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MEDITERRANEAN MODELS FOR INTEGRATING ENVIRONMENTAL EDUCATION AND EARTH SCIENCES THROUGH EARTH SYSTEMS EDUCATION

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Abstract - *Practitioners of modern environmental education frequently find themselves collaborating with those who are engaged in integrating the science disciplines in search of answers to natural hazard prediction/protection, understanding the deep sea and space, and especially confronting pressing environmental concerns with a basis in Earth sciences. Indeed, it is a lack of understanding of Earth systems processes and feedback mechanisms that has resulted in humans initiating or exacerbating environmental problems for centuries. In this paper the authors provide a perspective on the established fields of environmental education and Earth science, and propose a practical combination that is of larger global import as well as more personal relevance than either of the originals: Earth systems Education. The role of the Earth systems education model in integrating the science curriculum is discussed with regional examples from Israel and Cyprus.*

The need for a new model

At the start of the 21st Century, more than ever before, 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 the 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. As Dr. Jane Lubchenco, President of the American Association for the Advancement of Science, said in her presidential address to the organization in 1998:

> *"Fundamental research is more relevant and needed than ever before… adequately addressing broadly defined environmental and social needs will*

> *require substantial basic research… We can no longer afford to have the environment be accorded marginal status on our agendas. The environment is not a marginal issue, it is the issue of the future, and the future is here now.”*

Accumulating evidence from academic research, historical records, modern community development, and political decisions in the first years of the 21st Century points to the fact that most people do not have an accurate picture of how the fundamental natural processes of Earth function, or how their own actions relate to those processes. The magnitude of this problem indicates it could lead to global systems that are not sustainable for the future. A prime example is the reluctance of the U.S. administration at the start of the century to acknowledge the role of current U.S. policy and actions in the acceleration of global climate change. As a world opinion leader, but more importantly as a top contributor to the increase of atmospheric CO_2, inaction by the United States exacerbates this global issue. Global science literacy, based on integration of Earth sciences and environmental education, is key to addressing such problems in this and future generations.

Environmental education

It is suggested 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, each one influencing the other ones. They should understand that any manipulation in one part of this complex system might cause a chain reaction with dire consequences. 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 educators worldwide recognize their scope of work through a definition crafted in a 1969 conference in Tbilisi, Russia:

> *“Environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated*

problems, aware of how to help solve these problems, and motivated to work toward their solution" (Stapp. et al.,1969)

Modern interpretations of these goals of knowledge, issue awareness and commitment to action take many forms, and a growing body of research is suggesting productive means of meeting the objectives. School science education is the source of the knowledge upon which hopes for environmental education depend (Fortner, 2001).

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 multi-disciplinary 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 also be included with association to all the scientific disciplines.

Earth sciences

The world model for science education is based on disciplinary boundaries and traditionally sees a hierarchy that puts classical physics in the most influential position, followed by chemistry and biology. Most listings of the hierarchy stop with these disciplines as the critical ones, grouping remaining disciplines as "Other," without mention of the Earth sciences (Mayer and Fortner, 2002). Such an approach relegates to the bottom tier of science priorities those fields that study the way the planet works. It leaves to chance the opportunity to learn how to evaluate the risk of an earthquake, to understand how changes in a river's flow affect more than the amount of water it carries, or how changes in sea temperature relate to ocean current patterns, world weather, and the distribution of sea life.

In the United States only 3% of high schools offer a course in Earth Science, the most relevant venue for teaching about the way natural processes work. Such courses are more common in middle schools, but at both levels most textbooks separate the components into meteorology, astronomy, oceanography and geology, a convenient way to match the quarter-year grading periods but an impossible way to teach how critical subject matter is integrated. If such curricula were to be built upon the study of environmental issues, the natural processes of earth would clearly be shown as interacting systems. Two examples follow:

1) "Fossil fuels" as a topic: lessons highlight their biological origins in Earth history, extraction from the lithosphere, combustion into the atmosphere, with resulting effects on atmospheric composition, climate patterns, biological responses (human health), and the like.
2) "Watersheds" as a topic: lessons include the geological structures that shape the area, patterns of precipitation, erosion effects, protection of watersheds through development of vegetational buffers, importance of watersheds in distribution of pollutants.

The curriculum in Physical Geography, more common in schools of the Mediterranean, suffers from a lack of attention, as well as partitioning of subject matter into disciplines, just as in the United States. What could be an integrated course at gymnasium level in Cyprus may be taught by several teachers with backgrounds in the more specific sciences of geology, physics, and such.

Need for combining EE and ES

Based on the issues noted, the traditional values of science teaching need to be re-evaluated in light of the needs of Earth inhabitants of the 21st Century. Curriculum reform efforts throughout the world are looking at such evaluations, but change comes slowly without incentives. Sustaining the environment of the Mediterranean region should be incentive enough for change in regional curricula.

In the scientific community there are two main schools of looking at environmental studies. Both approaches focus on the interrelationships between humans 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 environmental hazards from the human life perspective. This approach gives more concern to the interrelation between energy and environment, especially the exploitation of our limited energy resources and its effects on the environment. Human society, in this approach, is an integral part of the Earth systems. Technology has a dual role in the societal-environmental interaction. On the one hand, the technological revolution and the over-using of energy resources has dramatically increased the damage to some aspects of the environment, but on the other hand, new technologies can help in limiting environmental hazards and in providing alternative energy resources.

Research indicates specific needs for both of these perspectives. Using a systems approach has documented value in increasing understanding, and applies theory from wider research into the realm of education (Garigliano, 1975; Chen and Stroup, 1993; Hill and Redden, 1985; Lawton, 2001). In general, students, as well as college students and preservice teachers, frequently hold incorrect perceptions about Earth system relationships as well as how human activities impact those systems. Results regarding misconceptions are remarkably similar across education levels. The most common student misconceptions about climate change, according to a synthesis by Gowda, Fox and Magelky (1997) are:

- Inflated estimates of temperature change (11^{0}F/decade,compared to IPCC estimates of 0.5 F)
- Confusion between CFCs, the ozone hole, and climate change (ozone layer depletion causes climate change; stop using aerosols to prevent global warming)
- Perceived evidence – warmer weather (reportedly they could personally sense rising climatic temperatures or changes in long-term weather)
- All environmental harms cause climate change (aerosols, acid rain, even solid waste disposal)
- Confusing weather and climate

In many Mediterranean countries the way to teach about the environment is to have children in school groups plant trees and clean up rubbish from parks and beaches. While these are admirable activities, educators should question what is being learned that relates to making the child a globally literate citizen. The same children are likely to expect that their parents will drive them the short distances to the bakery or after-school lessons, and parents expect that doing so will make life better for their offspring. School science could be doing more to educate for the environment.

Components of new models

In an era seeing a revolution in science education all over the world, education leaders and governments are seeing the value of providing a high quality of science education to all students, not just those who are college-bound. The first paragraph in the *National [U.S.] Standards for Science Education* (NRC, 1996) states:

> *"In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choies that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world." (p.1)*

As educational systems start to move towards this "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. Key components of the Earth systems Education approach include the following list.

Integration

In preparation for teaching an Earth systems/environmental education course for Cyprus teachers, author Fortner asked teaching colleagues to give a simple survey to a sample of students in a Nicosia lyceum and in the 9th grade in a U.S. high school. The students were asked to list the most important environmental issues in the world and in their own community. A review of the responses reveals the combination of science disciplines, human relationships, and technology aspects that go to make up the concerns of adolescents in the new century (Table 1).

TABLE 1: High school students' perceptions of the importance of environmental issues

Cyprus Students (N=85)			**U.S. Students (N=65)**		
Issue	World rank*	Local rank*	Issue	World rank*	Local rank**
Greenhouse effect	1		Ozone hole	1	
Ozone hole	2		Global warming	2	
Acid rain	3		Overpopulation	3	
Forest destruction	4	3	Pollution	4	
Sea pollution	5	5	Oil spills	5	
Drought		1	Endangering species	6	
Air pollution (exhaust)		2	Using up natural resources	7	2
Rubbish		4	Damage to the beauty and balance of the Earth	8	1

* Based on average responses to questions: What are the most important environmental issues of today's world, in order of importance? What are the most important environmental issues of our community, in order of importance?
** Students struggled to identify issues in this clean, affluent community.

Are these students' concerns included in their science curriculum? Is the science in school serving all of them? It is clear that one science discipline, or even several sequenced in the curriculum, cannot address the breadth and interactive nature of these concerns. Intentionally focusing on environmental issues as case studies for science learning could accomplish the desired connections and facilitate learning on a need-to-know basis (Mayer, 1995). Integration might be facilitated by development of appropriate textbooks, but at least in the U.S. such resources either do not exist or do not reach their potential for teaching Earth science in a holistic manner (Bixel, 2002). An instructional methodology that helps to facilitate integration is the use of concept maps as ways for students and the teacher to organize ideas and show the ways that disciplines are integrated in a topic (Novak, 1990; Zieneddine and Abd-El-Kahalick, 2001).

Relevant local learning

An often-quoted mantra of environmental education admonishes people to "think globally, act locally." This presupposes having something to think about! Without knowledge of the interacting systems of Earth, and the human place within them, individuals are unlikely to think beyond their own needs to their role in shaping the future of the global community. In its early introduction to the study of Earth systems science, the U.S. National Aeronautics and Space Administration (NASA) demonstrated the time and space relationships of integrated topics through a graph (Figure 1). The idea of the graph is that as the scale of time and space expands, topics become more integrated and more far-reaching in their impacts. At the origin of the graph are the here-and-now science topics that are immediately visible and relevant to learners.

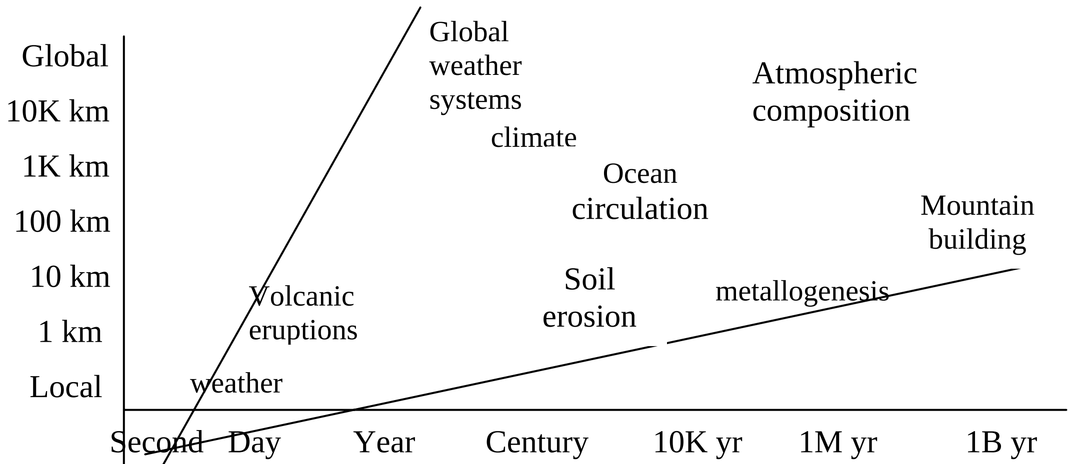

FIGURE 1: Earth system changes over scales of time and distance: Climate example (simplified from Earth Systems Science Committee, 1988)

Teaching children to learn about their own surroundings and the natural events happening there is not only scientifically sound, but also pedagogically correct. Teaching in the environment and using tangible natural events involves applying concrete operational learning styles. Piagetian theory would have us begin learning this way, moving later to the more global applications of concepts. It is more appropriate, then, to suggest that people "learn locally, apply globally" (http://earthsys.ag.ohio-state.edu/ESE-webslide/slide10.htm). If those lessons are effective, learners may eventually be stirred to act locally as environmental educators would hope (Fortner, 2001).

Within this component of the Earth Systems model comes the value of the outdoor learning environment. The Earth systems approach places the concrete environment at the heart of the learning process. Therefore there is no doubt that any Earth system-based curriculum should emphasize the use of the outdoors as a central learning environment. However, the "resources invested" in taking a class outdoors are very high in terms of organization, economics, logistics and safety. Therefore, the "educational payoff" should be very high as well.

It is suggested that the gap that exists between the high “resources invested” and the generally lower “educational payoff” is equal to the gap that exists between the high potential of the outdoor learning environment and its relatively limited fulfillment. This imbalance might be corrected only through a very clear definition of the unique educational contribution of the outdoor learning environment.

Orion and Hofstein (1994) suggested that the main cognitive contribution of the outdoor learning environment is in the concretization aspect. A more frequent use of the concrete-authentic outdoor learning environment might transform school learning into a more natural process for many children. However, the unique element of the outdoor experience is not in the concrete experiences themselves (which could also be provided in the laboratory and classroom), but the type of experiences. Students could view slides of a dune and investigate quartz grains in the laboratory, but it is only by climbing the steep front slope of a sand dune that a student could receive a direct sensori-motor experience of learning about the structure of a dune. Experiential (hands on) activities can facilitate the construction of abstract concepts and can serve as subsumers that enhance meaningful learning and provide the framework for long-term memory retention. Having stated this, one should be very careful not to cross the line between pedagogy and demagogy, since there is no way to teach abstract concepts such as the particle model, or the structure and function of cells through the characteristics of natural learning. However, in parallel to the many abstract concepts that any 21st century child of the developed world should know, there are still many concrete scientific concepts and skills that can be learnt in the out-of-school world. As already noted by Kempa and Orion (1996), Kali, Orion and Eylon (2003) and Dodick and Orion (2003), even very abstract concepts such as the rock cycle and the hydrological cycle might be internalized if their study includes the concrete component of the outdoor learning environment. Orion (1993) argued that an outdoor learning event should be planned as an integral part of the curriculum rather than as an isolated activity. He suggested a spiral model where concrete preparatory units in the school together with subsequent outdoor events constitute a concrete bridge towards more abstract learning levels.

Cooperative, collaborative learning

Not only the subject matter of Earth sciences and environment, but also the processes of integration and application as human endeavors are teachable skills. Like integration of topics, integration of people’s ideas is not commonly part of the traditional curriculum. Unfortunately competition, not cooperation, leads to academic success in a system based on testing for excellence in achievement.

Given that professional positions in science more and more frequently require cross-disciplinary activities and reliance on the expertise of diverse contributors, cooperative learning mimics life. In fact, the U.S. Department of Labor (1991) classified "problem identification," "cooperation with working groups," and "finding information from diverse sources" as necessary skills for the new century. Earth systems education assists students who are normally competitors to identify for themselves a new role as a cooperator in seeking solutions to environmental problems.

> *“Imagine how different the world would be if people were taught from the first days of life that the sharing they do on the playground would also serve them well in creating a peaceful world and an educational system fostering human development in its most positive patterns! …in the learning of science, we can’t all know it all, so why not share information, build each other’s competencies, and grow together?” (Fortner, 2002)*

Collaborative learning can also be the vehicle for integration of sciences. Student teams can be assisted in becoming "experts" on disciplinary aspects of an issue. A study of oceanic ridges and hydrothermal vents, for example, might involve a group studying, then sharing, information about the life forms found at the vents, while other groups study the chemistry of the superheated water, the crustal movements that created the ridges and vents, and the patterns of density created by the hot, mineral-rich water. In reality, scientists from diverse disciplines work together and no one scientist knows everything. Should every student be required to know everything, or is knowing multiple ways to access information the more lasting legacy of good science education?

Enlightened leadership by educators

Some curriculum reform efforts are being directed nationally by ministries of education, but top-down declarations do not foster meaningful curriculum change. Change happens inside the classroom, so teacher education and commitment to reform are necessities in reaching goals of educating in a systems approach. This “grassroots” type of restructuring has been fostered in the United States through the Program for Leadership in Earth systems Education, which produced a guide for educators called “Science is a Study of Earth” (Mayer and Fortner, 1995). The guide serves as a handbook and resource manual for teachers working to implement the integration, relevant learning, and collaborative classrooms that teach science by focusing on the Earth. It is used in on-line courses sponsored by NASA and in teacher education programs in a number of countries. The book provides suggestions on integrating disciplines within topics, in units of study or in whole courses, and identifies productive sequences of topics in integrated courses at high school, middle school, and elementary levels.

Earth systems education in Israel

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 environmental 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 Israel author Orion uses environmental issues as both a vehicle for learning scientific concepts and for organizing and implementing previous scientific knowledge. For example, the topic of global warming serves as a motivator for the study of chemical and/or biological processes that are involved in this phenomenon, and earthquakes serve as an advance organizer of learning about the earth crust. On the other hand, the carbon cycle is based on prerequisites of basic concepts in chemistry, biology and earth sciences.

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. Such case studies should be classified to three levels:

- The local level
- The national level
- The global level.

The 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. One of the most important environmental subjects at the Israeli national level is the hydrological system. The greenhouse effect and the global warming debate are examples of global topics. In the Earth systems approach, local topics would be sequenced early in science experiences because of their relevance to all students, their here-an-now importance. As students grow in science knowledge and experiences, the more global and abstract topics will be appropriate in their curriculum.

Thus in order to fulfill the educational challenge, author Orion and associates have taken the following actions: locating of appropriate niches for the infusion of environmental or Earth systems oriented units in the curricula; research concerning teachers' and students' difficulties in teaching and learning subjects in an integrative manner (Ben-Zvi-Assaraf and Orion, 2001; Gudovitch and Orion, 2001) development of appropriate learning and teaching strategies; development of appropriate learning/teaching materials; and a massive inservice teacher education effort. The efforts have involved the professional scientific community in the curriculum development and in political support.

Earth systems education in Cyprus

In the late 1990s there were already some efforts at science integration and incorporation of environmental topic areas in the schools of Cyprus. Several schools across the country participate in the environmental monitoring and data sharing of the GLOBE program (Global Learning and Observations to Benefit the Environment, *http://globe.gov*). Some lycaea were designated as pilot schools for teaching a course in Natural Science (Physiognostica), and the popularity of these courses continues to grow. Eco-Schools, encouraged and assisted by the Cyprus Marine Environment Protection Association, adopt curriculum innovations that introduce global environmental issues and local action to elementary students.

By 2001, plans for a teacher education program at the graduate level were being implemented in the University of Cyprus. As part of the curriculum conceived by Guest Editor Constantinou, teachers pursuing master's degrees in education could enroll in courses such as

> ***EDU 664****: Integrated Curricula in Natural Sciences. Physical and chemical systems and mechanisms. Modeling of phenomena and other approaches of integration. Reasoning abilities and scientific thinking. The development of*

conceptual understanding through integrated curricula (physics, chemistry, biology and technology).

EDU 665*: Environmental Education. Earth systems. Interacting subsystems of soil, air, water and living organisms. The continuing evolution of geological systems. Ecosystems and ways of supporting and conserving them. The impact of human activities on the environment. The contribution of science and technology to environmental protection. Creativity in the design of curriculum materials for environmental education. Integrated approaches for developing environmental awareness, conceptual understanding and investigative skills.*

With the Integrated Curriculum course, teachers explore topic areas that demonstrate how no discipline stands alone and all must cooperate to study environmental issues such as global climate change (where will the new Mediterranean shoreline be?), nonnative species impacts (*Caulerpa taxifolia*, for instance), and how ocean debris is carried to all parts of the world (origins of Cyprus beach debris). They develop classroom teaching activities that involve interactive learning, concept mapping to demonstrate discipline linkages, nontraditional education experiences (no lectures!), and available classroom technologies. One student project, for example, was a courtroom scenario developed for the Internet. In the simulation, students examined the impact of introduction of different types of trees into the Cyprus environment. One of the trees, a eucalyptus, was brought in to dry up marshy areas, and in modern day drought conditions the trees are now nuisances in the environment as they continue to draw precious water from the ground. Students using the simulation examine the tree characteristics, pictures of their habitats, water cycle relationships, and human needs, and decide if a tree is "guilty" of damage to the environment.

With the Environmental Education course, the teachers examine theoretical and practical bases of curriculum integration, guidelines for excellence in curriculum materials (http://naaee.org/npeee/), and appropriate combinations of formal and nonformal experiences in the environment. They engage in classroom activities from Project WET and Project Wild, with emphasis on how topics of water and wildlife can be the basis for interdisciplinary learning in the sciences. The syllabi for these two courses as taught in 2002 are available from author Fortner. Projects developed by the teachers in both courses form the beginning of an alternative resource (non-textbook) set for teaching.

Discussion and conclusions

The environmental-Earth systems education approach presented here 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 complex interrelated systems and the development of system-cyclic thinking.

Implementation requires finding the most appropriate teaching and learning strategies for achieving these goals. Since the scenario for science education, namely time for teaching, is 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, implementers must find a way to avoid being too shallow or too deep, and to stay in the natural systems level without approaching environmental advocacy.

In order to fulfill the educational challenge we recommend the following actions for innovators:

1. Develop a close relationship with the professional science community to assure their strong support. According the multi-disciplinary nature of the environmental studies, there is no single scientist who can cover all the aspects of this large domain. 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.

2. Together with environmental and earth scientists and science educators, try to define what global science literacy involves in the context of the local or national school system.

3. With scientific support advocate that the Earth system should serve as framework for "Science for all" programs from K-12.

4. With assistance from leading teachers, identify those parts of the curriculum which can be taught in an environmental context.

5. Use the science education research tools in order to understand teachers' and students' difficulties in teaching and learning Earth system based curriculum.

6. Develop exemplary integrated curriculum materials for the science curricula from K-12. Teacher input is essential at this step as well.

7. Prepare teachers to

a. assess incoming skills and knowledge of students, and plan to build on the results.

b. focus on students' abilities and strategies in integration of concepts between different disciplines and within a single discipline

8. Prepare teachers to:

a. use new curriculum materials and new learning environments such as the outdoors and the computer.
b. develop appropriate strategies for the implementation of multi-disciplinary programs and subjects.

The locating of the 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 teacher education program, and the 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. Implementation in Cyprus is in its infancy, but together the model for Earth systems education developed in these countries offers to other Mediterranean countries a real alternative in science curriculum restructure for 21st Century relevance.

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