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Ecological Literacy in Design Education

A Theoretical Introduction

Abstract

Sustainability educators developed the concept of ecological literacy *to provide a basis for understanding environmental problems and developing new capacities and critical skills to respond effectively. This paper presents a theoretical introduction to ecological literacy for design education. It starts with a philosophical overview of why ecological literacy is necessary, including details of some of the planet's vital signs. The paper then describes six ecological principles (networks, nested systems, cycles, flows, development and dynamic balance) along with associated design concepts (resilience, epistemological awareness, a circular economy, energy literacy, emergence and the ecological footprint). The final section explains why critical ecological literacy is necessary to make the work of transforming unsustainable conditions and designing sustainable ways of living possible.*

Keywords: design education, sustainability, ecological literacy, environment, systems design

In an era of risk associated with environmental problems, the design disciplines have an important role to play in the creation of sustainable ways of living. Ecological knowledge is a foundation for informed decision-making. The concept of *ecological literacy* was coined by Professor of Environmental Studies and Politics David Orr in 1992 and has since been developed by sustainability educators such as Fritjof Capra (2009, 2005, 2003, 1997), Stephen Sterling (2003, 2001), Richard Kahn (2010) and others. Ecological literacy is relevant across all disciplines but is especially important in design, since design is a practice that is engaged with creating new ways of living. Ecologically literate education is a basis for responsible practice across design disciplines. This goal remains a significant challenge in design education. Ecological and sustainability literacy cannot be developed in a token "green week" fashion. Nor is it adequate for ecological literacy to be an elective that staff and students can decide to ignore. Part of the reason why the challenge of ecological learning is so severe is that it is not simply a collection of facts to be added onto what we already know, but rather it is a kind of learning that requires an interrogation of many basic premises. For example, in light of the recognition of humankind's interdependence with our environment, what right does anyone have to make pollution that will destroy the well-being of others — now and in the future? Partially due to the profoundly difficult nature of this type of question, ecological literacy remains marginal in education and in practice. Since ecological learning disrupts and challenges educational cultures and assumptions about what constitutes good design, there has been institutional resistance to the idea. Nevertheless, it is no exaggeration to say that the future of humanity rests on our capacity to become ecologically literate and to design ecologically sustainable ways of living. There will be no long-term future unless this goal becomes possible. For this reason, ecological literacy is a comprehensive program of learning that requires its own curriculum and research culture in design education.

Ecological Theory

The ambitious aim of ecological literacy is to create a frame of mind that recognizes relations and interdependency with the natural world and supports the development of new capacities to create sustainable ways of living. Ecological literacy is a kind of learning that understands the environment as the material basis for prosperity, and adjusts cultural priorities appropriately. David Orr coined the concept of ecological literacy 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. He stressed that ecological understanding must become a pedagogic priority across all disciplinary traditions, although the book often focuses on design education. Ecological literacy demands a type of education that nurtures the capacity to think broadly: a skill that 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, in the words of the environmentalist pioneer Aldo Leopold, helps learners move from an attitude of "conqueror of the land community to plain member and citizen of it" (Leopold, quoted in Orr, 1992, p. 90). Acknowledging geophysical relationships, and the consequences of these relations, is a foundational step toward transforming learning and cultural priorities.

Ecological literacy responds to severe environmental problems and offers the potential for addressing these problems based on ecological knowledge. 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 (Zalasiewicz, Williams, Haywood & Ellis, 2011). 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 by the foresight to use industrial capacities wisely; as a result, we will leave our descendants highly degraded ecological systems. Since 1970, the Living Planet Index (LPI; an indicator of the state of biodiversity) has fallen by 52 percent (WWF-I, 2014, p. 12). What this means is that in "less than two human generations, population sizes of vertebrate species have dropped by half" (WWF-I, 2014, p. 4). At a global level, the yearly ecological footprint takes 1.5 years of regenerative capacity to replace (WWF-I, 2014, p. 9). Thus biocapacity continues to shrink while consumption rates continue to grow. Even the most basic analysis indicates the danger of this situation. The vital signs of the planet are included here as they are the basic background knowledge necessary for responsible design education. Even if we have no concern for the non-human natural world for its own sake, the degradation and destabilization of global ecological systems (especially the climate system) creates grave risks for humanity (Rockström et al., 2009).

Ecological theorists suggest that humankind's current environmental problems result from a highly reductive way of knowing and an intellectual tradition characterized by atomism, mechanism, anthropocentrism, rationalism, individualism and a dualistic tradition that pits humanity versus the non-human natural world. This radical discontinuity with nature constitutes an error in understanding. This epistemological error (Bateson, 1972) is currently reproduced across disciplines and in design theory and practice, resulting in deeply unsustainable ways of living. Society's tendency toward fragmentation makes sustainability an impossible achievement when approached through reductive modes of analysis and the ensuing focus on highly individualistic consumer choices. Ecological literacy addresses these fundamental philosophic errors. Epistemological error determines that humankind is incapable of perceiving systemic interconnections and is 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 and erroneous epistemological tradition. Ecological literacy addresses these philosophical problems.

Ecologically Literate Design Education

Ecological literacy implies a radical rethinking of many basic philosophical premises in design education. Design education must broaden its inquiry to build capacity for designers to understand the social and ecological consequences of the objects, spaces and communication processes they create. As a starting point, Orr describes four prerequisites for ecological literacy:

- to know that "our health, well-being and ultimately survival depends on working with, not against, natural forces";
- to have an understanding of the scope and speed of the current crisis and a familiarity with "the vital signs of the planet and its ecosystems";
- to have a historical understanding of how we have become so destructive;
- to take 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" (Orr, 1992, pp. 93-94).

These four building blocks of ecological literacy are the beginning of a much longer learning curve required as a basis for sustainable design. Educational theorist Stephen Sterling describes the learning necessary for sustainable education as "third order learning," i.e. learning that emphasizes capacity-building, enactment and transformative practice (2001, p.78). These prerequisites build capacities for learners to become able to influence industry to create genuinely sustainable solutions — and not simply quick fixes or "greenwashing". While there is no guarantee that ecological literacy will motivate learners to create sustainable options, without ecological knowledge there are no possibilities for sustainable alternatives. The next section will examine ecological principles for design.

Ecological Principles for Design

Ecological theorists describe patterns and processes in natural systems as providing time-tested models for the design of sustainable ways of living. The physicist and ecological literacy advocate Fritjof Capra explains that learners must "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) in Berkeley, California, defines six principles in ecological systems: *networks*, *nested systems*, *cycles*, *flows*, *development* and *dynamic balance*. In the following section each of these principles will be linked to a concept in design. This theoretical framework serves as a guide to putting the principles into practice. It should not be considered absolute, since many concepts are relevant for different principles. The design concepts are *resilience*, *epistemological awareness*, a *circular economy*, *energy literacy*, *emergence* and the *ecological footprint*. Linking each principle to a concept informing design strategies, this section explores how ecological principles can inform ecologically literate design education. Each of the following sections begins with a relevant quote from the CEL.

Networks + Resilience

"All living things in an ecosystem are interconnected through networks of relationship" (CEL, 2015).

Network science has provided new understanding of the structure, properties, patterns and organizing dynamics of complex systems. Ecosystems are characterized by robust networks with many interconnections. Highly interconnected complex networks are resilient to shocks and failure because there are a diversity of means for achieving systemic goals. If one node is destroyed, other nodes and links can replace its function. The network theorist Albert-László 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*. This resiliency is different from design in industrial systems, which is typically optimized for maximum efficiency and short-term profitability. Designing for resilience is fundamentally different than designing for efficiency. According to Orr, the basic design principles of resilient systems consist of small units dispersed in space that are designed for redundancy, diversity, decentralized control, quick feedback, self-reliance and at an appropriate scale (2002, pp.114-117). Designing for resilience is a strategy of sustainable design informed by ecological literacy.

Nested Systems + Epistemic Awareness

"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, 2015).

The term *nested systems* refers to the relationship between systems. The concept is important because systemic dysfunction arises when the relationships between nested systems break down. Ecological economists describe unsustainable development as being caused by a dys-functional relationship between the economic, social and ecological systems. The economic system has not been "designed" as a subsystem of the larger ecological system in which it is embedded (Daly, 2008). The economic system does not respond adequately 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 parasitic growth that destroys the system in which it is embedded when it does not acknowledge itself as interdependent with its context. Systems design requires conceptual awareness of embeddedness and the ability to distinguish between different types of premises for different levels of embedded systems. For example, the reductive logic that works within economic processes is not the same as the logic that "works" within ecological processes. Epistemological flexibility enables "conscious movement between different levels of abstract-tion" (Ison, 2008, p. 147). Sustainable design depends on such new capacities for systems thinking, such as epistemic awareness and flexibility across different levels in embedded systems.

Cycles + A Circular Economy

"Members of an ecological community depend on the exchange of resources in continual cycles" (CEL, 2015).

Cycles are perhaps the most obvious pattern in nature (e.g., days, years, the water cycle or the carbon cycle). There is no waste in nature's cycles as all elements are endlessly re-used. These natural cycles are again very different from current industrial production processes where an estimated 99 percent of materials extracted from the Earth become "waste" in just six months (Lovins, Lovins & Hawkins, 1999, p. 81). Our economy is dependent upon a continuous flow of natural resources that are extracted from the Earth and then move through industrial processes, resulting in various types of pollution. Economic growth has material demands. 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 or water scarcity). 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 effecttive cradle-to-cradle system of nutrient flow and metabolism in which the very concept of waste does not exist" (Braungart & McDonough, 2002, pp.103-104). The imitation of natural processes (i.e. biomimicry) is another strategy for sustainable design. Both biomimicry and cradle-to-cradle methods hold enormous promise *if* they are used as part of a larger strategy of economic, social and cultural transformation for sustainability.

Flows + Energy Literacy

"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, 2015).

Flows of energy and natural resources provide living systems with essential energy and materials. Flows, feedbacks, stocks and delays describe a wide variety of ecological processes and are also basic concepts of systems thinking. The availability (i.e. 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. Energy literacy is increasingly important for designers. The flow of conventional fossil fuels is declining due to the increasing scarcity of easy to access reserves. Unconventional fossil fuels are now being extracted with even more severe ecological consequences than conventional fossil fuels (Kitchen, 2014). Meanwhile, global demand escalates as developing nations follow prodigiously wasteful Western models of unsustainable development. While pathways to wean Western economies off of fossil fuels have been developed—for example, the Centre of Alternative Technologies' *Zero Carbon Britain* (Kemp & Wexler, 2010) — 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*, which refers to "the continual decline in net energy supply supporting humanity" (Hopkins, 2008, p. 53). Energy descent 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 includes an awareness of concepts such as embedded energy, energy return on investment (EROI) and the rebound effect, along with knowledge about pathways for carbon reduction. These are all elements of ecological literacy and should be part of sustainable design education.

Development + Emergence

"All life — from individual organisms to species to ecosystems — changes over time. Individuals develop and learn, species adapt and evolve, and organisms in ecosystems coevolve" (CEL, 2015).

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 behavior. Emergent properties can have positive or negative implications, but one key insight is that the behavior of complex systems is never completely predictable. Increasing relational thinking is an emergent process of reflexive self-organization as humankind responds to environment problems. Thus ecological literacy itself is an emergent phenomenon. The emergent order of reflective ecological awareness 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, reductive and purely instrumental approaches to design and sustainability have limited capacity to address environmental problems.

Dynamic Balance + the Ecological Footprint

"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, 2015).

Dynamic balance is created as systems organize themselves in response to feedback from subsystems and meta-systems. Ecological systems maintain their processes through feedback loops that allow nested 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. According to the Global Footprint Network (GFN), the ecological footprint is a metric that calculates 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. (GFN, 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. One key point is that if ecosystems are damaged beyond critical thresholds, dramatic change and even collapse can occur on various scales. The Stockholm Resilience Centre developed the concept of "planetary boundaries" as a framework that establishes boundary conditions and tolerance limits of various Earth systems (Rockström et al., 2009). Rockström and colleagues' research describes four planetary boundaries as having already been transgressed: climate change, biosphere integrity, biogeochemical flows and land-system change. Two of these — climate change and biosphere integrity — have the potential to drive the Earth into a new state (Steffen et al., 2015). While this work has received widespread critical attention within scientific communities, it is still far from being integrated into the design disciplines that will be required to respond by addressing these severe problems. Ecological footprints and planetary boundaries are elements of an ecologically literate design education curriculum.

The ecological principles described above (networks, nested systems, cycles, flows, development and dynamic balance) describe key features of ecological processes. Each of these principles is linked to a concept in design (resilience, epistemological awareness, a circular economy, energy literacy, emergence and ecological footprints) to illustrate how these ideas can inform the design of sustainable ways of living. Nature's processes and patterns are a basis for ecologically informed design. Patterns in the non-human 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 between all elements of a network, 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 in order to analyze the political problems and societal dynamics 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.

Critical Ecological Literacy

Within a highly unsustainable world, design must be critically informed about the relationships between power and knowledge in order to challenge the interests that support business as usual or some slight variation thereof. While some new design approaches are systemic, many 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 traditions, development frameworks and powerful interests that determine the systemic priorities of the design industry (Boehnert, 2014). 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 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 widely enough to include the full impact of products and the industrial systems that support our 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 the ecological damage of industrial practices are often weak or non-existent. Thus sustainability continues to be an elusive goal. While individual products proudly proclaim their green credentials, the overall impact of consumer lifestyles continues to accelerate the degradation of natural systems — the most dramatic of which is climate change.

To many of those who notice the larger context and dynamics of escalating ecological crises, *sustainability* is a term that is often associated with greenwashing. Since marketing a product or process as sustainable is easier than actually creating sustainable ways of living, greenwashing is plentiful. Brands have an interest in projecting a green image, and so the idea of sustainability is typically used to reassure consumers that unsustainable consumption is morally acceptable, contrary to the fact that current ways of living are causing climate change (IPCC, 2013) and severely degrading other Earth systems (Rockström et al., 2009). For many sustainability theorists the economic model itself is recognized as a primary cause of unsustainable ways of living.

The contradiction of infinite economic growth within the context of a 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?* (Jackson, 2009). This report analyzed how quantitative market growth now 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 the resulting pollution. Quantitative economic growth demands a constant increase in the flow of ecological resources, as mechanical engineering professor Roderick Smith warned in a speech at the UK Royal Academy of Engineering:

> . . . relatively modest annual percentage growth rates lead to surprisingly short doubling times. Thus, a 3 percent growth rate, which is typical of the rate of a developed economy, leads to a doubling time of just over 23 years. The 10 percent 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 *Qualitative 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 that are extracted from the Earth, moved through the economic system and generally returned 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; the latter includes the flow of carbon dioxide waste into the atmosphere, which subsequently leads to climate change.

"Sustainability" has been associated with "development" since the 1987 Brundtland Commission report. This dual role for sustainability (simultaneously meaning "ecological care" and "development") 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, the late David Orton claimed: "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 — thus requiring more resources) increases ecological harm in the current development model.

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. Julian Agyeman, a professor of urban and environmental policy and planning, coined the term *just sustainability* to prioritize justice and to "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). The philosopher and design theorist Tony Fry uses the concept of *sustainment* 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" (2009, p. 2). A discourse on scarcity reflects, according to the architect and educator Jeremy Till: "a condition defined by insufficiency of resources" (2011, 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 the idea of 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 rather is 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 United Kingdom is 4.71 gha and 7.19 gha in the United States (WWF-I, 2012, pp.144-145), these two nations have cumulative ways of living that are not sustainable. (The *global hectare* is a measurement unit for quantifying both the ecological footprint and biocapacity). While the behavior of certain individuals is below the threshold (i.e. they personally use fewer resources and create less pollution), the gross impact of the collective system is the indicator that matters, as it is the collective effect that causes total ecological harm. Ecological literacy emphasizes the contextual and relational characteristics of ecological well-being and learning as being central to the pursuit of sustainability.

Conclusion

This paper has described a philosophical foundation of ecological literacy as well as six ecological principles, and it has briefly introduced critical ecological literacy. The work of advancing new values that prioritize environmental and social sustainability in design education remains a formidable challenge. Despite the best intentions of many designers and educators, over two decades after the introduction of the term *ecological literacy*, it remains an elusive goal. Since ecological literacy remains marginal in design education, design practice and in society at large, unsustainable conditions continue to be reproduced by design. The struggle to embed ecological literacy into professional design practice is situated most intensely at universities. Educational establishments have a responsibility to ensure that students graduate with an understanding of the consequences of unsustainable design and the skills to do something about it. The various design disciplines all have important roles to play in the design of sustainable futures. Designers are among the key professionals 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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