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A personal view: environmental education—its content and delivery

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Abstract Arguably, no challenge faced by humanity is more critical than generating an environmentally literate public. Otherwise the present "business as usual" course of human affairs will lead inevitably to a collapse of civilization. I list obvious topics that should be covered in education from kindergarten through college, and constantly updated by public education and the media. For instance, these include earth science (especially climatology), the importance of biodiversity, basic demography, the problems of overconsumption, the fact that the current economic system compels producers and consumers to do the wrong thing environmentally, and the I=PAT equation. I also summarize less well-recognized aspects of the environmental situation that are critical but are only rarely taught or discussed, such as the nonlinear effects of continued population growth, the impacts of climate disruption on agricultural production, and the basic issues of human behavior, including economic behavior. Finally, I suggest some of the ways that this material can be made a major focus of all education, ranging from using environmental examples in kindergarten stories and middle school math to establish an international discussion of the behavioral barriers to sustainability.

Keywords Environment · Education · Culture gap population · Consumption

Dedicated to my close friend and colleague the late Stephen H. Schneider, one of the great environmental educators.

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Global human society is challenged in a way never before seen in human history. For the first time, humanity is fundamentally altering global ecosystems in ways that can threaten the continuation of our social order. The struggle to develop appropriate modes of behavior compatible with maintaining vital ecological processes is the great challenge of the twenty-first century. Educational systems are pivotal to meeting this challenge by equipping people with the knowledge and values to understand and address the human predicament. Thus, environmental education needs to be a vital component of all educational processes in developed nations from kindergarten to doctoral studies and continuing through the use of mainstream and social media.

However, in my view, environmental education is given much too little attention in the school systems of the USA and other rich nations, and is often poorly timed and structured when it is delivered. The situation is only marginally better in colleges and universities, despite the good efforts of environmental educators. Perhaps the best evidence for the inadequacy of environmental education is that "out of the classroom, people have failed to make the link between their individual actions and the environmental condition" (Blumstein and Saylan 2007, 2011). A basic problem is educational systems for the young are designed to fill people with various packages of "tailored" knowledge, and then send them "out in the world" to use that knowledge, especially to make a living. There is too little systematic thought given to the ever-changing needs of responsible citizens facing the culture gap—the enormous and growing gulf between the non-genetic information possessed by each individual society and that possessed by society (Ehrlich and Ehrlich 2010).

It is also insufficient to simply become more aware of the environmental consequences of what we do. Even the

most green-minded, and enlightened corporate managers cannot deal properly with environmental issues in the absence of appropriate collective action (public policy). Without leveling the playing field, well-intentioned corporate decision makers would lose market share, upset stockholders, and likely become jobless.

What I outline here is what is required for individuals to receive an adequate environmental education. It reads like a big order, but remember, it would be expected to be stretched over ~16 years of formal education and *should* be continually reinforced and updated through the media. On the optimistic side, I have found that a 20-lecture Stanford undergraduate course with no prerequisites but supplemented by a text designed for the course (Ehrlich and Ehrlich 2009) can at least provide the majority of students some familiarity with most topics and a sense of the big picture—how the "topics" relate to one another and to their lives. Of course, much more could be transmitted if environmental education were integrated into the schooling and lives of everyone before college.

I will not focus on the numerous political, financial, logistic, and other barriers that make creating an environmentally literate public so difficult at present. Those of us who are now actually trying to close key parts of the culture gap at the college level or by communicating with the general public and policy makers are only too familiar with them.

What should everyone know if exposed to an adequate environmental education?

Merely acquiring knowledge is of course not enough. Grasping some key topics is essential for critical assessment of current environmental issues.

Some of those topics are so obvious to this audience their mention can be brief here.

Energy and the laws of thermodynamics Energy is central to our lives and to most environmental issues. Everyone should be acquainted with the significance of the first and second laws so they can better grasp issues related to energy issues, such as the structure of food chains and the impossibility of recycling energy.

The key role of photosynthesis The sun and photosynthesis are the basic source of almost all energy that runs organisms and are also the source of fossil fuels.

Basic earth science Orogeny, pedogeneisis, erosion, plate tectonics, ocean circulation, etc. This centrally must include how the climate system works, tying back again to the sun.

Basics of evolutionary biology Background for learning about topics from pesticide resistance to the capacity for empathy and many other human attributes.

The basics of human population growth and structure To underscore the importance of one of the three major drivers of environmental deterioration. Issues related to age composition and migration should not be neglected.

Biodiversity, natural capital, and ecosystem services How they work and key functions that are deteriorating, like the critical needs for pollination, carbon sequestration, soil generation, and water purification.

The I=PAT equation in its basic and elaborated forms (Dietz and Rosa 1994) To emphasize that the ***I***mpacts of ***P***opulation, per-capita consumption ("***A***ffluence") and the ***T***echnologies, social, cultural, economic, and political systems involved in servicing the consumption, multiply together.

The way negative externalities (like pollution) tilt the economic system against the environment A basic understanding of how markets yield undesirable environmental outcomes in the presence of externalities, and a recognition of ways that public policy can remedy these problems by "leveling the economic playing field."

Other points that are less obvious, that should be taught, and are often neglected

General

How science is actually done (Godfrey-Smith 2003), as opposed to high-school "scientific method" recipes, probability, and uncertainty in general need to be deeply indoctrinated (e.g., science never proves anything, introduction to frequentist and Bayesian thinking, use of models to predict likely outcomes).

Population

The nonlinearities associated with population growth, especially the disproportionate impact of additional people (Ehrlich and Holdren 1971; Harte 2007) (Daily and Ehrlich 1996b). The issues of the human carrying capacity of Earth (Daily and Ehrlich 1996b; Daily et al. 1994; Ehrlich and Goulder 2007) are generally absent from the media despite their crucial importance. The impossibility of perpetual population growth and that population control has the classic characteristics of a government function (ensuring

that individual decisions don't endanger public welfare) are, sadly, rarely mentioned.

Consumption

Some analysts who do not wish to offend various constituencies try to focus on the per capita consumption factor in the I=PAT equation, even though trying to separate its central contribution from that of population size is as impossible as separating the contributions of length and width to the area of a rectangle (of course, if the area is changing size, one can find it informative to analyze what's changing, the length or width or both).

Education systems' neglect of the crucial problem of overconsumption is reflected in the mind of average person (and certainly the average economist) viewing consumption as an unalloyed good. While there is a growing literature on consumption as a central problem (e.g., Arrow et al. 2004; Durning 1992; Ehrlich and Ehrlich 2005; Jackson 2009; Knight and Rosa 2011; Myers and Kent 2004; Princen et al. 2002), it needs to be integrated into education and the lack of analysis pointing to solutions emphasized. Students need to understand that the mix of things we consume is greatly influenced by prices. If people faced the social prices for various forms of energy, the patterns of energy consumption—as well as the total level of such consumption—would be much more in keeping with the social good. Finding ways to reduce unnecessary consumption could be a major topic for paper writing and research projects, starting in grade school. Remember that although population size is a central determinant of aggregate consumption, it is the consumption itself that does the vast majority of environmental damage.

The most environmentally damaging form of human consumption is eating. The scale of the agricultural enterprise, its dependence on fossil fuels, and its environmental impacts are unknown to most "educated" people in developed nations, whose answer to the question "where does your food come from?" is almost invariably "the supermarket." While there is reasonable media coverage of the decline of oceanic fisheries, the ecological damage done by fish farming (Naylor et al. 2000) is rarely mentioned, nor are the benefits of marine reserves (Lubchenco et al. 2003) (and the threat to them of climate change).

Technologies

Roles of technology in enhancing efficiency but creating environmental disruption and the need to deal with it, and technology's relationship to the economic system, need to be explained. Such things as the issues related to the environmental Kuznets curve (e.g., Carson 2010) and Jevon's paradox, and the failure of past technological "cures" such as "nuclear agro-industrial complexes" that would use nuclear power to desalinate sea water and grow crops in desert areas (Oak Ridge National Laboratory 1968). Especially critical is making people aware of the extent of infrastructure that supports civilization, the need to redesign parts of it, especially those that deal with energy and water, to be resilient to global change (Ehrlich and Ehrlich 2010), and the long lead time required to make needed major modifications.

Climate

In discussions of climate disruption, much attention is paid to the dangers of sea level rise, because it threatens the lives and well-being of tens of millions of people in low-lying areas (Dasgupta et al. 2009). However, not enough attention is devoted to changing patterns of precipitation and the influence of heating on yields of staple crops, which could potentially endanger *billions* of people (Lobell et al. 2008; Lobell and Field 2007; Schmidhuber and Tubiello 2007). Similarly the press reports regularly on the threat of heating to spectacular coral reefs, where damage is easily visible to scuba enthusiasts, but does not give adequate coverage to acidification of the oceans, or the synergisms among the varied assaults on oceanic ecosystems (Jackson 2008). And not enough attention is paid to the importance of time lags and feedbacks. All this, and the absurdity of most "geo-engineering" fixes for climate warming (e.g., Trenberth and Dai 2007) should be part of the knowledge of every adult. Introducing the complexities of climate is also an ideal place to begin introducing the complexities of climate politics (e.g., Trenberth 2010). Furthermore, many people are convinced that climate disruption is essentially the only serious global environmental problem, when, in fact, others may be equally or more dangerous (Bradshaw 2009).

Loss of ecosystem services

Extinctions, interacting with climate disruption, may prove worse than the disruption itself. The key role of the *population diversity* of plants and animals in supplying ecosystem services and the extinction crisis is largely neglected. At the moment, it is more serious and more indicative of the biodiversity crisis than are species extinctions (Hughes et al. 1997). Populations are, after all, what supply ecosystem services, such as soil generation, pest control, pollination, flood control, cultural services, and so on.

Toxics

We know almost nothing about the impacts of most of the 100,000 or so potentially toxic synthetic compounds that

now permeate the environment from pole to pole. Worse yet, essentially nothing is known about the possible synergisms among toxins, cases where the toxicity of a combination is worse than the sum of the toxicities of the ingredients (e.g., Doudoroff and Katz 1953). This includes not just two-way synergisms among these compounds, to say nothing of the possible three-way, four-way…etc. synergisms. The importance of toxics that mimic our hormones and often have non-linear dose-response curves is generally ignored. While most people are at least somewhat aware of the threats of poisoning from toxic compounds, most are convinced that "the dose makes the poison" (Myers and Hessler 2007). Yet very tiny doses of hormone mimics can disrupt development in young organisms whereas larger doses may have little or no effect.

It is especially important that people understand that the threat of toxification might be as serious, or even more serious, than that of climate disruption. And some research has indicated that a warming climate could mobilize many toxic chemicals that have been released into the environment—an unexpected synergism (Lovett 2010). For climate disruption, though, we can at least contemplate the science-fiction "cures" of geoengineers. We don't even have any similar speculative "solutions" for everyone starting to suffer from fatal cancers, reproductive failures, or other symptoms of poisoning.

Infectious disease

Rapid globalization is accelerating the movement of people and bringing previously separated societies together. This and the increasing speed of transportation are facilitating the rapid spread of disease organisms (Pirages 2007). Deterioration of the epidemiological environment is another problem that might prove more severe than climate disruption. As the human population grows, the probability increases that novel infectious diseases will successfully invade it from animal reservoirs and cause vast epidemics (Anderson and May 1991). Also heightening that probability is growth in the number of malnourished and thus relatively susceptible individuals. Misuse of antibiotics, leading to serious problems of resistance (a concept that should have been introduced early in secondary school in connection with teaching evolution), further darkens the outlook, as does the poleward and altitudinal spread of tropical diseases on a warming planet (Daily and Ehrlich 1996a).

Human evolution

Societies evolve culturally as well as biologically. Changing values and institutions are part of our agenda for reaching sustainability. Issues of race and gender that damage that agenda should be taught in a context of human evolution, with the idea of the biological unity of *Homo sapiens*, our possession of a theory of mind, and our capacity for empathy, versus the great diversity introduced by cultural evolution (Ehrlich 2000). Human behavior is key to solving environmental problems, and people should understand what is known of its fundamentals. Above all, they should not be fooled by the notion, especially prevalent among scientists, that given the proper information on the state of the environment people will act in a rational matter. There is massive evidence that this is incorrect, and that many "irrational" factors need to be grasped to understand our behavior.

Economics

In the context of behavior, some basic background in economics and social processes is essential for everyone (e.g., Dasgupta 2007). Topics such as externalities, common property (cooperative governance or the tragedy of the commons), and the differences among markets, corporations, and capitalism, need to be understood. Environmental or ecological economics (Ehrlich 2008) also need to be explained. Sound economic analysis indicates that, contrary to many claims, government intervention can improve the functioning of markets and create social net benefits. People should learn that unfettered markets are often far from ideal and compel anti-environmental behavior. Adam Smith's views in *The Theory of Moral Sentiments* (Smith 1759\1974) should be explained to counter the common misuse of quotes from *The Wealth of Nations* (Smith (1776\1976)) to drive home this point. People also need to grasp the importance of the varieties of capital beyond financial and produced capital. The roles of human and social capital and, especially, natural capital and the ecosystem services that are the "interest" flowing from it, how natural capital is rarely depreciated in accounts of the wealth of nations (Repetto et al. 1987), and what GNP is and is not (e.g., Daly and Farley 2004) also should be communicated. In this context students should be introduced to new measures of progress to replace GNP, both those proposed and those needed.

The need for appropriate information—for "getting prices right"—in order for markets to function properly needs to be repeatedly emphasized. If environmentally damaging goods or services were appropriately priced, then consumers would have all the information they needed – they could do the right thing just by comparing prices, and many damaging externalities could be internalized. If not, what turns out to be privately less costly proves socially more costly (Goulder 2000). For example, a carbon tax would cause downstream goods and services to be appropriately priced (at least in terms of the carbon damage associated with their production or use).

Everyone should realize that people often do not do the right thing just because they know it's right, even when they have appropriate information. A stunning example of this was the refusal of European Jews to believe the Nazis aimed to exteminate them until it was too late, despite massive and building evidence that that was the German goal (Friedländer 2007). The current failure to address climate disruption shares many features with this tragic example. But sometimes people will do what's right, even if it goes against their economic interests, as the abolition of slavery in the USA illustrated.

Governance and institutions

The importance of effective governments capable of making environmentally sound policies should be stressed. Environmental issues in governance should become part and parcel of a continuing effort to inform students of how collective decision-making works, whether by informal communities, by governments, or by world bodies. It should be recognized that the nation state (a rather recent development) is often an impediment to reaching sustainability, and that government reform is required at various levels. Institutions from legislatures to churches and universities need to be altered to meet the realities of global change.

Ethics

Much more attention is needed to ethics in schools and media—with discussion of such topics as intergenerational equity, environmental justice, empathy, etc. Ethical issues are rarely discussed in our society; when they are it is often in the context of an introductory college course or putative rules set down by mythical beings. Many of the most difficult ethical dilemmas today are closely tied to environmental issues, from animal rights and exploitation of endangered species to human reproduction and migration (Ehrlich 2009; Singer 2002). People should be made aware of the issue of existence values in relation to biodiversity (Ehrlich and Ehrlich 1981, ch. 3).

How should environmental science be made an important focus of everyone's education?

Start early

In the face of today's knowledge explosion, combined with the "endarkenment" of current anti-education, anti-science political trends, especially in the USA, closing key parts of the culture gap is extremely challenging. Successful environmental education would start in nursery and grammar school and continue to be integrated into education from then on. The "see Spot run" approach to early readers needs to be transformed into "see the plant grow in the sun" and the equivalent, so that youngsters learn early the basic facts of life on Earth. Furthermore, starting early and continuing throughout life, society would benefit from more direct exposure of an increasingly urbanized human population to natural systems—to active field trips at all levels, since video and simulations give a limited glimpse of the environment and its decay.

Tie environmental issues into standard parts of curricula

In middle school mathematics, students should be thoroughly introduced to exponential growth, so that they will not only be able to understand interest rate problems but always remember that a long history of exponential growth does not imply a long future of exponential growth. It is here that the norm of believing that perpetual population and economic growth is possible needs first to be undermined, as well as the idea that that unlimited economic growth can be based on energy from fossil fuels. This opens the door to discussing interest rates and then discount rates, with the latter feeding eventually into the ethical issues of intergenerational equity. Needless to say, one would hope that all students would be introduced to basic calculus, especially growth functions, before the end of high school.

Ideally, information on the epidemiological environment could be folded into material on how to deal better with medications and the medical system that themselves badly need to be integrated into school curricula. Sex education should be one place where this is done, and it should be included with related but usually omitted topics such as evolution of the family (Ehrlich and Ornstein 2010; Hrdy 2009), ecoethics, reproductive behavior, and so on. Human behavior is, after all, what is threatening civilization, and it pays for everyone to understand as much as possible its roots, variation, and how it plays out in governance (Ehrlich 2000; Ehrlich and Ehrlich 2005).

The importance of regulation of population size as a government function should be introduced early in civics classes, perhaps using the analogy that just as the government needs to restrict one's freedom to drive on either side of the road or make it illegal to refuse to be immunized against an epidemic disease, it has the duty to see to it that the size of the population is not causing social or ecological harm.

Revise the education of teachers

One of the most challenging tasks we face in the environmental education enterprise is revising the educa-

tion of teachers, especially those of the lower grades. This could probably best be accomplished by dissolving schools and departments of education, integrating what is known about learning (much from the work of psychologists (e.g., Bandura 2004) into general education, and (of course) radically improving the status of those who educate the young.

Reform college/university curricula

While the basics of environmental science should be taught in elementary and high school, a serious challenge for all of us is to deepen understanding at the college level. In particular, this will require modifying the antique disciplinary structure that so degrades higher education, especially in the humanities and social sciences. Continuing education, even for tenured professors, is essential to deal with these accelerating environmental issues, and help correct the severe cultural lag that afflicts colleges and universities.

For instance, a dominant theme of international relations in the twenty-first century will clearly be environmental, broadly defined to include avoidance of resource wars (potentially nuclear). Nonetheless, in the antique structure of universities, schools of international relations tend to be the domain of political scientists unaware of many environmental issues. This is just one instance of the "siloing" (compartmentalization) of higher education, tracing to Aristotle, that all scholars need to struggle to reform. A major challenge for environmental educators is to fuse research and education in international relations with environmental studies. Other failures have to do with taboos and omission of certain topics in curricula. A prime example is the power relations that run the world but are rarely considered. Another is the negative aspects of organized religion, which are often neglected despite their frequently dreary impact on societies as exemplified by their role in the slaughter of millions and the waste of vast amounts of human time and talent examining the minutiae of the behavior and wishes of mythical beings.

In my view, the *relative* success of the natural sciences in keeping disciplinary boundaries more flexible is not due to the scientists' having an unusual openness to change, but to their being forced to face change as understanding of the world has demanded it. When I first joined Stanford's faculty in 1959, neither biochemistry nor climatology were part of environmental biology; in most universities there were separate departments of zoology, botany, and even entomology, and no one would have imagined economics being an important part of an ecologist's training. Now our "biology" department has many biochemists, climate is a central topic in conservation biology, there are relatively few departments of zoology, botany, or entomology left in first-rate institutions in the USA, and graduate students in ecology are encouraged to learn some economics. Similar restructuring of the social sciences, a need long recognized by some social scientists (Wallerstein et al. 1996), is in part a challenge for environmental educators, especially since it now makes little sense to separate natural and social sciences. Fortunately there is a small cadre of social scientists who have been bringing their expertise into the battle to achieve environmental sustainability (e.g., Arrow et al. 2004; Brulle and Young 2007; Dasgupta 2001; Pirages and DeGeest 2003; Rosa et al. 2004)

At the end of formal education, every Ph.D. or postdoctoral fellow, regardless of discipline, should know what the second law of thermodynamics says and know how human beings depend upon ecosystem services, just as they should be at least vaguely familiar with MacBeth, Van Gogh, and Plato's cave.

Beyond schooling

As you can see from the perspective of what I think people need to know, current curricula are deeply flawed. Much of the reform needs to be done through school systems, although in many countries the tendency to standardize curricula is a tendency to lock in disaster. The situation in universities is even worse, even though curricula there are *relatively* free of outside interference. The sad facts are that even in the greatest of research universities students often graduate or even get a doctorate and remain profoundly ignorant of how the world works. At Stanford it is possible to complete an education and know essentially nothing about science (which along with technology is at least half of our culture) – to say nothing of environmental science.

But schooling is not enough. Beyond schooling, continuing public education is necessary for the survival of civilization, and it must be continuing. We need to change the entire concept of education from the present "fill young people up with information for a specific type of job" view to an essential life-long process of upgrading. This is required by the speed of cultural evolution, especially in the areas of science (including social sciences) and technology. The world is changing so rapidly that other sources of information are required if one is to have at least a basic grasp of what is going on. But in a world of rapidly multiplying sources, knowing how to evaluate them and assemble a useful world view is crucial.

Given this situation, students, starting in middle school, need to be made aware that there are powerful propaganda organizations at work (Oreskes and Conway 2010) and that no single channel, or even set of channels, of information on the environment can be fully trusted (including my own books and articles). Ideally, good citizens will acquire the basic scientific background and then carefully sample books, articles, the media, and the Internet to form their

own conclusions. It can be especially helpful to organize groups of friends in which individuals specialize in keeping track of what is happening in different areas, and share their knowledge with others. Social media tools can assist in this endeavor. And promoting the reading of more general environmental literature, in the broadest sense (e.g., Diamond 1997; Garrett 1994; McKibben 1999; Weisman 2007; Wilson 1992, 1994), can aid greatly in encouraging environmental literacy.

Taking environmental education global

Scientific information is necessary but not sufficient to move to a sustainable society. Scholars now know more than enough to say how society could be turning in that direction, but it is not doing so. That's why a new initiative, called (following the lead of the Millennium Ecosystem Assessment) the Millennium Assessment of Human Behavior (MAHB) has been established. The objective is to begin a discussion and an assessment of human goals and the barriers to achieving them, ethical considerations, and how and why people are behaving as they do—involving not only natural and social scientists, but also scholars from the humanities, decision makers, and members of the general public. Whether or not the MAHB is successful, all citizens should be made critically aware of the behavioral and ethical dimensions of human behavior, and how they relate to the culture gap between collective and individual knowledge. Above all, the real possibility that continuing on the business-as-usual course, a growth-oriented, fossil-fueled, capitalist system, could lead to the first collapse ever of a global civilization. Introducing everyone to that key point, and the cultural behavior that makes it difficult to alter (e.g., Leahy et al. 2010; Norgaard 2006a, b), is a central challenge for environmental educators.

Conclusions

Obviously, fulfilling my view of an appropriate environmental education would not be simple, and might simply prove impossible in all its details. But I present it here not as something I think is good, ideal, or doable. I assert that will be *required* if humanity is to achieve a sustainable society in a battered ecosphere. Our small-group animal is struggling to learn how to live in gigantic groups (Ehrlich and Ornstein 2010). Unless at least a substantial minority of human beings is familiar with the essentials of how environmental and socio-political systems work and interact, and how to retain their functionality, I do not think we have a hope of succeeding. Retooling education is an utterly necessary but not sufficient requirement for giving us a chance.

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