Earth Sciences Education + Environmental Education = Earth Systems Education.

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[Dr. Orion provided this special overview as background for the three abstracts that follow.]

Today, more then ever, there is a worldwide recognition that living in peace with our environment is more than just a slogan, it is an existential need. It is also agreed that understanding of each of the earth's sub-systems and the environment as a whole is indispensable in order to live in peace with the environment. This understanding is actually what science all about. There are many ways of approaching environmental education. It is suggested that life on earth should be the starting point and the end product of

environmental education. I believe that the main purpose of environmental education is to bring students to understand the interrelations between life and the physical environment. Our future citizens should understand that life influences and is influenced by the natural environment. The natural environment is a system of interacting natural subsystems, which each one influences the other ones. They should understand that any manipulation in one part of this complex system might cause a chain reaction that could come back as a boomerang effect. The translation of these noble ideas to a practical educational plan is a very challenging task. Our view is that real understanding of the environment is based on understanding of its scientific principles and processes. The societal and technological aspects of this area should provide the relevant context for the study of the scientific concepts.

Environmental education should be an integral and indispensable part of the science curricula from K-12. Moreover, its critical necessity for our society, its relevancy to students' daily life, and its multidisciplinary nature demand that environmental education should have an honored central place in the science curricula. The multi-disciplinary characteristic of environmental studies, their relevant importance and educational potential inevitably suggest that this subject should be also included with association to all the scientific disciplines. One way to introduce environmental topics to the science curricula is by using relevant environmental topics as a motivation to learn scientific concepts, and in higher learning levels, one can use previous scientific knowledge and principles in dealing with earth systems. Their should be clear definitions in relation to the knowledge and principles of educational literacy as we have in all the scientific disciplines. The environmental content should focus on two main domains: a) Case studies of environmental issues (the symptoms), and b) the development of an environmental insight.

What does "environment" mean?

Environment is a very broad term. It ranges from the natural environment through the man-made environment, the home environment and the personal environment. However, the most common consideration of the "environment" is in relation to pollution of the environment or in the positive side of the coin—the quality of the environment. Also, these two parallel terms have a large range of aspects, from worldwide issues such as global warming, to regional issues such as water pollution, to more local issues like conservation of specific localities; from economical and technological derived debates such as alternative energy sources, to values such as the development of roots towards the homeland and to more moral decisions such as protection of endangered species. In principle and also in practice, one can relate almost everything under the *environment* title.

In the scientific community there are two main schools of looking at environmental studies. Both approaches look over the interrelationships between man and the physical environment, however they differ by their perspectives. One school is more concerned with the understanding of the physical environment: studying the five interacting Earth subsystems or spheres—atmosphere, biosphere, cryosphere (ice), hydrosphere and lithosphere. The other school is more concerned with the environmental hazards from the human life perspective. This approach gives more attention to the interrelation between energy and environment, the exploitation of our limited energy resources, and its effects on the environment. The human society, for this approach, is an integral part of the earth system. Technology has a dual part in the societal-environmental interaction. On the one hand, the technological revolution and the over-using of energy resources dramatically increased the damage of some aspects of the environment, but on the other hand, new technologies can help in limiting environmental hazards and in providing alternative energy resources.

Our Perception of Environmental Education

As a result of the multi-disciplinary characteristic of the "environment," namely social, technological and scientific aspects, different educators give different interpretations and focus to the term ENVIRONMENT and consequently to the term environmental education. The central topic of the Israeli educational system during the year 1993–94 has been the environment. Based on my observations throughout this year, it seems that many environmental programs did not go far beyond topics such as cleaning our living area, recycling and protection of the nature. All these topics are no doubt very important, however, environmental education, in my perception, should deal with a deeper consideration. In order to develop environmentally literate citizens, it is not enough to focus on the affective domains of the environment. The main task of a science educator is to translate the scientific ideas into a practical educational plan. In relation to the two scientific approaches described above I have no doubt that the human perspective should be the focus of environmental education. According to the relevancy of environmental issues to students' daily life and the main purpose of the educational system which is to educate, life on earth should be the starting point and the end product of environmental education. However, as we can see from many existing environmental oriented programs, any attempt to develop environmental literate students without giv-

ing them, at least, general acquaintance with and understanding of the physical environment could never reach far beyond the level of recycling and cleaning of the school yard. This acquaintance and understanding means study about the earth systems. Each subsystem for its own, the interrelationships between them and mainly their interrelationships with man. The key role for real understanding of the physical environment is the understanding of the basic scientific principles and processes which are related to earth systems. Thus, the starting point and the end product of environmental education should be the man, but in the middle, the key for achieving any basic environmental insight involves the study of the scientific characteristics of all the earth systems including the physical environment.

The integration of Earth systems within science education

The suggestion that development of environmental insight is based on scientific literacy means that studying our earth systems should be an integral and indispensable part of the science curricula from K–12. In an era of a revolution in science education all over the world, which starts to move towards "Science for all" approach, earth systems education should take a central place in the science curricula from K–12. This demand is based equally on the critical necessity of environmentally literate citizens for our society and the educational potential of this subject, namely its relevancy to students' daily life and its multi-disciplinary nature. In order to give the noble ideas a real meaning and authority, there should be a definition of what is an environmental literacy. This should be done by a committee of environmental scientists and science educators. In Israel we use two ways of introducing environmental-earth systems topics into the science curricula. One approach is to use relevant environmental topics as a motivator vehicle to learn scientific concepts. For example, the topic of global warming, which is mentioned quite often in the media, could serve as a motivator for the study of chemical and/or biological processes which are involved in this phenomenon. Earthquakes, for example, could serve as an advance organizer of learning about the earth crust and about change as a physical phenomenon. On the other hand, one can use previous scientific knowledge and principles in dealing with environmental topics. For example, the study of the carbon cycle should be based on prerequisites of basic concepts in chemistry, biology and earth sciences.

We find that both approaches are useful and can be implemented successfully in relation to a specific age and program.

- The environmental-earth systems content should be included in the science curricula
- The environmental-earth systems content should focus on two main domains:—Case studies of environmental issues (the symptoms).—The development of environmental insight through studying of systems.

As mentioned above, environmental issues can serve both as a vehicle for learning scientific concepts and for organizing and implementing previous scientific knowledge. Environmental case studies should be selected in relation to the relevancy of the phenomenon to the students' daily life experiences and its importance to the future of the humankind. It is suggested to classify such case studies to three levels:

—The local level

—The national level

—The global level.

Local case studies are varied from one locality to another. For example, air pollution is a very relevant topic for students who live in the Haifa gulf region, while floods are more relevant to other localities. An example for one of the most important environmental subject in the Israeli national level is the hydrological system. The greenhouse effect and the global warming debate is an example of global topics. Through such case studies, students might understand the cause of some specific hazards and hopefully, what should be done to recover or prevent them. However, for me, the main purpose of environmental education is the development of environmental insight. This insight is based on the understanding the system-cyclical mechanisms of our planet. The common factor for all environmental hazards that humanity faces is that they are derived from people's unawareness of the fact that society is a part of the environment which is composed of several interrelated subsystems. They are not aware that any manipulation in one part of this complex system might cause a chain reaction that might come back as a boomerang effect. In order to develop this insight I would recommend focusing on geochemical and biogeochemical systems such as: rock cycle, water cycle, food chain, carbon cycle, oxygen cycle and energy cycles. However, the studying of such systems should not be sterilized and should be conducted in the context of its influence on man's daily life.

The educational challenge

The environmental-earth systems education approach which is presented above is quite a challenging scheme. It involves the development of cross-curricular and cross-age programs. It involves interdisciplinary subjects and most of all it involves the teaching and learning about quite complex interrelated systems and the development of system-cyclic thinking. Thus, sci-

ence education must find the most appropriate teaching and learning strategies for achieving these goals. Since the resources of science education, namely teaching hours, are very limited, an additional important challenge of science education will be to find the minimal scientific background needed for the development of environmental literacy. In other words, they will have to find a way for not being too shallow in one hand, and not to go too deep and staying in the natural systems level, without reaching the human perspective of the environment.

In order to fulfill the educational challenge we have taken the following actions:

1. Together with environmental and earth scientists and science educators we try to define what is educational literacy or environmental insight.
2. We try to convince educators (with the scientific support) that the earth system should serve as framework for "Science for all" programs from K–12.
3. Mapping of the different programs for science majors in the high school, in relation to earth systems subjects. The purpose of this survey is to point out those parts of the curricula which can be taught in an environmental context.
4. An intensive study which focuses on students' cognitive abilities in perceptions of cyclic multidimensional systems.
5. An intensive study which focuses on learning and teaching integrative or multi-disciplinary. It is my suggestion that the main constraints to implementation of environmental programs are due to both teachers' and students' difficulties in teaching and learning subjects in an integrative manner. Thus, the study will have two domains:
    a) A study will focus on students' abilities and strategies in integration of concepts between different disciplines and within a single discipline. The main object of this study is to suggest models and strategies to organize and to teach integrative subjects, and
    b) A study which will look for appropriate strategies for the implementation of multi-disciplinary programs and subjects.
6. The development of curriculum materials for the science curricula from K–12.
7. A key role for success in the above steps is a close relationship with the professional science community and their strong support. According to the multidisciplinary nature of environmental studies, there is no single scientist who can cover all the aspects of this large area. Therefore, one of the most important conditions for the development of scientifically sound curriculum materials is a strong scientific backing of a group of scientists who are specialized in different aspects of the earth sciences and environment studies.
8. In-service training for teachers. The implementation of the learning materials is involved with massive in-service training (INSET) programs for the teachers who have to teach these new materials. Since for many of them both the subject matter and the integrative approach are quite novel, the INSET programs should be focus on both subject matter enrichment and the development of the appropriate teaching strategies for cross curricular teaching.

The locating of appropriate niches for the infusion of environmental or earth systems oriented units in the curricula, the development of appropriate learning and teaching strategies, the development of appropriate learning/teaching materials, a massive INSET programs and a strong support of professional scientists are already starting to have their positive influence on the quality and quantity of the earth systems teaching and learning within the Israeli educational system.