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Sustainable Design: A New Paradigm for Engineering Education*

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This essay rejects the notion that we understand sustainability well enough to talk about 'sustaining sustainable design'. The wide-ranging literature is surveyed to explore the contested meaning of sustainability. What emerges is an evolution of the meaning, with enlarging scope and philosophical basis, from an environmental emphasis to a focus on human flourishing and caring. A definition consistent with the most evolved view is that: 'Sustainability is the possibility that humans and other life will flourish on the Earth forever.' Ideas are presented about how flourishing can guide design.

Keywords: sustainability; design; education; engineering; paradigm

1. INTRODUCTION

WHEN I FIRST read the announcement of this workshop, *Sustaining Sustainable Design*, I admit that I was confused. I've been working on understanding sustainability in the context of engineering education for nearly two decades, and I'm still not sure what it means and how to teach it. I taught my first course on sustainability in 1990 [1], and have since then developed and taught two other courses, 'Design for Society' in the mid-1990s [2], and for the last four years, 'Sustainable Design'.

I therefore thought it would be worthwhile to further explore the literature and to communicate what I and others do understand about sustainability, while also bringing attention to contested issues. That is the purpose of this essay. I will attempt to survey some of the wide-ranging and intellectually challenging literature, challenging because of the continual evolution of the meaning of sustainability and also because of the various fields of the writers including philosophy, sociology, education, and ecology. After this survey, I will summarize the insights gleaned for their relevance to current practice, as well as future practice. I reach the conclusion that John Ehrenfeld in his new book, *Sustainability by Design*, has reached, that sustainability 'will require both radical new technologies and new ways of understanding humanness [3]'.

I refer to a new paradigm in the title because that is what it will take for sustainability to emerge. Our current world view, or paradigm, has led us to our current unsustainable state of affairs. Much of our current attempts toward sustainability are doomed to failure as they do not address fundamental flaws in our world views. Therefore, before beginning to explore the meaning of sustainability, I describe our current paradigm.

2. THE MODERN WORLD VIEW

Something happened in the middle of the last millennium as the prevalent western world view shifted from one of social stability and emphasis on transcendental achievements. The Enlightenment reframed the world from one imbued with meaning and enchantment, of cosmic belonging, to one of rational order, mind-body dualism, and the possibility of creating a heaven on earth. As Morris Berman observes in *The Reenchantment of the World*:

> The most important change was the shift from quality to quantity, from 'why' to 'how.' The universe, once seen as alive, possessing its own goals and purposes, is now a collection of inert matter, hurrying around endlessly and meaninglessly . . . [4]

A key aspect of our modern world view is the prevalence of dualism, particularly mind-body dualism. Though this project of separating our minds from our bodies, and ourselves from nature, began at least as long ago as the time of the Greek philosophers, it reached a new level in the Enlightenment as typified by Descartes' 'I think therefore I am.' As Val Plumwood observes: 'The essence of dualistic thought is not the attempt to draw distinctions, even radical distinctions, but is the attempt to establish the hierarchical supremacy of a superior (the master subject) over an inferior (the master's subject). [5] Thus we have the oppression of nature linked to oppression based on gender, class and race. This separation from, and supremacy over, nature is a major obstacle to developing a participative coevolving relationship that is critical to a sustainable world view.

Another important characteristic of our modern

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world view is that we view technology as value-neutral, and simply instrumental in its relationship to us. Yet as Davison points out [6]:

> Technology in all its manifestations is as ambivalent, as unpredictable, as honorable, and as depraved as are human agents themselves. Technology is not the neutral vehicle of human agency, it is the essence of human agency.

He goes on to stress the importance of 'recognizing technology as the practices through which we come to know ourselves, each other, and our shared world.' In the sustainable world view, we must regain the awareness that through technology we build the world. It should lead us then to the kinds of questions suggested by Winner: 'How can we limit modern technology to match our best sense of who we are and the kind of world we would like to build? [7]' If we replace the word 'limit' with the word 'design' we have an excellent basis for developing the concept of sustainable design.

Ironically, we have built our faith in reason and technology to liberate us from drudgery, suffering, and scarcity, and to provide us easily with the things for which we used to have to strive. Yet in fulfilling this promise, we have ended up detaching ourselves from the very world that is our source of meaning. 'Devices undermine our relationships to those things, places, and people we want to free to be able to cherish [3].'

Another perspective on our modern paradigm highlights three characteristic causes of unsustainability: reality, rationality and technology [3]. Our concept of reality is that a detached human observer can objectively perceive an external reality that exists separate from our observations. This is an extension of the dualism mentioned earlier, and leads to treating nature as something to be dominated and managed. An alternative participative concept of reality holds that we are inherently participants in creating reality. It is only through our interacting with the world that reality is revealed to us. This presents an opportunity for design to facilitate that revealing and to make us more aware of how each of us makes the world. Authenticity arises when we are conscious of our world-making. Rationality is the link between reality and action. If we act against prevailing norms, we are said to be unreasonable and irrational. And one of those norms is that we are economic beings, with an inherent tendency to maximize our self-interested well-being. Sustainability will be stifled without changing some of these norms. Technology is the tools we use to facilitate our actions, and as Davison noted earlier, technology can serve to remove us from our relationship with the world, or help reveal that relationship.

3. DEFINING SUSTAINABILITY

Before reviewing the contested definitions of sustainability, it is worth reflecting on the concept. It is clear to me now that sustainability is not a thing in the sense that it can be achieved once and for all, nor can it be readily measured. Ehrenfeld points out that sustainability, like other '-ities,' starts out as a qualitative property of systems. Our modern tendency is to reify these qualitative assessments into things that can be measured and managed. He uses love and happiness as examples of important qualities that have been made object-like. We'll return to Ehrenfeld at the end of this section, leaving with his caution: ' . . . sustainability needs to avoid becoming just another thing to measure and manage, and instead become a word that will bring forth an image of the world as we would hope it to be.'

3.1 Meaning via themes

By the mid 1990s, there were over 300 definitions of sustainability [8]. With such a highly contested definition, Andres Edwards took a different tack in trying to understand sustainability by examining the principles that underlie the actions of various different sustainability organizations [9]. The focal categories of groups examined included community, commerce, natural resources, ecological design and the biosphere. After reviewing 39 sources spanning the period from 1978 to 2003, Edwards found seven common themes:

1. Stewardship.
2. Respect for limits.
3. Interdependence.
4. Economic restructuring.
5. Fair distribution.
6. Intergenerational perspective.
7. Nature as model and teacher.

These themes are useful in that they begin to paint a picture of this new paradigm from which sustainability may emerge. I think it is fair and accurate to say that every one of these themes runs counter to the technological world view and the idea of unlimited material progress.

3.2 Meaning via typology

Instead of trying to define sustainability, Dobson uses a discursive strategy to describe the evolution of the term 'environmental sustainability [8].' Using a set of fundamental questions, Dobson develops a schematic representation of the various concepts of environmental sustainability as shown in Table 1 [8].

Before exploring this typology, I want to point out that the term 'environmental sustainability' is a limited version of sustainability as it is developed in this paper. Yet we do gain some insight into some of the important questions and the variety of responses. Of interest here is the movement from concept A to D. In the case of what to sustain, we move from a classical economic, anthropocentric answer of capital, easily substituted (concept A), to a more philosophical ecocentric answer of 'units of significance,' referring to natural forms and

Table 1. Conceptions of environmental sustainability [8]

	A	B	C	D
What to sustain?	Total capital (human-made and natural).	Critical natural capital: e.g. 'ecological processes'.	Irreversible natural capital.	'Units of significance'.
Why?	Human welfare (material).	Human welfare (material and aesthetic).	Human welfare (material and aesthetic) and obligations to nature.	Obligations to nature.
Object(s) of primary concern (in priority order).	Present human needs, present human wants, future human needs, future human wants.	Present human needs, future human needs, present human wants, future human wants.	Present human needs, present non-human needs, future human needs, future non-human needs.	Present non-human needs, present human needs, future non-human needs, future human needs.
Secondary.		Present non-human needs, future non-human needs.	Present human wants, future human wants.	Present human wants, future human wants.
Substitutability between human-made and natural capital.	Considerable.	Not between human-made capital and critical natural capital.	Not between human-made capital and irreversible natural capital.	Eschews the substitutability debate.

processes (concept D). In answer to why, we move from a purely utilitarian answer to one that acknowledges intrinsic value in nature. In the third row, there is consistently favor to the present over the future, and a movement from solely human-centered to a shared interest in humans and non-humans. Finally on the substitutability question, we move from a classical economics view to a non-economic one.

In attempting to use the typology in Table 1 to consider the concept of 'sustainable development,' Dobson concludes that it can fit into concepts A or B, but not C or D 'because the principal motivation behind any conception or theory of sustainable development is human interest in human welfare. Sustainable development is, in my view, an anthropocentric notion in a way that environmental sustainability need not (but may) be [8].'

3.3 Technocratic and cultural distinctions

On the more general discourse on the meaning of sustainability, we can distinguish between *technocratic sustainability* and *cultural sustainability* [6]. Technocratic sustainability is aligned with our modern world view that technology is the key to progress. Rather than bringing our attention to the political, cultural and ethical issues related to sustainability, technocratic sustainability limits the discussion to science, engineering and business. Considering the sustainability discourse in this way, the typology of environmental sustainability in Table 1 is primarily technocratic, just as is the concept of sustainable development. The global ethic of sustainable development 'is presented as being maximum sustainable consumption of optimally efficient technologies [6]'.

Cultural sustainability, rather than focusing on technology, focuses on human communities (maybe the community of life on earth) and the political, social and moral issues related to sustainability. Norgaard argues that 'sustainability can be contested only within discourses and practices that place the coevolution of social systems and ecological systems as a prerequisite to any vision of technological development [10]'. *Sustenance* becomes the organizing principle of society's relationship with nature. We are then forced to communally confront normative questions such as: 'What are our values? What are our roots? What sustains us? What do we want to pass on to our grandchildren? [11]' 'It is not just a matter of examining the ecological means to determined ends; ultimately sustainability requires a political-normative judgment on the ends themselves [12].

3.4 Meaning in higher education

Focusing more on sustainability education, Stephen Sterling has pictured the evolution of meaning as shown in Fig. 1 [13]. In this figure, EE is environmental education, ESD is education for sustainable development, and EFS is education for sustainability. The vertical dimension is intended to correspond to the philosophical base and the horizontal to the scope, with the evolution direction indicating how both the philosophical base and scope grow and become more inclusive. Here are Sterling's relevant comments on the terms [13]:

> Thus, EE has been traditionally concerned with the quality of the environment, and less concerned with social, economic and political aspects of change. . . . Partly a product of the confluence of the concerns of environmental education and development education, ESD has sought to encompass the social, economic and environmental dimensions of change and of alternative futures. . . . The proponents of EFS have argued that ESD is too outer-directed and possibly too instrumentally oriented, and that we need to consider the inner dimensions of valuative psychological and perceptual change. They argue for education 'for being' rather than (just) education 'for becoming'. Lastly, some commentators like myself argue that sustainability indicates both the grounding and pos-

> sibility of a change of educational paradigm as a whole—hence, 'sustainable education'.

Sterling goes on to describe his vision of sustainable education, and the transformation in educational thinking and practice that is called for:

> Essentially, sustainability (or indeed, unsustainability), like justice or health, is an emergent quality arising from sets of relationships in a system, whether viewed at the macro or micro scale. . . . In people's views of sustainability, there is a tension, they suggest, between the scientism, objectivism and reductionism of the dominant paradigm that attempts such precision, and an emerging paradigm which the authors describe as systemic, holistic and participative. The latter holds that sustainability is more—or less—likely to arise depending upon the degree to which our attention shifts from 'things' to relationships, and from a segregated view of the world towards an integrative and participative perspective. This involves more than a simple and dualistic environmentalism, and indicates, instead, the need for 'whole systems thinking' arising from ecologism and systemic thinking, which transcends and subsumes an appropriate mechanism and reductionism. This is why the prospect of sustainable education is, at heart, an epistemological issue.

This new paradigm of sustainable education can be summarized by its key characteristics in Table 2. Sterling does not attempt to describe how this new paradigm might be achieved in higher education, but is clear about its importance. He also warns that 'there remains a real danger that a 'safe' and neutered form of ESD will be accommodated in the mainstream, which otherwise remains largely unaffected.'

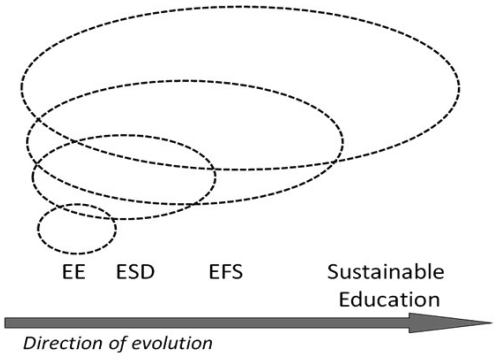

Fig. 1. The evolution of key terms [13].

My own experience leads me to a similar place as Sterling. A few years ago, I presented a paper to the American Society for Engineering Education that proposed this ethic: 'Engineers shall hold paramount the improvement of both human life and the larger community of life, for present and future generations [14].' My intent was to reframe sustainability in a positive light by referring to improving life, while being more explicit about considering the entire community of life. In hindsight, I can see my technocratic progressive belief that engineers can improve life. It's also interesting that I chose to drop the term sustainability entirely.

3.5 Sustainability as emergent property

I'm happy to report that there is a new conception of sustainability that reflects a positive light and a different way of viewing the world: 'Sustainability is the possibility that human and other life will flourish on the planet forever [3].' By using the term 'possibility,' Ehrenfeld cleverly avoids turning sustainability into a thing, opening up its visioning potential. As he says: 'Possibility may be the most powerful word in our language because it enable humans to visualize and strive for a future that neither is available in the present nor may have existed in the past.' Then there is the inspirational life-affirming goal of 'flourishing.' Being careful not to define flourishing, there is this wonderful quote from Rabbi Michael Lerner [15]:

> Recognize that people hunger for a world that has meaning and love; for a sense of aliveness, energy, and authenticity; for a life embedded in a community in which they are valued for who they most deeply are, with all their warts and limitations, and feel genuinely seen and recognized; for a sense of contributing to the good; and for a life that is about something more than just money and accumulating material goods.

4. HISTORICAL PERSPECTIVE: COUNTERCULTURAL AND MODERNIST WAVES

An excellent source for understanding the historical development of the meaning of sustainability is Aidan Davison's *Technology and the Contested Meanings of Sustainability* [6]. With

Table 2. Towards a sustainable education paradigm: key characteristics [13]

Ontology	Realist/idealist (relational).
Epistemology	Participatory.
Theory of learning	Participative/systemic.
Function of education	Remedial/developmental/transformative.
Main emphasis	Towards transformative learning experience.
Focus	Meaning-making appropriate to context.
Seeks	Wholeness and sustainability.
Reflects	Intrinsic and transformative values.
Pedagogy	Transformative.
Desired change	Contextually appropriate balance between autonomy and integration (i.e., healthy, sustainable relationships) in and between systemic levels.

degrees in biochemistry, science and technology policy, and environmental philosophy, Davison brings a perspective that is multidisciplinary and intellectually rigorous. In my broad readings in preparation for this paper, Davison presents one of the most articulate and provocative analyses of the meaning of sustainability.

Consistent with my discomfort with the conference theme, Davison states in his preface:

> I consider questions about sustainability to be essentially normative and any answers they prompt essentially contested. The engineer's search for the design specifications of Sustainable Technology—a technology promised to produce efficiency and equity in equal measure—is therefore profoundly misleading.

Davison describes two waves of environmental concern connected to sustainability. The first wave from the 1950s to the late 1970s 'was deeply skeptical of the modernist model of progress and called for far-reaching spiritual, moral and economic change in technological societies [6].' This countercultural wave of 'concern was bound up with a broad platform of political reform encompassing peace, civil rights, feminist, New Left, and neo-Marxist movements.'

One of my favorite books from this era is Barry Commoner's *The Closing Circle* [16] . Commoner elucidates how the pattern of economic and industrial growth following World War II was 'counter-ecological.' While population growth and increased affluence contributed in part to the greatly increased damage to the environment, the largest contributor was the production technologies. Commoner shows that in the 25 years following WWII the amount of basic economic goods went up very little.

> However, his food is now grown on less land with much more fertilizer and pesticides than before; his clothes are more likely to be made of synthetic fibers than of cotton or wool; he launders with synthetic detergents rather than soap; he lives and works in buildings that depend more heavily on aluminum, concrete, and plastic than on steel and lumber; the goods he uses are increasingly shipped by truck rather than rail; he drinks beer out of nonreturnable bottles or cans rather than out of returnable bottles or at the tavern bar. He is more likely to live and work in air-conditioned surroundings than before. He also drives about twice as far as he did in 1946, in a heavier car, on synthetic rather than natural rubber tires, using more gasoline per mile, containing more tetraethyl lead, fed into an engine of increased horsepower and compression ratio.

Commoner blames the ecological failure of technology on reductionism. He does not give up on technology though, claiming that ecological survival (sustainability?) 'requires that technology be derived from a scientific analysis that is appropriate to the natural world on which technology intrudes.' Commoner states four 'laws of ecology':

1. Everything is connected to everything else.
2. Everything must go somewhere.
3. Nature knows best.
4. There is no such thing as a free lunch.

We will see this idea of harmonizing technology with ecological principles develop into a fundamental idea in the second wave of environmental concern.

Davison describes how this first wave was skeptical of the modernist ideal of unlimited economic growth and technological globalization. Typical of this sentiment is the 1972 *Blueprint for Survival* the claims that the 'principal defect of the industrial way of life with its ethos of expansion is that it is not sustainable. [17]' This questioning of growth was met with skepticism in both the industrialized North and the burgeoning South. In the South in the 1970s, environmental concern was focused on social justice, motivated in part by exploitation by the North. In the North, mainstream institutions were denying that there was any ecological or cultural crisis.

The second wave of environmental concern, in which we are currently immersed, emerged out of critiques of 'limits to growth' sentiment of the first wave, leading to policies for 'ecological modernization,' or what Davison calls the 'cultural project of ecomodernism.' 'Ecological modernization proposes that policies for economic development and environmental protection can be combined to synergistic effect. [18]' Thus we have in 1987 the Brundtland Report's now classic statement: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. [19]' Davison claims that:

> *Our Common Future* undermined the limits to growth arguments by placing at the centre of the language of sustainable development the following question: How is economic growth and technological expansion to be sustained?

A fundamental attitude in the ecomodernist perspective is technological optimism, that technology can be transformed by social institutions to lead us into a sustainable age of plenty. Indeed this attitude is reflected in my current teaching of Sustainable Design. Thus we have the Council of Academies of Engineering and Technology Sciences stating that while there are 'many obstacles to the transition to sustainable development, technology provides a means to overcome them [20].'

At the heart of the ecomodernist world view is faith in technological progress and more fundamentally in rational, scientific management, i.e. technological optimism. Overly simplified, the project is to tweak our current unsustainable ways of doing things so that they are sustainable. In economics, the call is to internalize the costs of externalities so that prices reflect the full costs. Or further, to account for natural capital along with other forms of capital. In design, we need to consider products from cradle-to-cradle and perform a life-cycle assessment to adequately

account for environmental impacts. While these changes are important, they assume that technological adjustments will somehow lead to real sustainable human progress.

But there is a new wave, a new paradigm, now taking shape, and it is this paradigm that I seek to describe to provide guidance for teaching Sustainable Design.

5. A SUSTAINABLE WORLD VIEW

What we seek in this sustainable world view is first and foremost a sense of what human living is about. As Davison says: 'Sustainability is nothing less, in late modernity, than the craft of moral life [6].' Ehrenfeld makes this assertion: 'Sustainability is an existential problem, not an environmental or social one. [3]' He further states that: 'Flourishing can occur only if we pay attention to the three critical domains that the forces of modernity have dimmed:

- Our sense of ourselves as human beings: the human domain.
- Our sense of our place in the [natural] world: the natural domain.
- Our sense of doing the right thing: the ethical domain [3]'.

Figure 2 illustrates these three domains as overlapping fields, with sustainability found in the intersection of all three.

The root human value of all of these domains is *care*. Ethics is about taking care of others. The human domain is about taking care of ourselves, and the natural domain is about taking care of nature. Only by simultaneously developing caring in these three domains will sustainability emerge. Davison, after describing his day-to-day life, says:

> . . . I seek to be so full of care for the things bequeathed to my present by the past that the future will be able to take care of itself [6].

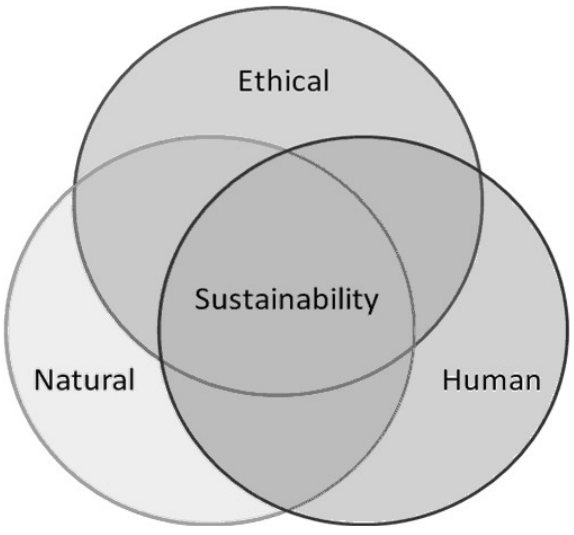

Fig. 2. The Tao of sustainability [3].

6. SUSTAINABILITY BY DESIGN

As engineers and designers, our role is to develop designs that lead to human flourishing. Ehrenfeld recommends three steps to design [3]:

1. Replace the ubiquitous commodified devices with tools that are designed to engage us and build our skills in observation and reflection.
2. Embed scripts in these tools to guide the way use them such that we replace old unsustainable beliefs and norms with a new set.
3. Substitute new collective processes (organization or institutional tools) in place of those that reinforce the current unsustainable societal set of beliefs and norms.

The model that is recommended to guide this design process is pragmatism, 'shifting the primary mode of individual understanding and action from positivist/rational to experiential/pragmatic [3].' By becoming more aware of our interactions and reflecting on their effects, we regain and redevelop our humanity. 'The good work of sustaining technology is the work of encouraging ourselves and each other through the reality of our technological being to nourish the human capacity for grace, play, and care [6].'

For Ehrenfeld, the two sources of inspiration for this process are nature and Being. Looking to nature, we observe that it is complex, both complicated and unpredictable. An important feature of complex living systems is emergent properties which are properties that can be observed at the system level, but not in the individual members. Emergent properties arise from the interactions within the system and are difficult if not impossible to explain scientifically. Flourishing is one such emergent property of living systems, as is beauty. Another observation regarding nature is the interconnectedness and interdependence of living ecosystems. Every organism exists in a symbiotic relationship with other organisms. And finally, the interaction between the observer and nature is essential.

Being refers to the way of being of human beings. One of the first to use this term was psychoanalyst Erich Fromm in his 1976 book *To Have or To Be* [21]. Fromm describes two forms of Being. One in contrast to having, 'means aliveness and authentic relatedness to the world [21].' The other form is in contrast to appearing, and 'refers to the true nature, the true reality, of a person or thing . . . [21]' Fromm says more about the first form of Being:

> To be active means to give expression to one's faculties, talents, to the wealth of human gifts with which—though in varying degrees—every human being is endowed. It means to renew oneself, to grow, to flow out, to love, to transcend the prison of one's isolated ego, to be interested, to 'list,' to give.

Using Being as inspiration, Ehrenfeld asks: 'Is there a way to design our tools (equipment) such

that they promote our appreciation of the care structure of Being rather than hide it from us? [3]'

7. PRESENCING

Ehrenfeld refers to presencing as 'an experience in which an awareness of the worldly context of the action shows itself to the actor [3].' It provides us an opportunity to make a conscious choice and an opportunity for authentic action, i.e. for Being to happen. As an example of presencing in a technology, the two-button toilet is described. Such a toilet has one button for urine, resulting in less water use, and another button for feces, resulting in a more water use. By presenting the user with a choice, her attention is required, including reflection on what is right to do, and perhaps an awareness of connection to the larger world.

Another example of presencing by design is the variety of containers now found in the hallways of our university. Using different shaped openings as well as labels, one is confronted with a choice and an opportunity for authentic caring behavior when it comes to disposing of 'waste.'

Scripts are a way to induce presencing by the design of the device. The script embedded in the design 'speaks' to us about how we should interact with the device. This can be quite obvious or more subtle. A hypothetical device with an obvious script is a green light that comes on by a house thermostat when the thermostat is in the cooling mode. The green light indicates that it is cool enough outside to turn the cooling system off and to open the windows for cooling. Some might argue that a really 'smart' house would have automatic systems that would sense this condition and by using electric actuators, open the windows without having to bother the occupants. While this might be a good idea if nobody is home, if people are home, the green light gets their attention and opens up the opportunity for participating in the action, and for realizing authentic behavior.

8. CONCLUSIONS

I hope that the insights provided by this paper have reinforced my earlier observation that it is premature to talk about sustaining sustainable design, if we mean sustainability in the sense developed here. I am not trying to diminish the efforts of engineering educators who teach concepts of eco-efficiency and eco-effectiveness, because first of all I am one of them and secondly, there is value in these efforts to raise our awareness of the limitations of conventional design. Yet I am convinced that an exciting, enriching and fulfilling set of opportunities awaits us as we start down the challenging path of founding our technologies on flourishing and on caring.

So what can we do to make genuine progress toward sustainability? One step that I think needs immediate attention is to understand our tendency, especially as engineers, to frame problems technologically. We educators need to help our students, and our colleagues, to explore the technocratic world view, and begin to create new stories that include Being and caring. While I think this will eventually mean fundamental changes to university education, we can utilize the general education courses that students now take to help them understand their place in the world and the realm of cultural sustainability. In engineering design, we can present them with projects that ask them to consider how their designs contribute to the human, ethical and natural domains.

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