A Simple Model for Environmental Courses

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WHEN ENVIRONMENTAL ISSUES became popular several years ago, rapid changes in courses and curricula at all levels were initiated to reflect the relevancy of current environmental concerns. As educators gathered data beyond the obvious "pollution" issues, they found themselves exploring disciplines and topics they had never previously studied or taught. For some this exploration became a delightful adventure in interdisciplinary teaching while for others it became an entanglement of disconnected facts and fables in a morass of highly emotional and irrational opinions. Unfortunately, many persons taught and learned new facts without any understanding of the underlying concepts and principles.

Today it is obvious that the subject matter for courses in environmental science comes from a wide variety of disciplines such as ecology, physical geography, meteorology, soil science, chemistry, and so on. Only when aspects of these disciplines become integrated does a course become truly interdisciplinary rather than a series of minicourses on selected topics.

The simple framework for either a course or a curriculum in environmental science or related areas is an understanding of the two basic, fundamental themes which integrate all of the disciplines concerned with environmental topics: the *flow of energy* and the *recycling of matter*. A thorough understanding of these two principles is necessary to maintain a proper perspective in the design of an environmental course or curriculum and in the choice of appropriate textbooks and reading materials. Using the model presented in this article, teachers can pursue a reasonable detail in selected areas based on the students' interests and the local community issues.

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Several years ago, the ecologist H. T. Odum (1957) developed an energy flow diagram for an aquatic ecosystem in Florida. I have adapted this scheme as an outline or model for an interdisciplinary laboratory science course primarily for nonscience students. This model has also been used in the design of environmental courses at the junior and senior high school level.

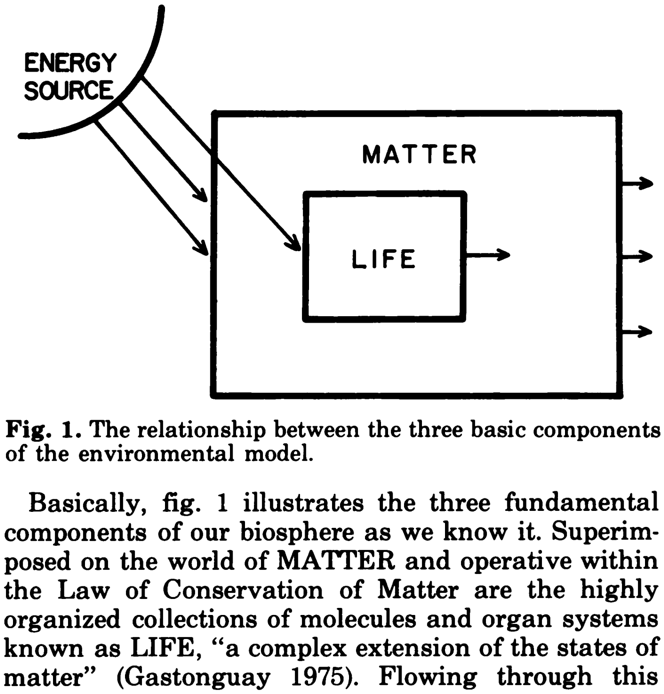

Fig. 1. The relationship between the three basic components of the environmental model.

Basically, fig. 1 illustrates the three fundamental components of our biosphere as we know it. Superimposed on the world of MATTER and operative within the Law of Conservation of Matter are the highly organized collections of molecules and organ systems known as LIFE, "a complex extension of the states of matter" (Gastonguay 1975). Flowing through this biophysical world is ENERGY with approximately as much energy leaving the biosphere as entering it from the earth's ultimate source of energy, the sun. The world of science hangs on this elementary scheme. This simple model may be divided into several components (fig. 2), each of which can be studied in much greater detail than is presented here. In fact, entire courses are taught and textbooks written about each component in this model. However, the importance of the fundamental underlying concepts of energy flow and recycling of matter must not be overlooked as one studies the details of environmental problems.

Solar Component

Beginning with the fact that the earth receives a constant supply of electromagnetic radiation from the sun (an average of 2 cal/cm^2/min at the outer atmosphere and about 1 cal/cm^2/min at the earth's surface) one can develop the various aspects of the energy input process and discuss the laws of black-body radiation. Of considerable interest is the effect of a change in the radiation input to the earth because of the presence of jet contrails, the use of aerosol sprays, and the presence of air particulates. The energy reaching the earth's surface varies considerably from hour to hour and day to day. Students can develop an appreciation of the variability of solar energy input through the measurement of this component with the relatively simple pyrheliometer (Belfort Instrument, 1600 S. Clinton St., Baltimore 21224). The next obvious question is "How is the solar radiation distributed on the earth?" Table 1 demonstrates that an extremely small quantity of energy is transformed by green plants from radiant energy to chemical potential energy, that is, photosynthesis, the basis of food chains.

To amplify this component an interesting laboratory experience or course on biometeorology and microclimatology can be developed. By using relatively inexpensive instrumentation such as thermometers, homemade sling psychrometers, anemometers, and so on, students learn to collect, tabulate, graph, and analyze a large amount of data.

Trophic Level Component

The transfer of energy from one trophic or food level to another and the interaction among populations in various trophic levels lead to a study of the subject matter traditionally found in the area of ecology. From fig. 2, it is clear that the autotrophs, due to the presence of chlorophyll, are a vital link in the energy flow process as they convert radiant energy into chemical potential energy upon which every heterotroph, including man, is totally dependent. Of special significance is the dramatic change in biomass from autotrophs through primary, secondary, and tertiary consumers as described by Odum (1957) and Lindeman (1942).

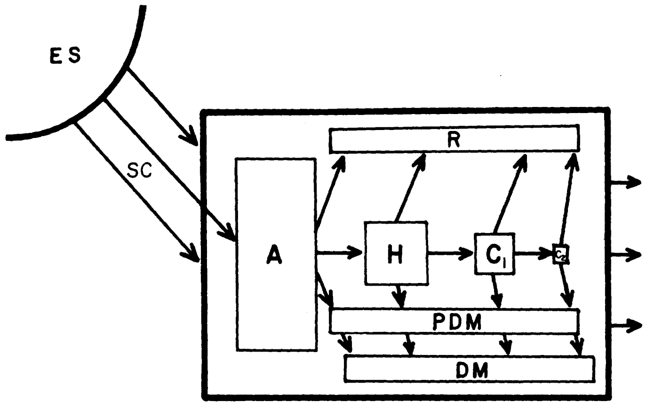

Fig. 2. An amplified version of fig. 1, showing the various compartments and energy pathways of the LIFE component. ES, energy source; SC, solar component; A, autotrophs; H, herbivores; C_1, first-level carnivore; C_2, second-level carnivore; R, respiration; PDM, partially decomposed matter; DM, decomposed matter.

Table 1. Distribution of solar energy on the earth (Hubbert 1971).

Reflected and scattered back into space	30%
Absorbed as heat in oceans, land, and atmosphere	47%
Hydrolic cycle (evaporation, convection, precipitation, and surface runoff)	23%
Atmospheric currents and ocean currents	0.21%
Photosynthesis	0.023%

Decomposer Component

The role of decomposers in an ecosystem is relatively unknown. This was dramatically illustrated recently by one of my students who rushed up to me to ask, "What happens to dead squirrels?" More likely than not, this student had previously studied the mineral cycles. But apparently he had not seen the significance and the applications of this information. Today in our great concern over the recycling of materials we frequently lose sight of the fact that the recycling of minerals and other matter is one of the fundamental processes of the living world. The pathway for the flow of matter is not a one-way or flow-through process as is the flow of energy. Rather, it is a cyclic process which has been taught in biology classes for years with the examples of the cycles of carbon, nitrogen, and phosphorus.

Students can gain an appreciation of the role of the decomposers in an ecosystem through the study of soil organisms such as millipedes, earthworms, and nematodes and the rate of leaf decomposition in a woodlot. A simple 10X hand lens and perhaps a Tullgren funnel set-up (Cox 1972) are valuable aids.

Partially Decomposed Materials

Fossil fuels exist today as concentrated materials in a metastable energy state due to the fact that each year a small amount of living material is not degraded by decomposers to the lowest energy state and thus recycled in ecosystems. From the diagram (fig. 2) the pathway of radiant energy from the sun to the partially decomposed materials is obvious. I prefer to think of fossil fuels as *used sunshine* and the oil, gas, and coal corporations as *used sunshine dealers.* In a class discussion the students usually bring out that there are many ethical and moral questions involved with the rights of handling and dealing with used sunshine.

Laws of Thermodynamics

Any understanding of environmental science will have to contend with the laws of thermodynamics. This topic can be discussed on any level from the superficial to the extremely detailed. However, the basic concepts of the first two laws are really quite simple.

The first law of thermodynamics as it relates to ecosystems is that all of the energy going into the ecosystem can be accounted for, or that the earth is radiating as much energy as it is absorbing. This is consistent with the statement that energy is neither created nor destroyed. Regarding energy in an ecosystem, "You can't win" is a crude but accurate axiom.

The second law of thermodynamics crudely stated is that "not only can you not win, you can't break even." As fig. 2 demonstrates, the amount of energy transferred from one trophic level to the next is reduced by a factor of about ten. This drastic reduction is due not only to the fact that the predators and consumers do not eat every organism below them in the food chain but also that energy is expended for the maintenance of each living organism. A discussion of the difference between gross productivity and net productivity is appropriate at this point. In fact, one can go into considerable detail demonstrating that for a mature organism or ecosystem the energy input approximately equals the output, or P = R, where P is productivity and R is the respiration or maintenance component (Odum 1969).

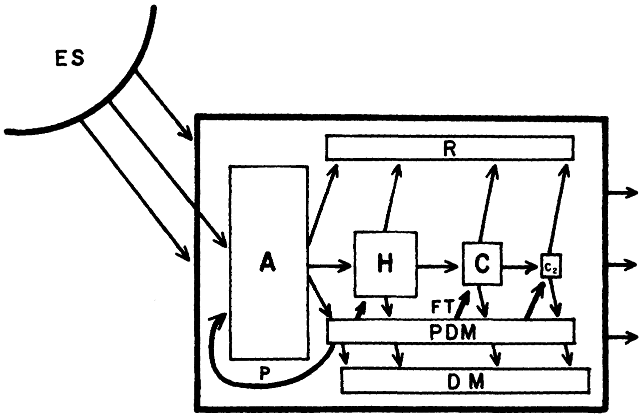

Fig. 3. The relationship of humans to the environmental model. P, energy for food and fiber production; FT, energy for fuel and transportation; see fig. 2 for explanation of other symbols.

Through a variety of methods these basic laws of thermodynamics may be demonstrated and amplified according to the available facilities, equipment, needs, and background of the students.

Human Component

Frequently environmental courses are taught as if the entire world were controlled by the whims and wishes of humans, rather than considering humans as a species subject to the same basic laws and regulations as other living creatures. The role and function of humans fits very well into this framework (fig. 3).

Humans may occupy all trophic levels except the first or autotrophic level, because humans are omnivores. It is quite clear from the diagram that it is energetically more costly to be a meat eater and occupy the third or fourth trophic level than it is to be an herbivore and occupy the second level. This observation alone should tell us something about the prices we must pay for meat, and why poor people eat less meat and more affluent persons eat "higher on the hog."

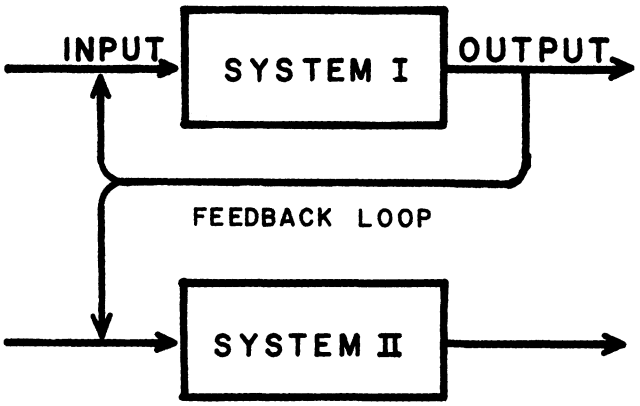

Fig. 4. A model for a teaching definition of pollution.

It is obvious that the energy crisis is caused by the fact that humans are using the nondecomposed matter (fossil fuels) at a much more rapid rate than these fuels are being formed. Such a great quantity of the fossil fuel supply is being channeled into the first trophic level to increase the production of autotrophs by means of improved agricultural machinery, improved seed stock (genetic research), and more rapid transportation of food and fiber crops, that it is quite likely that our production per acre per calorie input has decreased rather than increased over the years.

From the basic conception of the source of fossil fuels as used sunshine, students will be better prepared to handle the details of the energy problems and crises as they appear in the popular press.

A great deal of fossil fuel energy is used directly as fuel for the heating of buildings and the operation of transportation vehicles. This route degrades high energy compounds to low energy compounds (CO_2 and H_2O) in one rapid step. Such a practice does not appear to follow the route of decomposition in natural ecosystems, in which matter is degraded in a step-wise fashion with a great diversity of organisms receiving energy input in the decomposition process.

Pollution Component

To prevent environmental courses and topics from becoming doom-and-gloom sessions decrying the dirty water and smelly air, the topic of pollution must also be put into proper perspective. Despite all of the recent verbiage on pollution, very seldom does one find a definition of the term. Most definitions point to the activities of man in a natural world as being polluting activities. However, man is a part of the natural world and has been for thousands of years. By using a systems diagram (fig. 4) it seems reasonable that "pollution" falls under the category of negative feedback. Any time the output of one organism affects the input to itself or another organism so as to cause a decrease in the output of the organism, a negative feedback control is in operation. For example, sewage may not be a pollutant if it does not affect the health of any other organism. In fact, sewage is a resource for many organisms. A billboard may be an asset to the person receiving the economic benefits of the product being advertised, while it is a visual blight to the person expecting to view a natural landscape. Noise is not really pollution until it disrupts conversations or breeding cycles of organisms. Perhaps a fairly reasonable definition of pollution may still be "a resource out of place."

Conclusion

Through this brief summary I have attempted to demonstrate how the two basic principles of *energy flow* and *matter recycling* can be incorporated into a framework around which many classes, courses, and perhaps curricula could be designed. I would be appreciative of comments, suggestions, and experiences of other persons involved in similar educational situations. Hopefully, students with a solid foundation in the fundamental environmental concepts will be able to make significant contributions to our society in the future.

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dent to self-regulate and abstract the formal pattern from the particular situations. Bruner and Kenney suggest, and I concur, that this instructional procedure may be viewed as a microcosm of intellectual development in general.

If such a model is reasonably accurate, then it becomes clear that teachers in particular, and the educational system in general, carry a great responsibility for the final success or failure of the student in his pursuit of formal thought development.

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