GLOBAL SCIENCE LITERACY: DEFINITION, NEEDS ASSESSMENT AND CONCERNS FOR CYPRUS

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Abstract – *Global Science Literacy has as its goals to stimulate an interest in science, represent modern technological goals of science, develop international understanding, relate science to social needs, and develop thinking and problem-solving skills for the 21st Century. Such an approach is proposed as viable on an international basis for conceptual strength in integrated science courses. Assessment of GSL's potential in Cyprus serves as an example of preparations needed and concerns to be addressed if GSL is to become the basis of the science curriculum. Toward this end, a survey of teachers throughout Cyprus identified teachers' priorities for environmental issues and system science concepts their students should know, the teachers' knowledge of those concepts and issues, and their current levels of teaching them. This paper will discuss the teachers' relative perceptions of local and global understandings, Earth systems science, and teacher education issues involved in fostering Global Science Literacy.*

Introduction

Education about the environment and about the Earth systems sciences could provide information to answer important questions about some of the most relevant and pressing science-based issues of the 21st Century. The late Isaac Asimov wrote, 'Increasingly, our leaders must deal with dangers that threaten the entire world, where an understanding of those dangers and the possible solutions depends on a good grasp of science.

The ozone layer, the greenhouse effect, acid rain, questions of diet and heredity –– all require scientific literacy' (Augustine, 1998). In a world focused on the competitive testing that compares one country to another in science achievement, cooperation among countries to raise the science literacy of all requires a non-competitive, interdisciplinary approach to the entire curriculum. Global Science Literacy begins with Earth systems education, since ESE applies all the sciences to understanding and dealing with the natural processes and human-generated hazards of modern living.

Emerging concept of Earth Systems education

A growing number of scientists and educators are forwarding the notion that the appropriate focus for all of science in the curriculum is Earth, with its interacting components of water, land, air and life, and with its instant relevance and interest for students (Fortner and Mayer, 1998; Barstow, Geary and Yazijian, 2002). Education about the Earth system emphasizes the interdisciplinary aspects not only within science but of science with the other subjects of the curriculum as well.

System sciences in general have been characterized as operational in *levels* of organization of nature rather than in distinct categories or disciplines (Lazlo, 1995). The disciplines made great contributions over the centuries through their reduction of big ideas into their components, but 'in the twenty-first century, science will be in a position to begin putting the pieces together, in order to seek a synthetic or holistic understanding of Nature. The Earth sciences are inherently synthetic and are therefore uniquely placed to lead this development' (Alvarez, 1997). Mayer and Fortner (1995, 2002), Fortner and Mayer (1998) and colleagues at all levels of science education suggest that the concept of the Earth as a system could be central to science curricula worldwide, replacing the current disciplinary approach with an approach that recognizes the importance of concepts from all the sciences. In turn, Earth systems education can form the basis of global science literacy.

Framework of understandings for Earth Systems Education

1. Earth is unique, a planet of rare beauty and great value.
2. Human activities, collective and individual, conscious and inadvertent, affect Earth systems.
3. The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
4. The Earth system is composed of the interacting subsystems of water, land, ice, air and life.
5. Earth is more than 4 billion years old, and its subsystems are continually evolving.
6. Earth is a small subsystem of a Solar system within the vast and ancient universe.
7. There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

[Expanded version available at http://earthsys.ag.ohio-state.edu]

The key elements of Earth systems education are contained in a simple Framework of Understandings developed by scientists, science educators, and classroom teachers. These elements are also the basis of what many feel is important in global science literacy as well as much of what is traditionally considered the realm of environmental education. The scientific thinking and decision-making aspects of Earth systems education are appropriate bases for approaching environmental issues rationally.

The urgency of information about environmental systems, which justifies the position of values and stewardship as the first two Understandings, was noted by Dr. Jane Lubchenco (1998) in her presidential address to the American Association for the Advancement of Science: '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.' Not only do studies of the environment offer rich experiences with real data, and the need to consult many disciplines in search of answers, but they also provide a reason for doing science and a means of introducing the value of good stewardship of resources.

Needs assessment for ESE/GSL

Are educators in Mediterranean countries aware of the importance of Earth systems concepts and the value of environmental studies for the development of global science literacy? The TIMSS-III data show only one Mediterranean country (Italy) above the mean score for Grade 8 measures and six below the mean (Martin *et al*., 1999). However the test bank includes an overwhelming proportion of items testing knowledge of concepts in single disciplines. Cyprus students did best on environmental topics and had lowest scores on Earth science topics within their own country's sample, but internationally the country scored below the mean in both areas. Traditional competitive test scores may not be a good indicator of the development of global science literacy, but at this point in science education development they are serving to alert countries of needs they might have.

An administratively simple teacher perception survey offers a look at how an educational system may come to realize its own needs and preparation for environmental and/or Earth systems education. The method has been used successfully in identifying needs for Great Lakes education in North America (Fortner and Corney, 2002), and to find discrepancies between teachers' knowledge and priorities for teaching (Fortner and Meyer, 2000). The technique now offers a first step in assessing a region's potential interest and preparation for global science literacy. First a number of topics are identified for their relevance

to GSL goals. These should include some global environmental issues and some local ones, as well as topics or concepts representing the seven Earth Systems Understandings. Three questions are asked about each selected topic:

- How important is it for students in your school to know about the topic?
- How much do you know about the topic?
- To what extent are you currently teaching about the topic?

After they rate each of the topic areas three ways, the responding teachers are invited to provide reasons for not teaching some of the topics, and to identify the topics about which they wish to know more. They suggest their preferred mode of acquiring new science information for teaching, and conclude by providing some demographic information about themselves and their teaching situation.

The nature of the three key questions allows education professionals to examine whether the goals of GSL would be acceptable in the classroom and how much teacher preparation would be needed to implement it. Responses from teachers at different grade levels can indicate where the key topics might fit best based on teacher preparation, and how the topics might be sequenced for building learning through successively more complex and global understandings.

The Cyprus example

In Cyprus there is little precedent for integrating the sciences, even though the gymnasium level (middle school) curriculum was initially organized to foster multidisciplinary science experiences each year (Ministry, 1996). An exception currently being pilot tested is the offering of Natural Science in selected *lycaea* (high schools). TIMSS performance by Cypriot students indicates a lack of preparation in the area of physical geography and on other items that are somewhat representative of Earth systems content. The assumption is that implementation of GSL as the science curriculum goal, with ESE as the mechanism and environmental issues as an integrative medium, would foster greater science knowledge because of the relevance of topics and interrelationships of information.

Objectives of the Cyprus study were to answer key questions:

1) What priority do teachers place on certain Earth systems and environmental topics for students in their schools to know?
2) How do teachers assess their own knowledge levels about these topics?

3) To what extent are teachers currently teaching the topics?
4) What differences exist between primary and secondary teachers with regard to their priorities for, knowledge and teaching of the topics?
5) In what forms do teachers prefer to receive information and curriculum materials?

Methods

A survey was developed listing ten environmental issues identified by a focus group of Cyprus teachers, and a final two added by the authors based on observation of actual problems or potential issues faced by the island nation. The list of environmental issues salient for the focus group of teachers included the first ten items below. Soil loss and imported species were added based on evidence of their existence in the country.

Ozone depletion	Global warming
Trash disposal	Tourism pressure
Air pollution	Acid rain
Extinctions of living things	Sea pollution
Oil spills	Access to fresh drinking water
Imported species	Loss of soils

Another ten topics were assembled based on the Framework of Understandings to represent Earth systems content that curricula might include. Understanding #2 was covered in the environmental issues section, and geography and ecology of Cyprus were included because ESE uses the local environment for developing relevance of more global themes. The topics thus included in the ESE section, and the Understandings from which they were inferred, consisted of

Arts in science teaching (ESU #1)	Uses of technology for science (#3)
Interactions of air, water, land, life (#4)	Processes of science (#3)
Change over periods of time (#5)	Energy flow in nature (#6)
Careers in science (#7)	Earth's place in space (#6)
Ecology of Cyprus (local relevance)	Geography of Cyprus (local relevance)

The survey was administered to two groups of teachers:

1) Secondary science teachers at a required briefing held by the Ministry of Education and Culture. Respondents were science teachers of the Gymnasium

level (grades 7-9) and the Lyceum level (grades 10-12), in the four regions of the Republic of Cyprus (Fortner and Constantinou, 2000).

2) primary teachers in schools from the four Cyprus districts. Seven teachers participating in an Environmental Education course in the University of Cyprus' new graduate program for Learning in Science each gave the survey to at least 10 other primary (grades K-6) teachers in their own or other schools.

Results

Usable surveys were received from 96 primary and 116 secondary teachers. Secondary teacher respondents included 53 males and 44 females, with an average of 18 years' teaching experience (range 3-30 years). They had bachelors' degrees in science subjects or geography, and only 9 had masters' degrees. All were teaching in public schools and 90% were from cities rather than villages of Cyprus. Among the primary teacher respondents were 19 males, 36 females and the rest not reporting gender. They had been teaching for an average of 11 years (range 1 – 33 years), and 6 had Master's degrees. Most taught in cities of Cyprus, but 26 listed villages instead. Given the non-random selection of the sample the ensuing analysis is not generalizable to other groups of teachers, but the sample size makes it a good representation of the perceptions of Cyprus teachers.

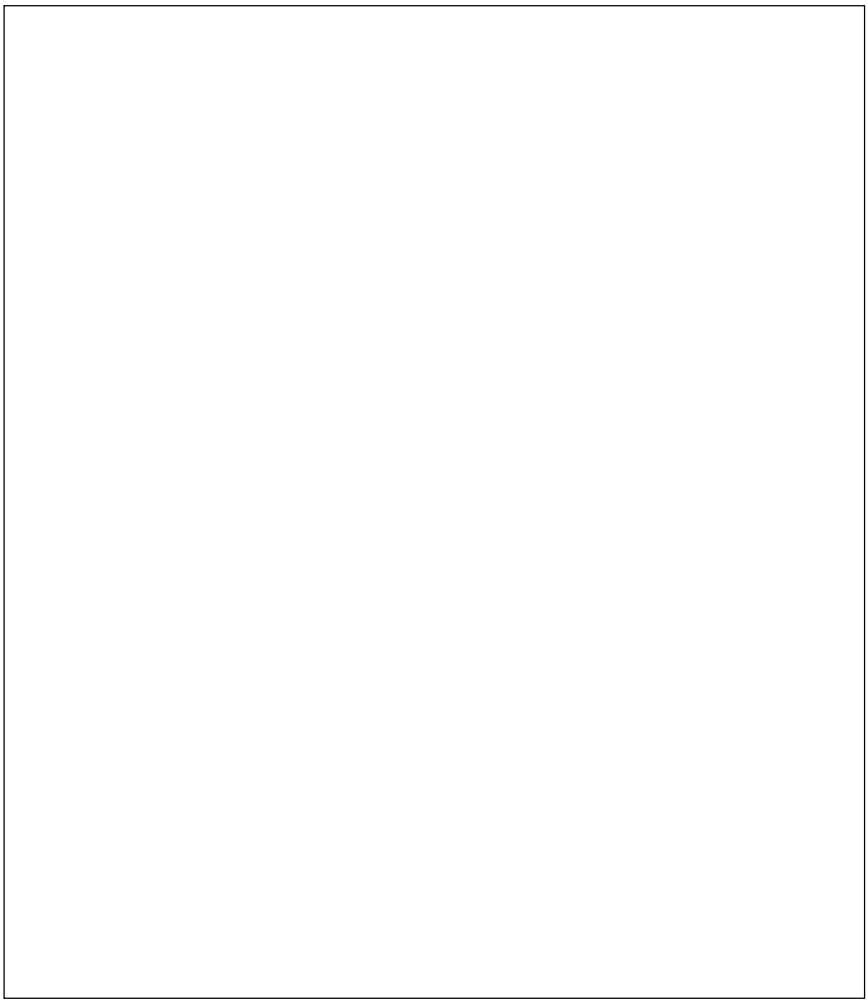
Since Understanding #2 relates to environmental topics, and the other six understandings in Earth systems education were also part of the survey, all 22 topics were analyzed as a single set. The authors acknowledge the weighting of environment in the list, but maintain that the interdisciplinary methods of ESE and the relevance it seeks make environmental studies a possible mechanism for getting all of ESE into the curriculum. Putting the 12 environmental issues together with the ten ESE topics allows the results to show the relative use of environment compared with other more general topic areas.

Priority

The topics selected as highest priority by the primary teachers (most important for students in their school to know) included three environmental issues and three ESE topics, in the order shown in Figure 1. The environmental issues represented one visible local issue (trash disposal, rated 3.7 out of 4), and two global issues with much local visibility (air and sea pollution, 3.7). High priority ESE topics (3.7) were Earth's place in space, a unit taught only in primary schools, and an item with obvious local relevance, ecology of Cyprus. Among secondary teachers the highest priorities were assigned to four environmental issues (ozone hole and air

pollution, both 3.9, acid rain and sea pollution, 3.7) and one ESE topic (ecology of Cyprus, 3.7). Both primary and secondary teachers named introduced species among the lowest priorities, with primary also adding careers in science, soil loss, and interactions of water, land, air and life. Secondary teachers also placed low priority on change over time and the arts in science teaching.

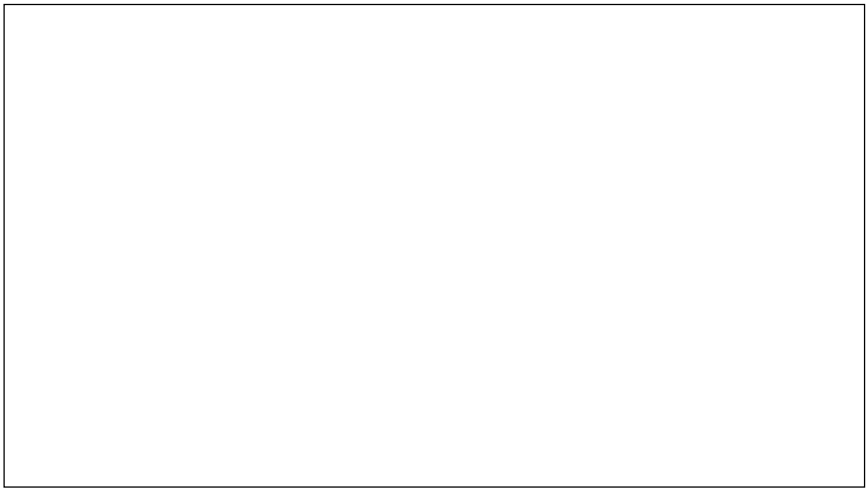
FIGURE 1: Priority for Cyprus students to learn about selected issues and topics for Global Science Literacy



Knowledge and teaching level

Teachers' self-reported knowledge of the 22 topics showed additional differences by teaching level (Figure 2). Primary teachers reported knowing most about air pollution and Earth's place in space (3.2 out of 4), while secondary teachers claimed acid rain and air pollution (3.7), sea pollution and Earth's place in space (3.5) as their most knowledgeable areas. The secondary teachers report teaching most about air pollution and the primary teachers sea pollution and physical geography (3.1 and 3, moderate teaching). Level of teaching of the topics was strongly correlated to teacher knowledge (primary $r = 0.87$; secondary $r = 0.97$) as shown by the lines in Figure 2.

FIGURE 2: Self-reported knowledge and level of teaching of issues and topics



The relationships of topic priority to teachers' knowledge and teaching level were assessed for each teacher group as well. Again relationships were strong for both groups of teachers on both measures. Priority was strongly and positively related to knowledge ($r = 0.76$ for primary teachers and .83 for secondary) as well as to amount of teaching ($r = 0.73$ and 0.84, respectively). Differences between primary and secondary teachers on overall measures of topic priority, knowledge and teaching were all significant (for priority, $p < 0.05$; for knowledge and teaching, $p < 0.001$).

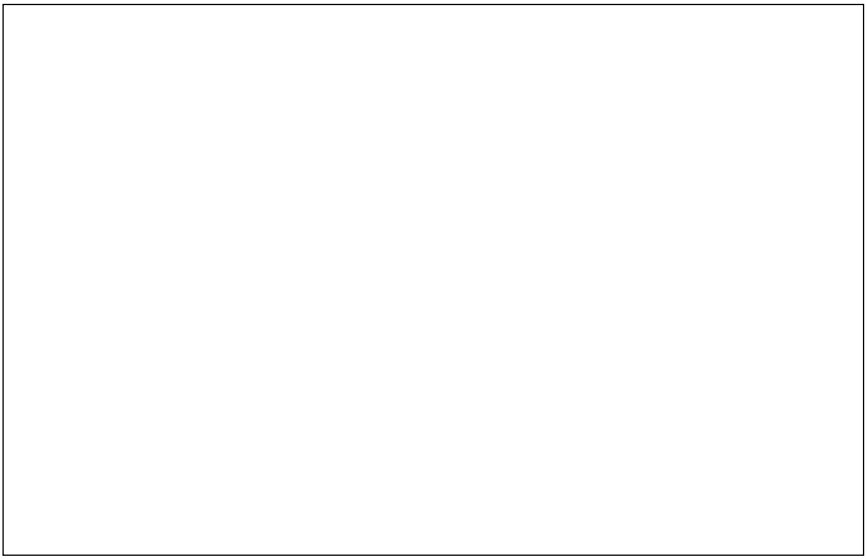
When asked why certain topics are not being taught, teachers responded most often that the topics were part of the responsibility of another subject area or

another grade level, or more generally they were 'not part of the curriculum.' 'It's not my job' is a legitimate reason for not doing a particular task. If it is important, however, that primary students be introduced to science careers, or that aesthetics become a way to meet certain learning styles in secondary schools, teachers are not responding to that information. 'There is not enough time' was another common reason for not including topics. Perhaps the length of the school day or contractual constraints of a strong teachers' union do not allow for additions to the curriculum that would enhance global science literacy to the extent that some of these topics are expected to do.

Where do teachers get their environmental information, and in what form would new instructional materials best be received? Primary teachers in 2002 reported getting most of their information for teaching about the environment from television, with secondary sources of workshops/classes and organizations (Figure 3). Secondary teachers in 1999 reported their information sources as specialty magazines and books, with television a third choice and workshops and classes a distant fifth.

The form of teacher education preferred by Cyprus primary teachers is a weekend workshop (30%) followed by one-day or credit workshops (16% each). Secondary teachers overwhelmingly preferred experiences bearing university

FIGURE 3: Primary teachers' sources of environmental information



credit (55%) with one-day workshops also acceptable (18%). If environmental education materials are to be useful to them, the form for primary teachers should be lesson plans, followed by audiovisual materials and then reference materials of various kinds. Secondary teachers want audiovisual aids and textbooks or reference materials.

Discussion

It is clear that Cyprus teachers at all K-12 levels see the set of selected topics as important for their students to learn (20 of 22 topics rated 2.7 or higher out of 4), and this alone might be used as justification for new efforts at implementation of steps toward global science literacy as exemplified by Earth systems education. Of the five topics rated most important at both levels, 3-4 were environmental issues and the remaining were the local-to-global combination of ecology of Cyprus and Earth's place in space. To continue schooling children without environmental studies is not educating them for informed global citizenship, and perhaps the teachers' ratings of issue importance are a signal that a curriculum to include the local and global environment would be accepted.

Local citizenship has an important environmental component too, but with the exception of trash disposal the local issues were rated as less important than the global ones. This result should raise some concern. While issues such as the ozone hole, air pollution, acid rain and sea pollution are all very important, they are not the kinds of issues that people see as requiring their personal commitment to the environment. It is easy to espouse learning about these issues, learning to shake our heads solemnly when confronting their global severity but continuing with the local lifestyles that contribute to them. The mass media and school textbooks with global viewpoints are probably responsible for the salience of global issues in teachers' thinking. At the same time, issues like soil loss (2.9 and 3.2 for primary and secondary, respectively) and introduced species (2.8 and 2.7), both obvious to a newcomer as issues that should be of local concern, are rated the lowest importance of the issues. Perhaps these are not seen by teachers as something that children can address personally, but they are certainly issues that have local relevance and can be seen in many examples, compared to the ozone hole and acid rain which are much more abstract and distant issues. As for the issue of trash disposal, the primary teachers found it very important but secondary teachers did not. Any early training in recycling and rubbish control is likely to go without reinforcement in later grades.

'Arts in science teaching' was a topic rated by secondary teachers as having low priority. Global education requires an holistic view, and countries such as Spain are trying to develop methods for addressing such a view through an interdisciplinary curriculum. Lillo and Lillo (2002) describe a cross-curricular approach for high school and first year university students that follows the ways ancient Greeks and Romans understood nature. According to the authors, 'The objectives for these activities are to develop positive ethical and aesthetic attitudes about the role of human beings in nature' (p. 137). Adaptation of this approach and materials could assist in meeting the Framework Understandings #1 and 2.

Two issues rated low in priority, system interaction in primary years and change over time at the secondary level, are key to Earth systems education. If students are not taught at an early age that 'everything is connected to everything else' (Commoner, 1971), it will be difficult for them to integrate science topics to answer important questions. Understanding the ecology of Cyprus, for example, one of the priority topics, requires awareness of the relationship of the hydrologic cycle and soil characteristics to the vegetation types supported at different island sites. Planting a tree for nature study will not succeed without attention to the water and soil conditions required by the selected tree species. As for change over time, a low priority for secondary, the teaching of organic evolution is key to modern biological principles, and the range of system changes becoming apparent in global climate change stands to alter not only ecology but human endeavours for the future. Adding ESE to the curriculum would assist with preparation of students for 21st Century needs and demands for decision making.

Finally the issue of introduced species, low priority for all Cyprus respondents, is a major factor in ecological change worldwide. The Great Lakes region of North America sees the introduction of several new species each year, and San Francisco Bay has over 250 exotic species now impacting its ecosystem. Nature in its normal state is in dynamic balance, and new species introductions disrupt that balance, nearly always in negative ways. Cyprus has no agricultural inspection at Customs, and people casually bring in attractive or culturally important plants from other parts of the world to decorate their island homes and gardens. One has only to look at the impact of the eucalyptus trees, brought in to dry up wetland areas, to see how successful imports can be. Even in the sea, invaders such as *Caulerpa taxifolia*, an aquarium plant apparently discarded in the western Mediterranean, are threatening the naturally diverse assemblage of sea organisms. Nowhere in the media or textbooks are such issues addressed, yet they have the potential to shape life in the Mediterranean region for centuries to come.

Conclusion

Global science literacy is a requirement for sustainable lifestyles in the 21st century. A combination of knowledge, awareness, and life skills in dealing with the environment and the interacting forces of Earth is needed by all inhabitants of the planet. If school is to be part of that preparation for survival, the science curriculum is the key.

Like other Mediterranean nations Cyprus has room to build a stronger science curriculum. With this research we have identified a list of priority areas that would be acceptable in that curriculum, and the ways that teachers learn about the topics. Combinations of public mass media and targeted publications can strengthen the science knowledge of the teaching population, and the teachers clearly indicate that topics are used in the classroom in proportion to how much the teachers know.

If the providers of science teacher education and curriculum materials wish to further increase the possibilities of teachers using Earth systems topics, the research has identified modes of in-service education and instructional resources that are most desired at the primary and secondary level. Developing courses for credit, with audiovisual and reference materials for secondary teachers would best serve that group in implementing new topics in teaching. For primary teachers the new topics are best introduced through classroom activities and lesson plans available through weekend workshops.

Using this simple survey format thus provides a concise but powerful needs assessment tool and helps identify the potential for success in curriculum innovation. The importance of global science literacy warrants attention of all Mediterranean countries to whether their schools' potential for contributing to such literacy is being met. Resources exist throughout the region for addressing these needs; what crisis of environment will convince educators that the time for fostering global science literacy is now?

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References

Alvarez, W. (1997) *T. Rex and the Crater of Doom*. Princeton, NJ: Princeton University Press.

Augustine, N. (1998) 'What we don't know does hurt us. How scientific illiteracy hobbles society.' *Science*, Vol.279, 1640-1641.

Barstow, D.; Geary, E. and Yazijian, H. (2002) 'The revolution in earth and space science education.' *Hands On!* Newsletter of the Technology Education Research Center, TERC, Vol.25(1), 8-9.

Commoner, B. (1971) *The Closing Circle: Nature, Man, and Technology*. New York: Random House.

Fortner, R.W. and Constantinou, C.P. (2000) 'Potential for Earth Systems Education in Cyprus.' In I., Clark (Ed.) *Proceedings of the Third International Conference for Geoscience Education*. Canberra: Australian Geological Survey Organization, p. 22-25.

Fortner, R.W. and Corney, J.R. (2002) 'Great Lakes educational needs assessment: Teachers' priorities for topics, material & training.' *Journal of Great Lakes Research*, Vol.28(1), 3-15.

Fortner, R.W. and Mayer, V.J. (Eds) (1998) 'Learning about the Earth as a System.' *Proceedings of the Second International Conference on Geoscience Education*. Columbus: The Ohio State University, Earth Systems Education Program. ERIC Document ED422163

Fortner, R.W. and Meyer, R.L. (2000) 'Discrepancies among teachers' priorities for and knowledge of freshwater topics.' *The Journal of Environmental Education*, Vol.31(4), 51-53.

Lazlo, E. (1995) *The Systems View of the World: The Natural Philosophy of the New Developments in the Sciences*. New York: George Braziller.

Lillo, F. and Lillo, J. (2002) 'Using historical events to develop ethical and aesthetic attitudes.' In V., Mayer (Ed.) *Global Science Literacy*. Dordrecht, The Netherlands: Kluwer.

Lubchenco, J. (1998) 'Entering the century of the environment: a new social contract for science.' *Science*, Vol.279, 491-497.

Martin, M.O. Mullis, I.V.S., Gonzalez, E.J., Gregory, K.D., Smith, T.A., Chrostowski, S.J., Garden, R.A., and O'Connor, K.M. (1999) *TIMSS 1999 International Science Report. Findings from IEA's Repeat of the Third International Science and Science Study at the Eighth Grade*. Chestnut Hill, MA: The International Study Center, Boston College. Chapters 1 and 3.

Mayer, V.J. (ed.) (2002) *Global Science Literacy*. Dordrecht, The Netherlands: Kluwer.

Mayer, V.J. and Fortner, R.W. (1995) *Science is a study of Earth*. Columbus: The Ohio State University, Earth Systems Education Program.

Mayer, V.J. and Fortner, R.W. (2002) 'A case history of science and science education policies.' In V. Mayer (Ed.) *Global Science Literacy*. Dordrecht, The Netherlands: Kluwer.

Ministry of Education and Culture (1996) *Development of Education 1994-96. National Report of Cyprus*. Prepared for the International Conference of Education, 45th session, Geneva. Nicosia: Author.