interrelated and influence behaviour. Evolutionary or ethological theories of attachment (Bowlby, 1988; Van der Horst, 2011) suggest that children come into the world biologically pre-programmed to form attachments with others, in particular in terms of infants' emotional ties to caregivers as an evolved response that promotes survival. Infants produce innate 'social releaser' behaviours such as crying and smiling that stimulate corresponding innate caregiving responses from adults. What creates the attachment is the nourishment provided, not so much in terms of food as of care and responsiveness. In our present study, we wish to consider the connection between relationship and emotion in terms of the nourishment that can be provided by the kind of evolutionary affiliation posited within the theory of biophilia, as an emotion that arises from the phylogenetic history of *Homo sapiens*.

Biophilia is defined as "the innate tendency to focus upon life and lifelike forms, and in certain circumstances to affiliate with them emotionally" (Wilson, 2002, p. 134). It manifests as attentional capacities and asymmetrical empathy towards that that appears alive and animated (Barbiero, 2011). According to E.O. Wilson, biophilia "is the innately *emotional* affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" (Wilson, 1991, p. 31, italics ours). In this article, we will explore biophilia as an emotion that arises in the interplay between genetically determined learning rules and stimuli from the natural world; an emotion that in some cases may be positive, reflecting an enjoyment of the various manifestations of Nature (biophilia), or in others negative, coupled with the sensation of fear or disgust towards certain manifestations of Nature (biophobia). As such, we will consider biophilia and biophobia as an emotional response that is immediate and pertinent to Nature's stimuli.

We contextualise biophilia and biophobia within the two main theories of emotional development in children: the Socioemotional Development Model by L. Alan Sroufe and the Differential Emotion Theory (DET) by Carroll E. Izard.

The Socioemotional Development Model

L. Alan Sroufe, Professor in Psychopedagogy at the University of Minnesota, retains that at birth children are endowed with a single undifferentiated emotional state that evolves over the following months into emotions that become ever the more differentiated. In newborns, a state of generalised activation can be recorded in the brain, although the intensity of this activation may vary. If the level of activation is too intense or continues for too long, negative emotions develop. Positive emotions, on the other hand, develop as a result of moderate fluctuations in the level of activation. Sroufe proposes that this *activation* forms the physiological basis upon which an emotion is able to develop on the psychological level. Within this progressive process of differentiation, Sroufe specifically identified three principal routes that are already distinct from each other from as early as the baby's first months of life: the pleasure-joy system, the circumspection-fear system and the frustration-anger system.

Within the first few days of life, the baby produces a type of smile known as the "endogenous smile", forming part of the 'pleasure-joy' system, caused by a slight fluctuation in the level of physiological activation. This type of smile manifests during moments of pleasure (it is not by chance that it occurs most often during deep sleep), but it is not yet an expression of joy. Smiles generated during the awake state are also produced in function of low levels of stimulation; whilst being tickled, for example, which induces physiological activation. Such expressions cannot, therefore, be attributed

to a context or to the capacity to assign meaning.

Within the first 2-3 months of a baby's life, the first emotions appear, although they are not yet differentiated. At this age, a baby is able to produce a "social smile", signalling an emotion of joy. The baby's reaction is now determined by the contents of the event that triggered the smile, and not by a simple stimulation leading to activation. Thus, the response is no longer physiological, but instead psychological and, in part, even cognitive. Indeed, it coincides with the period in which the baby starts to recognise the human face. From the 3rd month of life, the smile and the perception of pleasure evolve into the emotion joy that is clearly differentiated and that will principally manifest as "active laughter" (Sroufe, 2005). Around 8-9 months, babies will smile in immediate response to the appearance of their mother or whilst playing peekaboo (Sroufe, 1995, p. 141). Thus, it has become the significance of the event, and not the event itself, that acts as the stimulus.

A very similar developmental course can be observed in relation to the 'circumspection-fear' system (Sroufe, 2009). Crying in the newborn is essentially produced by stimuli that capture the baby's attention for a prolonged period of time, provoking "forced attention" (Sroufe, 2009), or by stimuli that are too intense and thereby "startle" the child, or by sensations of physical pain. In these cases, it is the state of physiological activation that varies, whereas the content and the significance of the triggering event are irrelevant. This reaction of discomfort represents the core of the emotion fear, in response to which circumspect behaviour is activated (Sroufe, 2009). Around 4 months of age, the unknown – for example, the appearance of a person unknown to the baby and not belonging to their affective circle – can startle the baby or provoke forced attention. The baby manifests a state of unease and cries. Although this does not regard a true emotion of fear, the emotional reaction is no longer only physiological and generalised, but involves the psychic sphere as it is determined by the contents of the event. Fear, as an emotion, is an immediate reaction to a specific negative event occurring to the baby (Sroufe, 2005). This type of reaction appears around 8 months and initially corresponds to fear of the unknown (Sroufe, 2005); successively, around the age of 12 months, it extends to the comprehension of a determined action within a mental scheme with negative connotation (Sroufe, 2009). Summarizing the above: three phases can be attributed to the circumspection-fear system: forced attention in the neonate; circumspection at around 4 months of age; and fear, starting at around 8-10 months of age.

The third route of differentiation constitutes the 'frustration-anger' system (Sroufe, et al. 2010). Anger is another emotion with a corresponding precursor. In the first 5 post-natal months, the baby is able to experience frustration and discomfort. If, for example, the baby is physically restrained, then it is probable that he/she will manifest a reaction that is very similar to that of forced attention, a form of constraint that over-stimulates the child (Sroufe et al. 2010). The experience of being constrained progressively evolves into one of frustration. The emotion anger appears from 6 months of age, as an immediate reaction in response to the interruption or the impediment of an intentional act that the child intended to do.

In the theory of emotional differentiation, each emotion appears via ontogenetic developmental stages that arise in parallel with the development of sensory motor intelligence. All emotions originate from a precursor state of prolonged physiological activation, of varying duration, that arises in the child at around 5 months of age and that constitutes the basis of true emotion. According to Sroufe, without cognitive processes, emotions in the strict sense would not exist, since it is cognitive activity that guides the interpretation and the effects of the excitation. The principal cognitive acquisitions necessary for the

development of emotions are: the capacity to distinguish between an individual's inner world and the outside; the concept of object permanence; the development of the self as a separate individual; and thought as symbolic representation. These acquisitions could provide a potential correlation between biophilia and biophobia with naturalistic intelligence (Gardner, 1999).

Differential Emotion Theory

Carroll E. Izard, Psychologist at the University of Delaware, developed an alternative theory of emotional development called the Differential Emotion Theory (Boyle, 2015). Izard's model proposes a phylogenetic vision of child development, according to which the emotions are predetermined from birth and programmed to appear at the appropriate moment of development in the absence of any processes of differentiation or evolution. Izard sustains the existence of innate and universal neural programmes that are distinct for each primary emotion (Izard, 1993). He observed that the primary emotions exhibit unique and permanent characteristics that are present from their first manifestation. Thus, the emotions follow a programme of innate maturation and functional adaption and combine into complex configurations. Cognitive development and socialisation he says do not determine the development of the emotions, since the time of their appearance are unrelated. Cognitive development and socialisation provide a 'frame' within which situations can arise that trigger emotions and their cognitive integration, as well as the opportunity to exercise emotional control.

According to Izard, the primary emotions are already well defined since the time of their initial appearance. What vary – according to age, experience and situation – are the cognitive expressions of these emotions. Emotion is necessary because it activates a process of becoming aware of experience. Izard states there to be three levels of experience of which one can become conscious. The first level is that of the "sensory-affective" experience and it manifests within the first two months of life in the neonate. In this period, the expression of emotions is fundamental in order to manifest needs and to initiate the establishment of the mother-baby bond. Interest in the external world is the most prevalent positive emotion; while discomfort and disgust are the most prevalent negative emotions.

The second level regards the "perceptive-affective" processes, which start to manifest from the 4th month of life. The baby passes from a simple discrimination (interesting-disgusting) to being able to manifest selective attention for specific, distinct perceptions of things or people. At this level, the social smile appears as a manifestation of an experience that goes beyond simple interest, thus entering into the sphere of interexchange. The baby starts to understand the difference between interaction with an object and interaction with a person. This permits the expression of the emotions joy, surprise, fear and fury. The baby starts to be aware of the causality and of the importance of reciprocity.

The third level is characterised by "cognitive-affective" processes and it manifests from around the 9th month of life. It is the phase in which awareness becomes independent of the need for perceptive data. The baby can operate on the basis of memory of past experiences and in anticipation of what he believes may occur in the future. In conclusion, we can say that the fundamental point of lizard's theory is the idea that emotions arise already differentiated and that they have a determining role in the cognitive development of the child.

Biophilia and emotional development in children

How does biophilia fit within these two theoretical frameworks of emotional development in the child as proposed by Sroufe and Izard, respectively? The model put

forward by Sroufe and the theory by Izard both describe emotional development as being strongly intertwined with the cognitive and social development of the child. Both recognise the importance of biological factors, such as the physiological maturation of the child, in determining the emotional response, inserted within a process of cognitive and social experience. Sroufe's and Izard's views differ, however, in relation to the appearance of emotions. Sroufe sustains that undifferentiated precursors of emotions exist before the emergence of differentiated emotions. Whereas Izard retains that emotions are already differentiated at birth and that they simply attend the right moment to be fully expressed. The perspective of Izard falls into the evolutionist/functionalist line of thought that presumes mammals, thus not only human beings, to be endowed with a repertoire of basic, pre-programmed emotions. These emotions are already developed because they have a high adaptive value, are required for survival, increase 'fitness', and are relatively independent of cognitive activity. Izard addresses the issue of emotions being innate, but does not contemplate the possibility of biophilia, or biophobia, as being innate emotions. Izard focuses on the concepts of attachment or interest (*philia*) and fear (*phobia*), emotions that usually refer to contact with other people, but not with Nature. Therefore, the problem regarding the definition of biophilia as an emotion remains to be answered, and it will assume different characteristics – and interesting psycho-pedagogical consequences – depending on whether biophilia is considered within the perspective of Sroufe or that of Lizard.

If, as proposed by Wilson, biophilia is established by "genetically determined learning rules" (Wilson, 1993), then, according to the Sroufe's theory, we can reasonably propose that biophilia manifests thanks to a series of stimuli that occur externally. This agrees with the empirical observation that biophilia is only expressed if the surrounding conditions are permitting (Barbiero, 2014). Biophilia can therefore be inserted into the 'pleasure-joy' system of Sroufe. Repeated contact with Nature (involving appropriate contexts) – gently oscillating between contact with Nature and contact with the caregiver – could, little by little, generate a sentiment of affiliation with the natural world. This type of experience would probably lead, as in the case of the appearance of joy, to the prolongation of the single, indistinct state of activation that Sroufe identifies as the original source of all emotions. At the same time, biophobia could derive from the 'circumspection-fear' system. Contact with the natural world, so rich in stimuli and fascinating, could over-stimulate a child by holding his attention for too long and too intensely; this could result in a state of excessive activation and in the manifestation of forced attention: i.e. crying. The attractive force that Nature exerts upon Man could therefore be manifested in two distinct ways: biophilia, as a specific manifestation of the 'pleasure-joy' system, and biophobia, as a derivation of the 'circumspection-fear system. According to Sroufe, the emotional systems have a physiological basis; biophilia could therefore form part of the general state of activation present in the neonate from birth, yet only manifesting itself later on, as is also the case for all other emotions.

According to Izard's Differential Emotional Theory, however, biophilia could also be innate, a kind of treasure held within each one of us, inscribed somewhere within our genetic heritage, and that is destined to be expressed; with cognitive and social development providing a framework only. If biophilia were to be recognised as an emotion, we could study it in terms of its timing and modality of appearance, in the same way that we do for anger, joy and disgust. Following the scheme set out by Izard, we could imagine that the appearance of biophilia occurs, if not already in the first period (i.e. the "sensory affective" period), in the following one: the "perceptive-affective" period. Biophilia also regards asymmetrical

empathy and therefore aspects attributable to the sensory and perceptual development of the baby.

Sroufe and Izard both view emotion as an immediate reaction, consequent to a stimulus. Biophilia and biophobia could be specific emotions that manifest in reaction to precise stimuli. In a child, a meadow might stimulate a positive emotion (biophilia) that entices the child to explore and play within this natural environment. But the same meadow could be perceived by another child as a hostile place, a source of hidden dangers, and the resulting emotion would be negative (biophobia). Thus, it is not Nature itself (the meadow) that generates the emotion, but the perception of Nature that triggers an affective process, be it positive or negative. Biophilia and biophobia could be emotions that become progressively more complex on the cognitive level. For example, it is important that the biophilic child learns to recognise the meadow, the wood and the meandering river as places of potential sources of danger. Similarly, the biophobic child should be helped to perceive the meadow, the wood and the meandering river as a place of interest where they can feel at home, protected.

The passage of the biophilic emotion from the sensorial and perceptive level to the cognitive level transforms it into a source of learning that stimulates the development of naturalistic intelligence (Gardner, 1999). According to Howard Gardner, an Educational Psychologist at Harvard University, the different forms of intelligence can be developed to more or less homogenous levels or in such a way that some become more pronounced than others, provided, that is, that the individual is exposed to the best affective and educational conditions. Considered as emotions, biophilia and biophobia constitute the initial emotional stimulus that reacts to the perception of the 'other-than-self' represented by Nature. In a certain sense, naturalistic intelligence represents the expression of biophilia in its most conscious form, as an expression of the 'cognitive-affective' processes (according to Izard) or as the 'representative-symbolic' organisation of the experience of Nature (according to Sroufe). In both cases, naturalistic intelligence enables a strong bond to be established between the natural environment and the child, and it permits the child to appreciate the effects that his actions have upon Nature. A good relationship with Nature requires an innate sensitivity for all that is living and a marked ability to perceive Nature (biophilia), as well as the capacity of reasoned logic (naturalistic intelligence) that permits the child to identify, categorise and remember each biophilic experience. Considering biophilia as an emotion helps us understand what contact with Nature and in what way this contact should be proposed to the child. If biophilia manifests on the basis of the context, starting from a single undifferentiated emotional base, we must be careful that contact with Nature occurs at repeated intervals (i.e. oscillating), such that it is not too oppressive or prolonged. The child must have a "safe place" available, to which he can return at any moment. Little by little, Nature will start to become part of this "safe place" for the child, a place in which they feel at home. If biophilia is instead an innate emotion ready to manifest itself at the right moment independent of the context, then it is pertinent to educate the child about the environment until, as biophilia progressively manifests, it is able to nourish naturalistic intelligence.

In either case, biophilia as an emotion constitutes a fundamental resource that each one of us has at our disposition; however, in order to make use of this resource, the individual must be aware of their dependence upon – and desire to interact with – the natural processes that physically, psychologically and spiritually nourish us.

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Researching the Sustainability of Teacher Professional Development

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Abstract.
This paper looks at ways of researching the sustainability of teacher professional development. The focus is placed on the relationships within and between learning environments and teacher professional profiles. Two principal perspectives are proposed linking the concepts of autopoiesis, organization and structure as a model for analysing these relationships and those of resilience, transformability and force-field analysis for investigating the sustainability of change and consequent development.

Key words.
Learning environments; teacher professional profiles; professional learning and development; autopoiesis, organization and structure; resilience, transformability and force-field analysis

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***Perspective**: Theoretical, research and educational visions*

***Fields**: Social processes and structures*

***Issues**: Teacher professional development*

Introduction

The aim of this brief and prospective paper is to explore a possible theoretical framework for researching the sustainability of teacher professional development. Sustainability is considered in terms of "an educational culture [that is] a transformative paradigm which values, sustains and realizes human potential in relation to the need to attain and sustain social, economic and ecological wellbeing, recognizing that they must be part of the same dynamic" (Sterling, 2001:22). Putting sustainability at the heart of professional development in education is considered as crucial for its efficacy. The professional development of teachers is a process of professional learning that takes place within the learning environments in which they work. Change must be sustainable for both teachers and environments since together they must be mutually sustaining. The framework proposed draws on various sources from different but overlapping fields that share a common inter- and trans-disciplinary perspective.

Education as a cultural practice takes place within and through the relationships between complex systems that include individuals, groups, the learning environments they inhabit, the communities in which they are embedded and the educational systems of which they are a part. Developments in any of these systems depend on the complex interactions of each one and between all of them. Teachers work in learning environments in order to promote processes of learning. In this respect education can be considered in terms both of the relationship between teachers and the learning processes of their students and of the teachers themselves who learn during and from their endeavour to teach. Teacher education can be seen as the product of teachers' professional learning processes, and the outcomes of their learning can be seen as sustainable teacher professional development when they give rise to something which promotes durable and ongoing change in terms both of thinking (understanding and modifying habits of mind) and acting (experimenting and consolidating new ways of being and doing).

What then are the characteristics of sustainability in professional development and what kinds of approaches for research in this field can be outlined? In particular, this paper focuses on the relationship between individual and group teacher professional development and learning environment development, inasmuch as the learning processes of teachers determine and are determined by the collective learning processes of the learning environments they inhabit and help to build. Teacher development is a motor for change in learning environments but also dependent on propitious conditions within those same environments. At the same time, professional development occurs within the confines of a given professional profile, constituted by the spheres of action involved and the competences required, which in turn determines what is the possible variety of developments of that profile, and the possible ways in which these developments can manifest themselves, in individuals and groups of teachers.

Autopoesis, organization and structure

This relationship between environment, profile and development can usefully be examined by using the description of the nature of living things as systems, both in terms of *autopoesis*, the capacity of a system to reproduce and maintain itself, and of the relationship between organization and structure that defines this capacity, as proposed by Maturana and Varela.

> "… [An] organization denotes those relations that must exist among components of a system for it to be a member of a specific class. Structure denotes the components and relations

> that actually constitute a particular unity [or thing]…" (1987:47).

Organization thus describes the relationships that both constitute a system as a whole and determine its characteristics as a given type. Systems of the same type have the same organization. Schools as learning environments have the same type of organization and this can be analysed as a composite of four variables: *space*, in terms of the physical locations that constitute the environment, *time*, in terms of the definition of when and for how long things happen in those locations, *people*, in terms of the roles played by the participants within the environment, and *activities*, in terms of what is actually done and by whom within the various locations. In the same way, from the perspective of the profile of teachers as members of a profession, organization can be considered as a question of the elements that constitute it. The spheres of action involved within the professional profile of teachers can be analysed in terms of formal and informal contexts, lessons, conversations and meetings, with individuals or groups of students, colleagues and families, while the competences required can be seen as the knowledge-building, communicative, methodological and operational, personal and social abilities developed within these spheres. Within this perspective, competence is considered as:

> … the ability to *orientate oneself* in life in such a way as to promote sustainability. In this sense, *orientation* is considered as identifying a position (for example, in space, in time, within thought processes) and taking a direction (for example, a point of reference, a pathway, a way of proceeding), thereby adapting to the circumstances presented by environments and specific settings. In other words, competence is the ability to understand situations with particular characteristics and act with awareness in order to achieve objectives … (Dodman, 2016: 20).

Structure refers to the particular manifestation of a given example of organization, in terms of the characteristics of these components and their interactions. Just as all cells have the same autopoietic organization, which can then manifest numerous different cell structures, so learning environments offer many examples of different structures that derive from the particular ways in which they decline and combine the variables of space, time, people and activities. In the same way, a professional profile is characterised by different practices within given spheres of action and the various ways in which competences can grow and be manifested. Moreover, a particular cell, or any other kind of system, changes its structure over time, and Maturana and Varela argue that the changes it undergoes are determined by *the nature of its structure at that point in time*, rather than by its interactions with its environment. Structural change is concerned with maintaining autopoiesis. Environmental perturbations encountered "trigger" change, but do not determine it. It is rather the structure itself that determines what can and what cannot be a trigger and what can and cannot be triggered. In this way, we can say that change in learning environments and in teachers themselves depends on the nature of their structure at a given point in time and the extent to which that nature can furnish a predisposition to a certain kind of change. Any attempt at promoting learning environment and teacher professional development that fails to take account of their organization and, more specifically, the particular nature of their structure, will be unsustainable.

How do the structure of a specific learning environment and the structure of a specific teacher profile determine given outcomes? To what extent do they permit or limit, open or close, new horizons for development? In what

ways do they determine the kinds of environmental perturbations that can best trigger structural change in terms of teacher professional development? What follows is an attempt to indicate some areas for research necessary in order to be able to understand and facilitate processes of change.

Relationships within and between learning environments and teacher professional profiles

If we take each of the variables that constitute the structure of learning environments, we can identify various key aspects that characterise the relationships within such systems. In terms of space, features such as the conception of given locations like classrooms, their fixed or flexible nature, the configuration of specific work spaces, the availability and functionality of given resources, all constitute interrelated factors which determine possible changes. Similar features related to time, such as linearity, circularity, duration and flexibility are equally influential. As regards people, of particular significance are the definitions of their roles and the kinds of practices and problems that can emerge in terms of *clarity*, *conflict* or *ambiguity* (between expectations and interpretations of the roles by a given person and between different colleagues), *overload* (in terms of too many expectations or taking on too much) and *underload* (too little to do or having roles that are not stimulating or gratifying), together with the ways of declining those roles in terms of collaboration (working together to help each other according to one another's needs) and cooperation (working together in order to realize common processes and products). The activities which take place in the environment can then be considered as the variable in which space, time and people become manifest through what people do (the types of learning activities proposed), how they do it (what types of interactive patterns and technological resources are used) and how they evaluate what happens and the outcomes produced (the validity and efficacy of choices and the assessment of the learning that takes place).

A complex and dynamic relationship then exists between these variables of learning environments and the components of teacher professional profiles. All the spheres of action outlined above are a specific composite of space, time, people and activities. And each sphere requires and can be a fertile microenvironment for promoting competences. As I have argued elsewhere (Dodman 2016), in terms of all learning processes, including therefore those of teachers as professional learners, competence should be seen as principally a knowledge-building process and not just as a knowledge-applying process, as is often the case in much literature. Research should help us understand what factors facilitate teachers in building knowledge about learning processes, about learners, about external factors which influence learning and other types of knowledge necessary for their professional profile. Research should also focus on aspects of communicative competence such as understanding, interpreting, interacting, narrating, describing, explaining, on aspects of methodological and operational competence such as planning steps and pathways, making and testing hypotheses, using technologies, handling activities, assessing learning, and on aspects of personal and social competence such as reflecting and evaluating, respecting, collaborating, cooperating. Moreover, it is essential to identify and collect indicators (observable data that give information and can be interpreted) for each of these competences and of how durable their nature can be.

Resilience and transformability

A further source useful for offering insightful perspectives concerning questions posed when researching the sustainability of professional development is provided by two terms which are recurrent in much

sustainability literature: *resilience* and *transformability* (Clark, 2001; Raskin et al., 2002; Walker et al., 2004; Chapin et al., 2010; Folke et al., 2010, 2011; Westley et al., 2011).

> We define resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change, so as to still retain essentially the same function, structure, identity, and feedbacks" … and transformability as the capacity to create untried beginnings from which to evolve a fundamentally new way of living when existing ecological, economic, and social conditions make the current system untenable (Westley et al., 2011: 763).

In terms of teacher professional development, *resilience* can be seen as the capacity to reorganize and maintain the integrity of one's professional profile in the face of perturbations (during teaching and all kinds of other situations related to professional learning) while undergoing change, and *transformability* as the capacity to develop new ways of being in order to make that change durable. Within the framework of autopoiesis, the capacity to reorganize and maintain integrity corresponds to structural change that develops in learning environments and teacher professional profiles while preserving their type of organization. In this sense, integrity is a composite of "function, structure, identity and feedbacks", as proposed by Westley et al., and can provide us with a fertile perspective for analysing relationships between space, time, people and activities and between spheres of action and competences, between what can act as a trigger for change and what can be triggered as change. In what ways can we consider integrity in terms of learning environments and teacher professional profiles and their development? In one sense, integrity concerns the capacity to remain integral (both for the school and the individual), in terms of being "whole" or "complete". Change cannot threaten the integrity of the overall organization and its particular structure or it risks causing disintegration. At the same time, while not everything can be changed, change that occurs in a part of the structure still has to involve the whole structure or it risks being isolated and ephemeral, unsustainable because not sustained by the relationships within that structure. In another sense, integrity is also the quality of being "honest" and "just", in that values are rendered explicit and there is a commitment to reflective practice and systematic questioning of ways of acting and being, in order to make them as *coherent* as possible with those values. Integrity is thus a prerequisite for transformability and a predisposition toward change, inasmuch as coherence is not a static state to be achieved but rather a dynamic process of developing new ways of acting and being as well as of adapting to experience and its perturbations as triggers of professional learning in individuals and groups.

Coherence and community

From the perspective of the characteristics of professional learning at the level of the teacher as individual, coherence can be analysed in terms of four interrelated elements that feed into and out of each other. Coherence needs *repetition*, in the sense of continuity and enrichment, in that previous experience is reiterated, but also within the context of the addition of some new element. In this way, repetition leads to *progression*, incorporating the new into the given so as to create a sense of moving in a certain direction, thereby building a pathway to follow. Progression requires *systematicity*, in that there is the perception of interdependence and consequentiality, a clear relationship between specific actions, outcomes and increasingly global dimensions that involve the learning environments in which development takes place. Moreover, systematicity interacts with *pertinence*, thereby meaning that the new is clearly

perceived as significant and useful within one's professional practice, functional in terms of one's professional learning and the subsequent development.

These characteristics of professional learning and development are interrelated with other elements at the level of teachers as members of groups. Change can come about only if there is both a perceived need to adapt to experience, a necessity or desire to move towards new outcomes, and an ability to create and nurture interpersonal relationships. In order to be sustainable, the characteristics of change must co-emerge (manifest themselves in terms of reciprocal needs) and co-specify (define themselves in terms of reciprocal answers) through a process of co-learning within given spheres of action and co-construction of competences within professional development communities ''with the capacity to promote and sustain the learning of all professionals in the school community with the collective purpose of enhancing student learning'' (Bolam et al., 2005: 145). To achieve this, groups need an environmental culture based on a system of shared values and norms, a focus on learning through reflective dialogue, building meaning together through exchanging and conversing. A crucial aspect of the relationship between organisation and structure, resilience and transformability, is the way in which every learning environment develops a particular culture capable of promoting the learning (for students and teachers) that is its very reason for being. To what extent is a given culture able to understand, devise and implement change? To what extent does it facilitate the functioning of groups that must share competences, resources and responsibilities, undertake action and assess the validity and efficacy of what has been planned and the way it has been put into practice?

Teacher professional development and force field analysis

Each one of these questions must be related both to the *here and now* experience of teachers in a given learning environment and the way in which this facilitates or hinders their ongoing development. If, as Sterling states, realizing human potential and wellbeing "must be part of the same dynamic", by modifying Lewin's (1936) assertion that human behavior can be analysed as a function of the relationship between a person and her/his environment, we can apply the following equation: Human Potential + Wellbeing = f (Person, Environment). Furthermore, by using Lewin's force-field analysis, we can consider such contexts in terms of factors that facilitate or create obstacles to change (Lewin, 1951). The model proposed is based on analysing the forces driving change and the forces restraining it. Where there is equilibrium between the two sets of forces there will be no change because the *status quo* is *frozen*. In order for change to occur, there must be a phase of *unfreezing* whereby the driving forces can be increased and the restraining forces decreased. In this respect, researching teacher professional development can be seen as providing ways both of identifying and understanding forces at work within the learning environment and also how a process of unfreezing can be promoted in order to facilitate change. If such a process does not take place, the risk will always be that of unsustainable change leading to reverting to old practices as the only apparent way of maintaining structural integrity.

Conclusions

This paper is an endeavour to propose perspectives and consider their applications in research within two interrelated contexts of development: that of teachers as professionals and that of the learning environments in which they work. In order to be sustainable in one of these, change must take place in both. The professional learning of teachers is an outcome of propitious circumstances and occasions, not of direct or

intentional causes, and the particular structure of professional profiles, together with that of as their environments, determine what can trigger change and what change can be triggered. The types of input that can function as perturbations in this sense can be internally-generated through personal experience in teaching-learning situations and collective participation in research groups, as well as externally-generated, for example, by attending courses or seminars and participating in networks and inter-institutional collaborations, or a mixture of both. Research into what types of perturbations can give rise to teacher professional development and how these function can be seen as a question of understanding autopoietic organization and the structures it can give rise to, through investigating the forces that can facilitate or impede the resilience and transformability that permit sustainable development in terms of human potential and wellbeing.

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Sam Kean. The Violinist's Thumb and Other Lost Tales of Love, War, and Genius, as Written by our Genetic Code.

(New York: Little, Brown & Company 2012)

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Dogma was just a catch phrase.

Francis Crick, 1988

When looking at the overall history of DNA studies and the investigations into its multiple functions, what is most striking is the recurrence of representations containing references to the laws of mechanics or informatics, identifying genetic information as the source of any biological alterations of living beings. On the other hand, DNA is not a biological mould able to totally determine the destiny of its possessor, even as far as the details of sexual, political, and cultural preferences, or the diseases that will affect health. Such still-dominant mechanistic perspectives concerning such a complex and multi-faceted phenomenon as DNA reveals what are the prevailing visions in science education and information.

Sam Kean, the American author of *The Violinist's Thumb: and Other Lost Tales of Love, War, and Genius, as Written by our Genetic Code* (New York, Little, Brown & Company, 2012), defines the Human Genome Project which aims to decode the entire DNA of *Homo sapiens* – widely acclaimed as a major scientific achievement – as "arguably the most reductionist biological project ever". Previously in *The Disappearing Spoon and the History of the World from the Periodic Table of the Elements* (New York, Little, Brown & Company 2010), Kean wrote stories dealing with chemical substances, in a fashion similar, although not exactly comparable, to the memorable autobiographic sketches by Primo Levi (*The periodic table*, 1975) and Oliver Sacks (*Uncle Tungsten*, 2001). In his latest book, *The Tale of the Duelling Neurosurgeons. The History of the Human Brain as Revealed by True Stories of Trauma, Madness, and Recovery* (New York, Little, Brown & Company 2014), Kean tackles the field of neurosciences, completing a best-seller trilogy built on systemic elements of science history: the periodic table of the elements, the genetic code and the nervous system.

In more than 400 pages, *The Violinist's Thumb* collects histories of scientists together with their research on the core issue of the DNA filament: the central element of biological reproduction. Kean has the ability to combine narration with scientific information. He provides plausible explanations of human misfortunes and bizarre lives, hypothesising relationships, for example, between the genetic code and a passion for cats, explaining why some people do not have digital fingerprints, and why some individuals have been able to survive the nuclear bombs of Hiroshima and Nagasaki. Indeed, in Chapter III (How Does Nature Read - and Misread - DNA?) we learn that at least 150 individuals, between 6 and 9 August 1945, had the misfortune to move from first of these towns to the other in Japan. Of all the reported double victims, the Japanese government has recognized only one official *nijyuu hibakusha* (double-exposure survivor), Tsutomu Yamaguchi, whose story is reconstructed by Kean, claiming that DNA had a major role in letting him survive both the explosions.

DNA combines genetics and environment.

People attribute to genes any biologic anomalies, from possessing tanned skin like John Kennedy to expressing genius like Albert Einstein. Certainly, genes provide some people with exceptional abilities. Sprinters are given a genic asset granting more elastic fibres and the Jamaican Usain Bolt, winner of all the sprint races at the Olympics in Beijing, London and Rio, combined this gift with that of height and longer legs, being on average 30 centimetres taller than is rivals. According to Kean, genes also have relationships with art, music and maths. For example, thanks to the flexibility of their joints, some people can become unique artists, like Niccolò Paganini – whose ability as a violinist is renowned and paid tribute to in the book's title. Scholars think that Paganini was affected by the Marfan syndrome, a genetic disorder of the connective tissues, making his hands much more flexible than the average person: "… he could unfurl and stretch his fingers

impossibly far, his skin seemingly about to rip apart. His finger joints themselves – Kean remarks – were also freakishly flexible: he could wrench his thumb across the back of his hand to touch his pinky (try this), and he could wriggle his middle finger joints *laterally,* like tiny metronomes. As a result, Paganini could dash off intricate riffs and arpeggios that other violinists didn't dare". The Italian musician had such a gift for producing extremely intricate arpeggios that people said he sold his soul to devil. Kean rather suggests a pact with DNA: a basic genetic anomaly could have bestowed him with such flexible fingers. The Marfan syndrome, however, also brought much pain and he was chronically weak and tired, unable to perform for long periods. The story of Paganini shows also how we are the result both of genetics and of our natural and social environment. A DNA fault enhanced his creativity, but equally important was the social *milieu* in which he grew up. If such a mutation had emerged in a different context, it would not have had such a positive outcome as giving birth to a virtuoso of the violin.

Discovering the DNA structure.

Kean tells the 150 years of DNA history by focusing on characters who are generally less well-known, but are equally important for the scientific basis of genetics. His writing also captures the reader's attention, despite the complexity of the topics dealt with. At school, we all learn that Gregor Mendel (1822-84) demonstrated the existence of what we now call genes making experiments with peas in the garden of his monastery. Kean summarizes Mendel's history and the importance of his research, but he also gives ample space to a less known contemporary scholar, the Swiss physiologist Johannes Friedrich Miescher (1844-95), who was the true discoverer of DNA, having extracted for the first time in 1869 the genetic filament from cells' nuclei. In fact, although it is not commonly understood, Francis Crick, James Watson, and Maurice Wilkins won the Nobel Prize in Medicine in 1962 for their findings concerning the molecular structure of nucleic acids, but they were not the actual discoverers of DNA. Almost a century before Crick, Watson, and Wilkins, Miescher had already identified in the leucocytes of blood a substance he called *nucleon*, later identified as *nucleic acid*, and later on as *deoxyribonucleic* acid or DNA. At the same time, he did not intend to isolate this substance, the existence of which he didn't even imagine, since he was searching for the protein components of leucocytes. To achieve this goal, he set out to recover used bandages – at times, Kean exploits macabre histories to sustain his storytelling – from a near surgery, collect the serum that remained on the patches, filter leucocytes, and from these finally extract the proteins. However, eventually he isolated in the cellular nuclei of leucocytes a new substance showing a major phosphorous content and resistance to proteolysis, i.e. the chemical digestion of proteins. "With experiments using other tissues, – Miescher wrote – it seems probable to me that a whole family of such slightly varying phosphorous-containing substances will appear, as a group of nucleons, equivalent to the proteins". In the following decades, renowned scientists such as Phoebus Levene and Erwin Chargaff carried out a series of research projects that unveiled further details on DNA molecules, including information about the primary chemical constituents and the ways these connect with each other. Without the scientific basis provided by all these pioneers of molecular genetics, Watson and Crick would never have been able to discover at Cambridge in 1953 the tridimensional double helix of the DNA molecule.

Dogma was just a catch phrase.

We owe the idea of DNA as the expression of a "scientific dogma" – an oxymoron – to one of the best-known discoverers of its structure, Francis Crick. He coined this unhappy idea to describe the flow of genetic information in a

lecture on protein synthesis given at University College London in September 1957. According to some scholars (R. Olby, Francis Crick, DNA, and the Central dogma, *Daedalus*, 99, 1970, 938-987; B. J. Strasser, A World in One Dimension: Linus Pauling, Francis Crick and the Central Dogma of Molecular Biology, *Hist. Phil. Life Sci.,* 28, 2006, 491-512), most of Crick's claims were unoriginal. Using a quantity of experimental facts recently published, he interpreted the work of others and, unfortunately, he tried to render explicit assumptions that in his view colleagues had left undeveloped in their own work. At the same time, as of 1956 the so-called *Central Dogma of Molecular Biology* at least formally defines the modalities ruling, one amino acid after another in the duplication mechanism of DNA.

Genetic information does not transfer from a protein to another – as previously hypothesized – nor from proteins to nucleic acid. The sequential hypothesis of Crick identifies a unique directionality for information transmission: "DNA originates ribonucleic acid (RNA) and RNA assembles proteins". This is an extreme simplification, which in the intentions of its authors did not preclude the possibility of an inversion of the information flow, from RNA to DNA for example. However, Crick reused the very same words for a paper on Nature in 1970 (F. Crick, Central Dogma of Molecular Biology, *Nature* 227, 561-563, 8 August 1970) and the use of dogma hindered for a long time any other possible hypothesis.

Eventually, this physicist-turned-biologist Nobel Prize winner changed his mind. He claimed in his autobiography (*What Mad Pursuit. A Personal View of Scientific Discovery,* New York, Basic Books*,* 1988**)** that he did not know the meaning of *dogma* exactly, but that he liked it because it seemed erudite.

Epigenetics, hereditariness, environment and education about DNA

In a passage dedicated to epigenetics *(Easy Come, Easy Go? How Come Identical Twins Aren't Identical,* Chapter XV), Kean explains how DNA mutations could influence the future of our species. DNA and above all RNA do not limit themselves to codifying proteins. In fact tens of RNA types exist, that act as regulators, while only three types are sufficient for genetic duplication: messenger, transfer, and ribosomal RNA. The hypothesis of biologic reductionism, according which we are expression only of our DNA, continuously loses ground and support. The principle stating that each gene corresponds to a unique protein is no longer valid and most of the actual degenerative diseases, among these diabetes and tumors, are polygenic. Studies on regulation and modulation of the genetic expression, and not merely on its sequence, gains larger relevance as concern grows for the possible interaction between RNA forms with regulating functions and the varieties of toxic substances ubiquitously distributed in the environment.

An important message emerging from the narrative approach of Kean offers good support to science education. The author repeatedly emphasizes that in the majority of cases scientific protagonists were for a long time convinced supporters of wrong hypothesis, before moving to more sustainable conclusions. Kean highlights, for example, how at the beginning of the nineteenth century, just before Mendel's genetics and Darwin's natural selection were unified within the so-called *new synthesis*, most scientists thought that each chromosome carried only one genetic character, while some believed that chromosomes had nothing to do with hereditariness. Thomas Hunt Morgan – another USA scientist rediscovered by Kean, winner of the Nobel Prize for his studies on the fruit fly, *Drosophila melanogaster* – was convinced that the theory of the relentless pace of evolution was an error of Darwin, until the moment when his own results made him change his mind. Even when the four nucleotide bases (Adenine, Guanine, Thymine, Cytosine) were discovered as

constituting the fundaments of the information codified in DNA, it appeared impossible that these could transmit all the traits from generation to generation. The theory of hereditariness on a protein basis still appeared more probable, because proteins are constructed on the combination of twenty amino acids, i.e. five times the number of nucleotide bases.

Another issue recurring in Kean's book is the inability of the scientific community to appreciate the important discoveries in genetics in the moment when they were made. Mendel was rediscovered long after his death. Barbara McClintock (1902-92), who discovered the transposable elements of DNA — fragments of gene that can move around a chromosome making insertions, suppressions or localized exchanges – gave up printing her results in the 1950s, frustrated by the criticisms of colleagues who refused to publish her works. Thirty years later, in 1983, she received the Nobel Prize for those very same observations. Even the director of the journal that published Miescher's first paper on DNA, eventually praised the contribution as important scientific progress, while considering it in terms of the study of empathic serum accumulating in the wounds.

The general significance of DNA has been of public domain since the middle of the last century and it is still a key concept for the historical awareness of our time. Nevertheless, while our society is based more and more on how techno-science plays a major role in public decisions, a truly comprehensive understanding of DNA functions has made only small steps in within the public audience and remains anchored to anachronistic dogmas. A wider diffusion of scientific information that could condition our choices and influence on our lives would be desirable. Moreover, studies of genetics have found applications that go well beyond biology. The analysis of mitochondrial DNA demonstrates for example that Neanderthal and humans coexisted for thousands of years, until much more recently than previously believed. Applications in archaeology, history and semiology provided fundamental results for human sciences too, as in the work of Alberto Piazza, Luca Cavalli-Sforza, and Paolo Menozzi, *History and Geography of Human Genes* (Milano, Adelphi, 1997). Based on genetic diversification among populations, these authors traced the map of human migration in the last 150 thousand years, confuting any possible justifications of racism on the basis of DNA studies. Therefore, genetics can contribute also to neutralizing atavistic prejudices and discriminations, as it shows that differences among individuals are only superficial and do not go beyond the color of skin or other irrelevant details. For the most part, among ourselves as human beings and together with animals, we are much more genetically similar than we usually suppose.

It is possible to question the way Kean chooses to present his arguments. During seminars he proposes himself as a speaker of *scientific cabaret*, and he places the accent on the extravagant aspects of science history capable of catching attention to make science more accessible, without staying too long on technical issues. "No equations, I promise!" he writes on his website for those inviting him to make speeches. At times, his stories are in danger of resulting much more interesting than the scientific ideas they serve to illustrate, but, as any teacher knows, students often find it easier to learn secondary and anecdotal particulars, rather than the boring, although crucial, parts of lessons. Telling stories is an effective means of illustrating science because the human mind is accustomed to memorizing information in narrative form, while the use of data and formulae makes their understanding more complex. It is probable that instead of remembering Miescher for having been the first at isolating DNA and showing it was not a protein molecule, the mind recalls how the cells he studied were extracted from the serum remained on bandages of patients suffering from chronic plagues. While science

education cannot only use narration, it is indeed true that once attention is caught it is much easier to go deeper into the issues dealt with.

The Violinist's Thumb is a book useful for spreading knowledge about genetics by moving questions concerning DNA from a merely technical perspective to a more accessible ground, thereby opening space for more widespread understanding and participation in debates.

All the books of Sam Kean are appropriate for those desiring to approach science with colorful notes and narrations. Moreover, teachers and specialists should appreciate an approach to science that is important in highlighting the nature of the experiments that underpin it and connecting the history of scientific research to what actually happens around us, beyond the laboratory, thereby making a contribution to the sustainability of science for all.