Efficiency and Miniaturization Forum
Solar 2000 American Solar Energy Society
Madison, WI June 2000

Ecology and Education for Sustainable Design

David Bainbridge
Environmental Studies Program Coordinator
United States International University
10455 Pomerado Road
San Diego, CA 92131

As I have argued for much of my career, we need a new approach to education that includes full consideration of sustainability in design, resource management, economics and ecosystem management (Bainbridge, 1985). Developing literacy in calculating and understanding the true economic and environmental cost of our behavior, integrating the value of nature's services and the current externalized costs of environmental damage and the health and social impacts of our actions and policies will be a critical step in this process. Every student should be aware of these issues when they graduate from high school and capable of understanding and undertaking life cycle cost assessments, ecosystem analysis and multidisciplinary team research by the time they graduate from college. This is particularly important in the design and planning professions (architecture, engineering, planning) where facilities, behavior, and resource commitments are made for 50 –100 years or more. Current subsidies, perverse incentives and incomplete costing encourage unsustainable practices and behavior, but these will not be changed until more people are conversant with these issues and their implications.

An important part of this educational effort will be placing humans within the ecosystem, as Aldo Leopold first argued more than 50 years ago (Leopold, 1948; Bainbridge, 1972;). As Robert Kates (1994) notes, we need to accept that: 1) cohabitation with the natural world is necessary, 2) there are limits to human activity, and 3) the benefits of human activity need to be more widely shared. This ecological context will help us understand that there is "no away" where wastes can be placed, and that local actions have global impacts. This ecosystem approach has quickly gained acceptance more quickly in industry, and the practice and theoretical bases of industrial ecology are growing rapidly (Frosch and Gallopoulos, 1989; Ayres and Simonis, 1994; Graedel and Allenby, 1995; Porter and van der Linde, 1995;

Socowlow et al., 1997; Anon, 1998; Frosch, 1998). This vision now needs to be extended to the design professions and to the general public (Environment Canada, 1993; Dunn and Steinemann, 1998). This will help us understand the relation between the parts and the wholes, our place in the local and global ecosystem, and the importance of today's choices on future options.

While considerable attention is now being paid to global warming and it's attendant risks in the press, increased storms, rising sea level, and changes in rainfall patterns, very little work is being done to evaluate the many other known impacts development has on the world. And even less is being spent to examine the responses of stress on critical ecosystem functions and structure. It is almost certainly going to be something we haven't imagined or studied that bites us hardest.

Recent advances in ecological science and understanding can help us develop and refine this new approach to education. For example, studies of the genetics of disease resistant sugar pines suggest that these wind pollinated trees, once thought to be similar across very large areas, are very local specific. The genetic similarity is greatest within two to three tree lengths—not miles or tens of miles as was previously thought. As we often ask in ecological restoration, "How local is local?" As it turns out, very local.

Studies of the effect of increasing CO_2 levels suggest that the subtle changes that may occur in many aspects of the environment may have serious consequences. One of the many surprises was the large impact increasing CO_2 had on fungal spore production, which increased dramatically (Klironomos and Allen, 199_). This provides a very important warning, that the unexpected little impacts that result from global warming might be the ones that cause us the most severe problems. This research also is relevant to architects as they develop building designs for high occupancy load buildings such as schools, where CO_2 levels and moisture are elevated. Sick building syndrome is quite likely often related to the response of fungi to elevated CO_2. On a global level it would suggest that asthma and allergies will increase, crops will more commonly afflicted by disease, and natural ecosystems will be disrupted by fungal pandemics. The design choices we make today will affect CO_2 production for tens or hundreds of years, each small local action must be made with the long term global implications carefully considered. Fortunately design for local selfreliance can minimize energy and resource consumption and protect global and local ecosystems (Bainbridge, 1987; Schmitz-Gunther, 1999).

The full consideration of costs will lead to dramatic changes in design and behavior. For example, a study of automobiles as transportation suggests that the current subsidy is 90% (Batt, 1998). If we paid the full cost we would design our cities and suburbs for pedestrians and bicycles. This miniaturization of our perspective would provide economic benefits, enormous ecological benefits and health benefits. In San Diego, arguably the best climate for bicycling in the United States if not the world, less than 1% of the commute is by bicycle. In Germany, with much worse weather, support for bicycle commuting has paid large dividends. In Freiburg the bicycle commute has risen from 12% in the 1970s to 19% today, and in Muenster bicycle commuting has increased to 32% ( ). In the Netherlands companies buy bicycles for their employees to use in the commute. The Netherlands also offers tax credits to people who commute by bicycle, acknowledging the savings to society and offsetting subsidies for cars. Thinking locally also helps maintain the local economy. Bicycles can be custom made locally, keeping money in the community instead of shipping it off to Detroit.

One of the most adverse impacts of development is the disruption of the hydrologic cycle. Streets, parking lots, sidewalks, and roofs dramatically increase the percentage of soil surface that is impervious to water (Arnold and Gibbons, 1996). Soil compacted by equipment, degraded by past overgrazing and abuse, and colonized by weeds may also retain much less rain water or snow melt than undisturbed natural ecosystems. Instead of infiltrating into the ground a high proportion of rain water runs off quickly into streams causing much more frequent and higher peak flows than existed in the natural watershed. Flood peaks may increase 6-fold, and floods once expected only one in a 100 years in an unurbanized setting may now recur every 10-20 years (Leopold, 1969). These high flows destabilize stream beds, mobilizing more sediment, which in turn can destabilize the lower stream reaches and cause additional problems. Flooding increases and with sediment blocking drains, flood damage increases even more. Flooding from a 100-year rainfall event can be catastrophic, reaching far beyond the 100 year flood plains calculated before urbanization took place. Water quality declines as stormwater collects debris and pollutants and ecosystems are disrupted and critical habitat and species are lost. People get sick from exposure to stormwater, and beaches and recreation are curtailed, at high economic cost. The solution is miniaturization, moving from consideration of regional storm sewers and treatment plants to minimizing or eliminating runoff by incorporating stormwater management in home, facility and transportation design. This worked very well in the innovative 220 unit solar subdivision known as Village Homes, but was fought bitterly by city engineers (Bainbridge et al., 1979; Corbett and Corbett, 2000). But even innovative stormwater infiltration systems carry a risk if the entry of pollutants into the environment is not curtailed (Lind and Karro, 1995).

A more subtle but important impact of design choices is nitrogen pollution. Nitrous oxides from fossil fuel consumption fall back to earth as dry particulates and in rain. Nitrogen deposition can reach more than 50 kilograms per hectare in auto dominated areas like Southern California, considerably more than the world average application of nitrogen fertilizer for farming. This high level of nitrogen addition appears to be having a very large negative impact on our native ecosystems. Sadly, we don't know much in most areas because studies have just started. One of the reasons we don't see the changes from these low level impacts is because they are slow and cumulative. A common impact study would evaluate only two or three years, and at some levels of added nitrogen this would reveal only positive changes. Yet over the long term very negative impacts develop. In areas where this has been studied it has been nothing short of catastrophic. A long term study in England, showed dramatic declines in the diversity of grassland plots with nitrogen added treatments at nitrogen levels well within current deposition rates (Brenchley, 1956; Wedin, and Tilman, 1996). On the Rothamsted plots diversity dropped from 30 species to 3 over the 90 years of the study, figure x. A 12 year study in Minnesota grasslands showed similar declines in species diversity and community composition. Species richness declined 50% and bunch grasses were replaced by invasive weedy European grasses. Recent reports from Sweden, where deposition can exceed 100 kg/ha, are alarming. Design affects energy and fossil fuel use determines nitrogen pollution. Miniaturization would minimize nitrogen pollution, walking, bicycling and naturally heated and cooled buildings require only a fraction of the energy of our current systems.

Cities should develop and maintain accounting systems for the inflow and outgo of nitrogen, phosphorus and other elements and compounds. To be sustainable in the long term they need to be in balance, yet as studies in Sweden have revealed, even coping with a non-toxic element like phosphorus is very difficult (Gunther, 1997). Developing balance will require local recycling. Miniaturization would return food production to local areas (much to homes), and growing most food locally using co-composted human waste can complete the phosphorus and many other nutrient cycle. This would reduce the energy cost, nitrogen pollution associated with long distance food transport. Lumber can also be produced locally, as it is in China, as an adjunct of land treatment of sewage and storm water.

Regional and national studies of more toxic compounds are also essential. Studies of heavy metal budgets in the Rhine Basin are even more disturbing, although they show signs of improvement (Stigliani and Anderberg, 1994). Design for disassembly and industrial ecology can minimize leakage of harmful materials into the environment.

The public around the world is more aware of environmental issues than their leaders, and as the saying goes "Where the people lead, the leaders will follow". The major challenge is now developing cost effective implementation programs and policies rather than creating awareness of problems (Trudgill, 1991; Bloom, 1995). The emerging discipline of ecological economics offers new approaches to better understanding our world and providing incentives for sustainable management (O'Riordan, 1994; Massarratt, 1997; Tietenberg, 2000). Often these are no cost options, such as making the polluter pay (Anderson, 1994).

Incorporating ecology in education is both possible and essential. Students and design professionals need to understand the whole to improve the parts. They need to learn that actions have effects, and that problems can't be solved in isolation (Charland, 1996). Teaching the skills of ecological footprint analysis, life cycle cost assessment, and environmental management systems should be a normal part of every curriculum (Graedel and Allenby, 1994; Uhl et al. 1996; Wackernagel and Rees, 1996). Environmental citizenship (Environment Canada, 1993) should be given the same weight as language and math skills, and can enrich lessons in both.

Universities and professional organizations must rise to the challenge of developing an understanding of sustainable behavior and culture throughout the educational system, particularly for those involved in the planning and development of land and buildings (Uhl et al., 1996; Fisk et al., 199?; Dunn and Steinemann, 1998). The University of Georgia now requires all of its 22,000 students to fulfill an environmental literacy requirement (Bainbridge, 1998). Making campuses more sustainable would provide the opportunity for students to learn and to demonstrate more responsible management of resources. Although student efforts have made some progress most campuses have made little progress toward sustainability (Creighton, 199 ;).

Almost 90% of first year college students believe the Federal Government is not doing enough to clean up the environment and 25% say involvement in programs to clean up the environment is a very important or essential personal objective (Dey et al., 1991). We must also develop much better linkages between countries, both at the professional and student levels so that progress can be made without repeating mistakes or ignoring lessons learned elsewhere.

It can and must be done! Having environmentally illiterate students, citizens, designers and politicians is as risky as having airline pilots who are exhausted, tanker captains who are drunk, and hazardous waste handlers who cannot read. It will lead to disaster.

Andersen, M.S. 1994. Governance by Green Taxes. Making Pollution Prevention Pay. Manchester University Press. UK.

Anon. 1998. The transition to sustainability. Environmental Business Journal 11(7):1-7, 14.

Arnold, C.J. and C.J. Chester. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association 62(2):243-258.

Ayres, R.U. and U.E. Simonis. 1994. Industrial Metabolism: Restructuring for Sustainable Development. United Nations University Press, NY.

Bainbridge, D.A. 1972. Man and the city: the human ecosystem. Bainbridge, Behrens, and Moore, Inc., Davis, CA.

Bainbridge, D.A. 1985. Ecological education: time for a new approach. Bulletin of the Ecological Society of America, December 66(4):461-462.

Bainbridge, D.A. 1987. Energy self-reliant neighborhoods. pp. 398-402. In D.A. Andrejko and J. Hayes, eds. 12th Passive Solar Conference Proceedings, American Section International Solar Energy Society (ASISES), Boulder, Colorado.

Bainbridge, D.A. 1997. The nitrogen pollution problem. Newsletter of the Society for Ecological Restoration, California Section. 7(3):3-4.

Bainbridge, D.A. 1998. The Environmental studies program at three -- Progress Report and Proposal. United States International University, San Diego, CA 33 p.

Bainbridge, D.A., J. Corbett and J. Hofacre. 1979. Village Homes' Solar House Designs.

Rodale Press, Emmaus, Pennsylvania.

Batt, H.W. 1998. Motor vehicle transportation and proper pricing: user fees, environmental fees and value capture. Ecological Economics Bulletin 3(1):10-14.

Brenchley, W. 1956. The Park Grass Plots. Rothamsted Research Center. England.

Bloom, D.E. 1995. International public opinion on the environment. Science 269:354-357.

Charland, J.W. 1996. The problem isolation paradigm. Journal of Forestry May: 6-9.

Corbett, M. and J. 2000. Designing Sustainable Communities: Learning from Village Homes. Island Press, Washington, DC.

Costanza, R., Cumberland, J., Daly, H., Goodland, R. and Norgaard, R., 1997. An Introduction to Ecological Economics. St. Lucie Press, Boca Raton, FL.

Creighton, S.H. 1998. Greening the Ivory Tower. MIT Press, Cambridge, MA.

Dey et al. 1991. The American Freshman: Twenty Five Year Trends. Higher Education Research Institute, UCLA

Dunn, B.G. and A. Steinemann. 1998. Industrial ecology for sustainable communities. Journal of Environmental Planning and Management. 41(6):661-672.

Environment Canada. 1993. A Primer on Environmental Citizenship.

Fisk III, P., R. MacMath and G. Vittori. 199?. Life cycle design principles for the architecture and planning professions. Proceedings ASISES ----

Frosch, R.A. 1998. Industrial ecology and sustainability. American Scientist 86(1):2.

Frosch, R.A. and N.E. Gallopoulos. 1989. Strategies for manufacturing. Scientific American Sept. 144-152.

Graedel, T.E. and B.R. Allenby. 1995. Industrial Ecology. Prentice Hall, Englewood Cliffs, NJ.

Gunther, F. 1997. Hampered effluent accumulation process: phosphorus management and societal structure. Ecological Economics 21:159-174.

Kates, R.W. 1994. Sustaining life on earth. Scientific American. October 114-122.

Krotscheck, C. and M. Nardoslawsky. 1996. The sustainable process index: a new dimension in ecological evaluation. Ecological Engineering 6:241-258.

Leopold, A. 1989 [1948]. The land ethic. Pp. 201-226. In A Sand County Almanac. Oxford University Press. NY.

Leopold, L. 1968. Hydrology for Urban Land Planning—A Guidebook on the Hydrologic Effects of Urban Land Use. U.S. Geological Survey Circular #554.

Lind, B.B. and E. Karro. 1995. Storm water infiltration and accumulation of heavy metals in raodside green areas in Goteborg, Sweden. Ecological Engineering 5:533-539.

Massarrat, M. 1997. Sustainability through cost internalization: theoretical rudiments for the analysis and reform of global structures. Ecological Economics. 22:29-39.

O'Riordan, T. 1994. The precaution principle in environmental management. pp. 299-318. In Ayres, R.U. and U.E. Simonis. Eds. Industrial Metabolism: Restructuring for Sustainable Development. United Nations University Press, NY.

Porter, M.E. and C. van der Linde. 1995. Green and competitive. Harvard Business Review. Oct/Nov:120-134.

Tietenberg, T. 2000. Environmental and Natural Resource Economics. Addison, Wesley, Longman, NY.

Schmitz-Gunther, T. ed. 1999. Living Spaces: Sustainable Building and Design. Konemann, Cologne, Germany.

Socolow, R., C. Andrews, F. Berkhout, and V. Thomas, eds. 1997. Industrial Ecology and Global Change. Cambridge University Press, NY.

Stigliani, W.M. and S. Anderberg, 1994. Industrial metabolism at the regional level: the Rhine Basin. Pp. 119-162. In Ayres, R.U. and U.E. Simonis. Eds. Industrial Metabolism: Restructuring for Sustainable Development. United Nations University Press, NY.

Trudgill, S. 1991. Environmental issues. Progress in Physical Geography 15(1):84-90.

Uhl, C., D. Kulakowski, J. Gerwing, M. Brown and M. Cochrane. 1996. Sustainability: a touchstone concept for university operations, education and research. Conservation Biology 10(5):1308-1311.

Wackernagel, M. and W. Rees. 1996. Our ecological footprint. Green Teacher 45:5-14.

Wedin, D.A. and D. Tilman. 1996. Influence of nitrogen loading and species composition on the carbon balance of grasslands. Science 274:1720-1721.