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Ecological Literacy in Design Education: A Foundation for Sustainable Design

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Abstract: *Responsible design in an era of scarcity and risk associated with environmental problems must be ecologically informed. Ecological literacy is necessary in order to both understand the nature of environmental problems and to respond effectively by designing sustainable ways of living. Embedding ecological literacy into design education is happening at the most progressive institutions – and yet for many others, sustainability education is still virtually absent from the curriculum. Progress is slow despite the fact that natural scientists warn that risks will escalate if we do not take dramatic action. Ecological literacy is a severe challenge as it disrupts educational cultures and challenges basic assumptions about what constitutes good design. While sustainability can seem profoundly difficult, ecological learning is the basis for sustainable design and thus it is a basic imperative in design education. Design education needs to expand its scope of inquiry to include a range of disciplines in order to address complex environmental problems. This paper will present an introduction to ecological literacy for design education, describe six ecological principles including associated concepts in systems design, and explain why critical thinking is necessary to make the work of transforming structurally unsustainable systems possible.*

Keywords: *sustainability, philosophy, design education, knowledge, ecological literacy, epistemology, philosophy of design education, multidisciplinary design education*

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Introduction

Whether or not we are interested in 'the environment' or identify with the concept of being 'an environmentalist' each of us is entirely dependent on the air we breathe, the food we eat and the environment we inhabit for life. Humankind is embedded within the natural world and dependent on ecological systems but we have designed a world that does not seem to recognize this basic interdependence. This is evidenced by the biodiversity crisis and climate change amongst a plethora of other severe and often irreparable environmental problems. In response to these dilemmas, sustainability educators developed the concept of ecological literacy (or ecoliteracy). Ecological literacy is a philosophical and educational programme that recognises humankind's essential relationship with the Earth and re-visions educational, social, political and economic priorities for the design of sustainable ways of living. It is no exaggeration to say that in a society with ever-increasing technological capacity for both beneficial and destructive industrial development, ecological literacy is an imperative not only for prosperity, but for long-term survival.

This paper will describe what ecological literacy is and why it is important for design education. Ecological learning is not simply a collection of facts to be added onto what we already know, but a kind of learning that requires an interrogation of philosophical and theoretical premises. For example, in light of the recognition of humankind's interdependence with ecological systems, what right does any individual have to make pollution that will destroy the well being of others? The paper will introduce the philosophy and ethics of ecological theory as relevant to design education. It will present six ecological principles and link these ideas to concepts in systems design. This paper will also describe why critical thinking is necessary to make the work of transforming structurally unsustainable systems possible.

To be clear, sustainability literacy is not developed in a token 'green week' fashion. Nor is it adequate for sustainable education to be an elective that staff and students can decide to ignore. Ecological literacy is a comprehensive programme of learning that requires its own curriculum and research culture in design education. An ecologically literate education is a basis for informed decision-making and responsible practice across design disciplines. This paper will review some of the difficulties involved with the work of building capacity for sustainability in design education. Ecological learning can be profoundly difficult due to the fact that it challenges basic epistemological assumptions, disrupts powerful vested interests, requires transdisciplinary collaborations beyond the scope of traditional design education and presents disturbing information many of us would rather ignore. For all these reasons, progress embedding ecological literacy in design education is slow. Unfortunately, the risks created by unsustainable development require much faster progress.

The Theory of Ecological Literacy

The ambitious aims of ecological literacy is to create the frame of mind that recognises relations and interdependency with the natural world and supports the development of new capacities to create sustainable way of living. David Orr coined the concept of 'ecological literacy' in 1992 in his seminal book *Ecological Literacy*. Orr proposed a need for education to impart an understanding of the interdependence between natural processes and human ways of living. Orr

stresses that ecological understanding must become a pedagogic priority across all disciplinary traditions, although he often focuses on design education. Ecological literacy demands a type of education that nurtures the capacity to think broadly, a skill has been "lost in an era of specialization" (1992, p. 87). In an industrially advanced society, understanding the ecological impacts of our actions is imperative for informed citizenship and the design of sustainable ways of living. Ecological literacy explores the "roots of our problems, not just the symptoms" (Orr 1992, p. 88) and help learners move from an attitude of "conqueror of the land community to plain member and citizen of it"(Aldo Leopold quoted in Orr 1992, p. 90). Acknowledging geophysical relationships is a foundational step toward transforming learning and cultural priorities.

Ecological literacy responds to crisis conditions in the Earth sciences and offers the potential for addressing environmental problems based on increased knowledge about ecological systems. Scientists warn that we are now exiting the relatively stable Holocene age in which civilization developed and entering a new geological epoch, that of the Anthropocene (Zalasiewciz, Williams, Haywood and Ellis 2011, p. 835). Humankind is responsible for altering the functioning of ecological systems with dramatic consequences. While science has given us power over nature, this technological innovation has not been accompanied with the foresight to use industrial capacities wisely: we will leave our descendents highly degraded ecological systems. Over the past forty years the Living Planet Index (an indicator of the state of biodiversity) has fallen by 30% in Northern Countries and 60% in the tropical world (WWF 2010, p.4,6). This higher number is largely due to the fact that richer nations both source resources and export wastes to the tropics. During this time there has been a doubling of demands on the natural systems. At a global level, the yearly ecological footprint of consumption takes 1.5 years of regenerative capacity or 'biocapacity' (WWF 2010, p.32) to replace. Thus biocapacity continues to shrink while consumption rates continue to grow. Even the most basic analysis indicates the danger of this situation. This information on the vital signs of the planet is included here as it is the basis background knowledge necessary for responsible design education. Even if we have no concern for the natural world, the destabilization of global ecological systems creates grave risks for humanity – including the possibility of human extinction (Ehrlich and Ehrlich 2013).

Ecological theorists suggest that humankind's current environmental problems result from the dominant epistemological tradition. We have inherited a highly reductive way of knowing, an intellectual tradition and a worldview characterized by atomism, mechanism, anthropocentrism, rationalism, individualism and a dualistic tradition pitting humanity versus the natural world. This radical discontinuity with nature constitutes an error in understanding, an epistemological error that is currently reproduced across disciplines and in design theory and practice, resulting in deeply unsustainable ways of living. Society's tendency towards fragmentation makes sustainability an impossible achievement through reductive modes of analysis and the ensuing focus on highly individualistic consumer choices. Ecological literacy addresses these fundamental philosophic errors. The hegemonic epistemology determines that humankind is incapable of perceiving systemic interconnections and ill-prepared to deal with the complexity presented by converging ecological, social and economic crises. It is not that we cannot deal with interconnectedness and interdependence, but that this reality is effectively hidden by the complexity of contemporary conditions and inadequate epistemological premises.

The notion that the dominant epistemological position is a poor reflection of reality was first proposed by Gregory Bateson in his seminal book *Steps to an Ecology of Mind* (1972). Bateson claimed that the dominant map of reality is a poor reflection of reality itself; "most of us are governed by epistemologies we know to be wrong" (1972, p. 493). Sustainability educator Stephen Sterling, builds on Bateson's ideas, explaining that "the dominant Western epistemology, or knowledge system, is no longer adequate to cope with the world that it itself has partly created" (2003, p. 3). This idea has been described in various ways by cultural commentators in multiple fields (Bertalanffry 1969; Bateson 1972; Shiva 1988; Orr 1992; Capra 1997; Spretnak 1997; Sterling 2001; Plumwood 2002; Barabasi 2002; Meadows 2008; McGilchrist 2009). Epistemological error becomes a serious problem when it is embedded, by design, into the world we inhabit. Epistemological error in a technologically advanced society is lethal – since the technology we create will destroy the basis of existence. The basic epistemological fallacy is that humans are separate from the natural world. The theory of epistemological error suggests that humankind is undergoing a crisis of perception, based on misperception. This misperception is a basic failure to perceive relations and recognize humankind as embedded in the natural world. Ecological literacy supports a radical shift in perception to facilitate an understanding of interdependence. Designers can also strategically nurture ecological literacy by creating practices that reveal interrelations.

Maintaining the illusion of humankind's ontological separateness from the natural world is profoundly dysfunctional in an industrialised society. Ecological theory proposes a better form of reason where behaviour is consistent with claims we make in regards to survival prospects. This ecological rationality challenges the "contrived blindness to ecological relationships is the fundamental condition underlying our destructive and insensitive technologies" (Plumwood 2002, p.8). Ecofeminist Val Plumwood explains that the "machine of reason depends on what it destroys for its survival. Its rationality is ultimately suicidal" (2002, p.236). Denial of ecological relations is irrational in so far as it dismisses and denies the ecological context that makes its own life possible. New forms of knowledge aiming for wholeness and participation are contributing to an ecological paradigm, a whole systems ecological worldview that describes humankind's complex interdependency with the natural world.

Complex environmental problems can only be addressed through interdisciplinary collaborative processes. Participation is important for sustainable design because it counters the technocratic shortcomings of traditional design methods, it builds capacities for the implementation of solutions and because it creates a more informed basis for analysis complex problems. Participation creates the learning communities that are necessary for social change to become possible. Sustainability emerges from new technologies and new social practices. Engaged actors are key this social transformation. Participatory design (especially when informed by practices such as action research) can become a tool of emancipatory learning and facilitate the development of agency, making social change possible. This approach to design engages with people as subjects capable of informed decision-making, rather than passive objects to be manipulated into various consumer choices. Participatory processes are also recognized as a basis of better decision-making (as a wide variety of viewpoints create a richer picture of design problems).

Design education will need to expand the scope of its inquiry to facilitate cross-disciplinary knowledge sharing while also paying greater attention to the ecological consequence of design practice. Ecologist and environmental

philosopher Aldo Leopold described an 'extension of ethics' to include the natural world. All ethics, according to Leopold, are based on "a single premise: that we are members of a community of interdependent parts" (1949, p. 98). Industrial processes that result in dramatic unintended consequences complicate the concept of extended ethical boundaries. The power to disrupt ecosystems and the remoteness of these consequences makes contemporary ethics extraordinarily difficult. The problems become not only ethical but practical in terms of building knowledge systems such that we are aware of the potential consequences. Developing ethical standards in this context demands an engagement in transdisciplinary research in order to monitor the wide-reaching impacts of industrial development. Industrial ecologist John Ehrenfeld explains:

> Ethics is responsibility, the idea of being accountable for one's actions, especially the act of avoiding harm knowingly. Modern technological life has diminished the ability to know the consequences of action taken by individuals or by collective social entities, because these consequences are often displaced in time and space, and as such have made responsibilities problematic. One result is the emergence of unintended consequences (2008, p. 60).

Unintended consequences result in a seeming loss of ethical ability to act responsibly because the consequences of our actions are remote. The proper response to unintended consequences is to attempt to understand their nature (rather than to deny their existence). Complexity and our basic inability to know all the potential consequences call for precaution as an operating principle (Enhrenfeld 2008, p. 186). Ecological ethics are a difficult task in a technologically powerful society where technology develops faster than the ethical frameworks and social institutions to ensure humankind uses innovation wisely. Design can play a significant role for the development of social practices to support sustainable ways of living (once it is ecologically informed).

Ecological Literacy in Design Education

The philosophical and practical challenges described above suggest that ecological literacy implies a radical rethink of many basic philosophical premises in design education. Design education must broaden its inquiry to build capacity to understand the social and ecological consequences of the objects, spaces and communication processes created by the designers. As a starting point, David Orr describes four prerequisites to ecological literacy:

- to know that "our health, well-being and ultimately survival depends on working with, not against, natural forces"
- an understanding of the scope and speed of the current crisis and a familiarity with "the vital signs of the planet and its ecosystems"
- a historical understanding of how we have become so destructive
- a practical and participatory approach; "the study of environmental problems is an exercise in despair unless it is regarded as only a preface to the study, design and implementation of solutions" (1992, pp.93-94)

These four building blocks of ecological literacy are only the beginning of a much longer learning curve in an intensive learning process required as a basis for sustainable design.

Making space within design education for these learning objectives can be best achieved with teaching practices such as experiential learning, critical

pedagogy and transformative learning. These practices create possibilities for deep learning. Educational theorist Stephen Sterling describes the learning necessary for sustainable education as 'third order learning', i.e. learning that emphasises capacity building, enactment and transformative practice (2001, p. 78). Once this kind of learning has been made possible, learners will develop greater awareness of ecological issues and potential solutions. These processes build capacities for learners to become able to influence industry to create genuinely sustainable solutions (and not simply quick fixes to avoid market risks or greenwash to deceive consumers). While there is no guarantee that ecological literacy will motivate learners to create sustainable options, without ecological awareness, there are simply no possibilities for sustainable alternatives. Designers who are oblivious to the geophysical conditions that make their own lives possible will be not be able to design effective sustainable solutions. Ecological literacy must be embedded into design education at all levels to attend to the dangerous blind spots created by traditions that ignore ecological realities. The next section will examine principles of ecology and systems design as an example of the kind of learning that will be integrated into an ecologically informed curriculum.

Ecological Principles for Design

Patterns and processes in natural systems provide models for the design of sustainable ways of living. Fritjof Capra explains that ecological literacy requires learners "to understand the principles of organization, common to all living systems, that ecosystems have evolved to sustain the web of life" (2003, p. 201). The 'Nature's Patterns and Processes' concept developed by Capra and the Center of Ecological Literacy (CEL) defines six principles in natural systems. Capra warns that; "it is no exaggeration to say that the survival of humanity will depend on our ability in the coming decades to understand these principles of ecology and live accordingly" (2005, p. 29). These patterns and processes of nature are: networks, nested systems, cycles, flows, development, and dynamic balance. In the following section, each of these principles will be linked to a concept in systems design. These concepts are: resilience, epistemological awareness, circular design, energy literacy, emergence and the ecological footprint. By linking each principle to an ecological design concept this section briefly explores how ecological principles can inform design education.

Networks

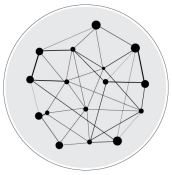

***Figure 1**. Networks. 'All living things in an ecosystem are interconnected through networks of relationship' (CEL website 2012). Image by EcoLabs: 2012.*

Network science has provided new understanding of the structure, properties, patterns and organizing dynamics of systems. Ecosystems are

characterized by robust networks with many interconnections. Highly interconnected complex networks are resilient to shocks and failure because there is a diversity of means for achieving systemic goals. If one node is destroyed, other nodes and links can replace its function. Albert-Laszlo Barabasi explains:

> Natural systems have a unique ability to survive in a wide range of conditions. Although internal failure can affect their behaviour, they often sustain their basic functions under very high error rates. This is in stark contrast to most products of human design, in which the breakdown of a single component often handicaps the whole device (2003, p.111).

Nature's designs are resilient, in sharp contrast to design in industrial systems that are often optimized for maximum efficiency and short-term profitability. Designing for resilience is fundamentally different than designing for efficiency. David Orr describes the basic design principles of resilience systems as consisting of small units dispersed in space, redundancy, diversity, decentralized control, quick feedback, self-reliance and appropriate scale (2002: 114-117). Designing for resilience is thus a core strategy of sustainable design.

Nested Systems

***Figure 2**. Nested Systems. 'Nature is made up of systems that are nested within systems. Each individual system is an integrated whole and - at the same time - part of larger systems' (CEL website 2012). Image by EcoLabs: 2012.*

Nested systems refer to the relationship between systems. The concept is important because systemic dysfunction arises when the relationship between the nested layers breaks down. Ecological economists claim that the relationships between economic, social and ecological systems are currently dysfunctional because the economic system has not been designed as a subsystem of the larger ecological system in which it is embedded (Daly 1996). Due to this fundamental error, the economic system does respond appropriately to feedback from the ecological system. Humankind has thereby created conditions of deep unsustainability. The implications of dysfunction in nested systems can be dramatic: a subsystem will behave as a cancer or a parasitic growth that destroys the system in which it is embedded. Systems design requires an ability to distinguish between different types of premises for different levels of systems. Epistemological flexibility enables "conscious movement between different levels of abstraction" (Ison 2008:147). Sustainable design depends on such new capacities for systems thinking.

Cycles

***Figure 3**. Cycles. 'Members of an ecological community depend on the exchange of resources in continual cycles' (CEL website 2012). Image by EcoLabs: 2012.*

Cycles are perhaps the most obvious pattern in nature (i.e. days, years, water cycle, carbon cycle, etc.). In nature's cycles there is no waste as all elements are endlessly re-used. These natural cycles are a stark contrast to the industrial production where 99% of materials extracted from the earth are 'waste' in just six months (Lovins, Lovins & Hawkins 1999:81). Our economy is dependent on a continuous flow of natural resources, extracted from the Earth and then moving through industrial processes, resulting in various types of pollution. Economic growth has material demands and the need for more resources and energy continues to grow as does pollution and the consequences of pollution (e.g. climate change, toxins in the food chain, water scarcity, etc.). Designers must learn how we can support the development and design of a circular economy in order to eliminate the concept of waste. The cradle-to-cradle method imitates "nature's highly effective cradle-to-cradle system of nutrient flow and metabolism in which the very concept of waste does not exist" (Braungart & McDonough 2002, p.103-104). The imitation of natural processes in biomimicry has significant potential here. The cyclical economy is a central aspect of sustainable design.

Flows

***Figure 4**. Flows. 'Each organism needs a continual flow of energy to stay alive. The constant flow of energy from the sun to Earth sustains life and drives most ecological cycles' (CEL website 2012). Image by EcoLabs: 2012.*

Flows of energy and natural resources provide living systems with essential energy and materials. Flows, feedbacks, stocks and delays between cause and effect are central to understanding ecological processes and are basic concepts of systems thinking. The availability and flow of natural resources will become increasingly important for designers in an age of increasing resource scarcity. One of the most important flows is that of energy, and energy literacy will be increasingly important for designers. The flow of conventional fossil fuels is set to decline sharply due to the increasing scarcity of easy to access reserves (although unconventional fossil fuels are now being extracted with even more

severe ecological consequences than conventional fossil fuels). Meanwhile, global demand escalates as developing nations follow prodigiously wasteful western models of unsustainable development. While pathways to wean modern economies off of fossil fuels have been developed (e.g. *Zero Carbon Britain* by the Centre of Alternative Technologies), there are no current energy sources that can provide energy in such abundance and as cheaply as fossil fuels have in the past (Trainer 2007). The challenge of meeting energy needs with significantly less fossil fuels leads to the concept of 'energy descent'. Energy descent refers to "the continual decline in net energy supply supporting humanity" (Hopkins 2007, p.53) and this is a central idea in permaculture and the Transition movement (due to both the scarcity of easily accessible fossil fuel resources and climate change). Energy literacy is increasingly important in sustainable design education.

Development

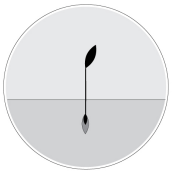

***Figure 5**. Development. 'All life - from individual organisms to species to ecosystems - changes over time. Individuals develop and learn, species adapt and evolve, and organisms in ecosystems coevolved' (CEL website 2012). Image by EcoLabs: 2012.*

As complex living systems develop they exhibit self-organizing properties. Development is a learning process in which 'individuals and environments adapt to one another' (Capra 2005, p. 27). Emergence is a process of self-organization of complex adaptive dynamic systems that results in the creation of entirely new properties. Emergence appears as the result of relationships wherein the whole is greater than the parts. The phenomenon of emergence is significant for sustainability because it implies that systems will exhibit unpredictable behaviour. Emergent properties can have positive or negative implications, but a key insight is that the behaviour of complex systems is never completely predictable. Increasing contextual thinking is an emergent process of reflexive self-organisation and thus ecological literacy itself is an emergent phenomenon. The emergent order of reflective ecological consciousness supports new cognitive and social capacities that could potentially facilitate the creation of more resilient and sustainable futures. As individuals develop relational understanding of networks and complex levels of causality, our collective capacity to attend to sustainability challenges is enhanced. Ecological learning allows us to use these new capacities to respond to environmental problems. New cognitive capacities for systemic thought support the design of sustainable ways of living – but emergence will always remain unpredictable. For this reason, instrumental approaches to design and sustainability will have limited capacity to address environmental problems.

Dynamic Balance

***Figure 6**. Dynamic Balance. 'Ecological communities act as feedback loops, so that the community maintains a relatively steady state that also has continual fluctuations. This dynamic balance provides resiliency in the face of ecosystem change' (CEL 2012). Image by EcoLabs: 2012.*

Dynamic balance is created as systems organise themselves in response to feedback from subsystems and meta-systems. Ecological systems maintain their processes through feedback loops that allow systems to self-regulate within tolerance limits (Capra 2005, p. 28). These limits can be described in various ways using ecological assessment tools such as the 'ecological footprint'. The ecological footprint is a metric that allows us to calculate human pressure on the planet by measuring how much "land and water area a human population requires to produce the resources it consumes and to absorb its carbon dioxide emissions, using prevailing technology" (Global Footprint Network 2011). Ecological accounting tools determine the area of productive land required for services and consumption patterns. Tolerance levels are determined by how much stress an ecological system is under due to resource extraction, pollution and other human activities. A key awareness is that if ecosystems are damaged beyond critical thresholds, dramatic change and even collapse can (and does) occur on various scales. The concept of 'planetary boundaries' is a framework developed by the Stockholm Resilience Centre that establishes boundary conditions and tolerance limits of various Earth systems. This research describes three planetary boundaries as having already been transgressed: climate change, rate of biodiversity loss and changes to the global nitrogen cycle (Rockstrom et al. 2009:1). While this work is receiving widespread critical attention within the scientific communities, it is still far from being integrated into the disciplines (such as design) that will be required to respond (by designing solutions). Ecological footprints and planetary boundaries are an important part of a design education curriculum.

The ecological principles described above (networks, nested systems, cycles, flows, development and dynamic balance) describe ecosystems dynamics. Each of these ideas was linked to a concept in systems design (resilience, epistemological awareness, circular design, energy literacy, emergence and ecological footprints). Nature's processes and patterns are a basis for ecologically informed design and have far-reaching implications. Patterns in the natural world are characterized by interconnectivity. This interconnectivity suggests that reductive modes of analysis will not work to make sustainability possible. Instead, sustainability must be viewed as a collective condition of a culture. Capra explains that 'sustainability is not an individual property, but a property of an entire network' (2005, p. 23). Ultimately, sustainability can only be achieved through systemic understanding and collaboration, since it is the collective impact on the ecological system that will

determine future conditions. While these ecological principles are a foundation for responsible design, transforming unsustainable systems requires not only ecological knowledge, but also critical skills to analyse the political problems that keep sustainable practices marginal. Transforming conditions of unsustainability requires practical ways of working to avoid reproducing current problems. The next section will briefly review the politics and practice of ecological design.

Criticality in Sustainable Education

Creating sustainable alternatives to current ways of living challenges hegemonic ideologies, cultural traditions, powerful corporate interests and public institutions. For this reason, critical thinking about issues of power and the political dimension of design is essential. Ecological design, situated within a unsustainable world, must be critically informed on the relationships between power and knowledge in order to address the interests that support 'business as usual' (or some slight variation thereof). While many new design approaches are systemic, most continue to lack a critical approach to issues of power. This lack of criticality results in a tendency for design to continue to prioritize profitable activities over those that are ecologically sustainable. Institutions and corporations maintain their legitimacy by publicizing green credentials, but are often far less likely to do the much harder work of building capacities to address environmental problems effectively. Ultimately, ecologically literate design must confront the cultural tradition and development frameworks that determine the systemic priorities of the design industry. A critical orientation to issues of sustainability in design is necessary to critique and transform design practice in the context of a deeply unsustainable culture.

The concept of 'sustainability' itself is inherently problematic and ideas on what can be called 'sustainable' are highly contested. Although sustainability can be measured using various environmental assessment processes, the lack of rigorous standards combined with the failure to adjust boundaries of concern wide enough to include the full impact of products, industrial systems and ways of living – results in rampant misuse of the term. Frameworks for making ecological assessment legally binding or holding corporations morally and legally accountable for ecological damage of industrial practices are either extraordinarily weak or non-existent. Thus sustainability continues to be an elusive goal. Whilst individual products proudly proclaim their green claims, the overall impact of consumer lifestyles continues to accelerate the degradation of natural systems. To those who notice the larger context and dynamics of escalating ecological crises, sustainability is a term is often associated with greenwash. Marketing a product or process as sustainable is easier than actually creating sustainable ways of living. Brands have an interest in portraying a green image and so the idea of 'sustainability' is generally used to reassure consumers that unsustainable consumption is morally acceptable, contrary to the consensus in the scientific community that current ways of living are causing climate change (IPCC 2007) and degrading other Earth systems (Rockström et al 2009). Many environmentalists claim that the economic model itself is a primary cause of unsustainable ways of living.

The problem of infinite economic growth within the context of planet with finite ecological resources is increasingly recognized as a root cause of ecological crisis conditions. In 2008 the UK Sustainable Development Commission published *Prosperity Without Growth*? a report that analysed how

quantitative market growth threatens not only social well being and ecological sustainability but also economic prosperity. Author Tim Jackson maintains that neither decoupling nor technological fixes can deliver sustainability in a market economy dedicated to quantitative growth due to the ever-increasing need for natural resources and energy. Economic growth demands the constant increase in the flow of ecological resources, as mechanical engineer Professor Roderick Smith warned in a noteworthy speech at the UK Royal Academy of Engineering:

> …relatively modest annual percentage growth rates lead to surprisingly short doubling times. Thus, a 3% growth rate, which is typical of the rate of a developed economy, leads to a doubling time of just over 23 years. The 10% rates of rapidly developing economies double the size of the economy in just under 7 years. These figures come as a surprise to many people, but the real surprise is that each successive doubling period consumes as much resource as all the previous doubling periods combined. This little appreciated fact lies at the heart of why our current economic model is unsustainable. (2007, p.17)

Ecological economist Herman Daly describes the need for 'a system that permits qualitative development but not aggregate quantitative growth' (Daly 2008, p.1). Fritjof Capra and Hazel Henderson's report Q*ualitative Growth* explains the difference between good and bad growth:

> …good growth is growth of more efficient production processes and services which fully internalise costs that involve renewable energies, zero emissions, continual recycling of natural resources and restoration of the Earth's ecosystems. (2009, p. 9)

Quantitative economic growth demands an ever-increasing flow of energy and natural resources, extracted from the Earth, moving through the economic system and generally returning to the ecological system as waste. This paper has already described the central role of flow of resources in our economic system and the associated problems with resource scarcity and pollution, such as the flow of carbon dioxide waste into the atmosphere causing climate change.

'Sustainability' has been associated with 'development' since the 1983 Brundtland Commission. This dual role for sustainability (meaning 'ecological care' and 'development' simultaneously) has been critiqued from its beginning. Wolfgang Sachs describes sustainable development as "conservation of development, not for the conservation of nature" (1999, p. 34). Similarly David Orton claims: 'with sustainable development there are no limits to growth. Greens and environmentalists who today still use this concept display ecological illiteracy' (Orton 1989, unpaginated). Sustaining or increasing levels of consumption on the diminishing resource base with more people wanting 'better' lifestyles (i.e. more consumption – requiring more resources) increases ecological harm (in the current development framework).

Researchers have proposed terms that reflect critical awareness of inherent shortcomings in the concept of sustainability. 'Just sustainability', 'sustainment' and 'scarcity' are three concepts that challenge the hegemony of 'sustainability'. 'Just sustainability' was coined by Julian Agyeman to prioritize justice and "ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems" (Agyeman et al. 2003, p. 5). Sustainment is a concept used by Tony Fry as an alternative to the "defuturing condition of unsustainability" (Fry 2009, p. 1). Fry writes, "myopically, the guiding forces of the status quo continue to sacrifice the future to sustain the excesses of the present" (Ibid, p. 2). A discourse on 'scarcity' has emerged reflecting, according to Jeremy Till; "a condition defined

by insufficiency of resources" (2010, p. 1) and the contradiction between unlimited human 'needs' and the limits of natural resources. This concept has its own set of problems as constructed scarcities can be made to seem 'natural' thereby justifying austerity measures and punishing the poor for the rampant consumption of the rich.

Despite the justified cynicism caused by the abuse of the word 'sustainability' it remains the dominant term used to describe meeting the needs of the present without compromising the ability of future generations to meet their own needs. Ecological literacy informs the debate on sustainability by revealing that ultimately sustainability is not a feature of a particular product but the condition of a culture relative to its gross impact on ecological systems. Since the cumulative impact of consumer lifestyles, or the ecological footprint of consumption in the UK is 4.71gha and 7.19gha in the United States (WWF 2012, p.144-145), nothing in our culture is sustainable. While the behaviour of certain individuals is below the threshold (i.e. they personally use fewer resources and create less population) the gross impact of the collective system is the indicator that matters (as it is the gross collective impact that cause total ecological harm). Ecological literacy emphasises the contextual and relational characteristics of ecological well being and learning as central to the pursuit of sustainability. Learning to recognize the impact that our ways of living have on the Earth is a basic imperative for intellectual coherence and long-term survival.

Conclusion

Sustainability requires disruptive ways of thinking that confront institutional practices and systems that are harmful to the environment. This paper has described how ecological literacy challenges traditions and educational cultures. Perhaps the greatest problem preventing wide spread ecological learning is the difficulty in acknowledging facts about the impact of humankind's industrial systems on the other living species and ecosystems (as well as our own future and the future of our descendents). Educational institutions avoid these difficult issues by avoiding ecological education. Thus the work of advancing new values that prioritise environmental and social sustainability in education remains a formidable challenge. As environmental problems continue to become more severe, institutions that ignore risks in order to cling onto ecologically destructive models of development and unsustainable design practices undermine their own legitimacy. Fortunately, embedding ecological literacy into design education is happening at the most progressive institutions.

When ecological literate, design becomes a powerful tool for the work of addressing contemporary social and environmental and economic problems. The various design disciplines all have important roles to play in the design of sustainable futures. This paper provides a brief overview of what ecological literacy means for design education. Despite the best intentions of many designers and educators, sustainability remains an allusive goal and ecological literacy remains margin in design education, design practice and in society at large. This situation seriously impedes efforts to effectively address environmental problems. The struggle to embed ecological literacy into professional design practice is situated at universities. Orr stresses the role of the university: "no institutions in modern society are better situated and none more obliged to facilitate the transition to a sustainable future than colleges and universities" (2002, p. 96). Educational theorist Chet Bower claims that the first

challenge for universities is to change entrenched positions that "control the forms of knowledge (including the legitimizing ideology and epistemology)… to recognize the scale and accelerating nature of the ecological crisis" (2005, p. 203). Educational establishments have a responsibility to ensure that students graduate with an understanding of the consequences of contemporary ways of living and the skills to do something about it. Designers are now responsible for the design of future sustainable ways of living; this task will only be possible when supported by ecological literacy.

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