Climate Change in School: Where Does It Fit and How Ready Are We?

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Abstract

Research indicates that teachers place a high priority on climate change as a topic their students should know, but report their own knowledge as inadequate for teaching it. Students (and some teachers) seem unable to distinguish among related environmental issues, and treat general "environmentally friendly" behavior as affecting all issues. The curricular fit of global climate change is best in Earth systems oriented classrooms but opportunities exist across the curriculum; instructional materials are available, though these may not address misconceptions. Some interest groups oppose human-mediated climate change as a curriculum topic, for the same reasons they oppose public action on the problem.

Résumé

D'après la recherche, les enseignants estiment qu'il est important pour leurs élèves d'être au courant du changement climatique, mais que leur propre connaissance du phénomène n'est pas à la hauteur. Les élèves et certains enseignants semblent incapables de distinguer les enjeux environnementaux connexes et considèrent que le comportement écologique en général affecte tous les enjeux. L'adéquation du changement climatique planétaire avec le programme d'études est plus réussie dans les cours axés sur les systèmes terrestres, mais il existe aussi d'autres possibilités. Des documents d'instruction sont aussi disponibles, quoiqu'ils n'abordent peut-être pas les interprétations erronés. Certains groupes d'intérêt refusent que le programme d'études aborde le sujet du changement climatique causé par les humains pour les mêmes raisons qu'ils s'opposent à l'action du public face au problème.

Background

Just as the concept of organic evolution serves as an organizer for modern biological science, global climate change is focusing the attentions of the Earth science community, justifying the need to organize its many disciplines. Like organic evolution, global climate change is complex and involves scales of time and space not well understood by the adult public. And like evolution, public opinion surveys (over 30 in the past decade) indicate a mix of attitudes and a wide range of knowledge levels about its science. On the whole, however, a majority of Americans seem to believe that global warming (used synonymously with global climate change) is a serious threat to their life as well as a reality (e.g., Gallup, 1997; Pew Research Center, 1997; Krosnick & Visser, 1998; Fortner, Lee, Corney, Romanello, Bonnell, Luthy, Figuerido, & Ntsiko, 2000). Nevertheless, people see this issue as being different from others in its level of uncertainty and intangibility, and so may confront it differently in making personal choices (Lee & Fortner, 2000).

Should a topic with such high media attention and potential impact, even though it is complex, uncertain, and intangible, be included in the school curriculum? Preparation for the responsibilities of citizenship in a global society, as well as development of individual sustainable lifestyles, should dictate that global climate change appear in formal education. Indeed, science curriculum restructuring efforts in the United States insist that reform should involve aspects that favour instruction on global climate change:

- "Science in personal and social perspectives" is a content area within the National Science Education Standards for the U.S. The subject matter includes Changes in Environments and Science and Technology in Local Challenges (National Research Center, 1996).
- Interdisciplinary curriculum is a goal for science literacy. Benchmarks (American Association for the Advancement of Science [AAAS], 1993) defines the concept as applying to:
  - integrated planning across disciplines,
  - interconnected knowledge, and
  - coherence of student experiences.
- Global climate change and the composition of the atmosphere are included in the Earth and Space Science standards for Grades 5-8 and 9-12.
- A specific Benchmark for Grade 12 is, "Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough

equilibrium. In the long run, however, ecosystems always change when climate changes . . . ." (AAAS, 1993)

A lesser known K-12 curriculum restructure effort, Earth Systems Education (Mayer & Fortner, 1995), and its higher education counterpart, Earth Systems Science Education, use global climate change as a unifying topic because it so vividly reflects the interrelationships of the model proposed for the National Aeronautics and Space Administration (Earth System Science Committee 1988, and http://www.usra.edu/esse/BrethColor.GIF).

Earth Systems Education is based on the simple premise that Science is a study of Earth (Mayer & Fortner, 1995), therefore all of science education K-12 can have a common theme. The scientists, science educators and teachers who developed the Earth Systems concept at this level in 1988 identified seven understandings into which the important aspects of science education could basically fit (see Figure 1). They include not only the interrelationships of the Earth subsystems (hydrosphere, atmosphere, lithosphere, biosphere), the processes and tools of science, and change over time, but unique statements that foster stewardship of Earth systems and aesthetic values of Earth. An Earth Systems focus increases the curriculum possibilities for global climate change 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 interacting subsystems of water, rock, 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 the study of Earth's origin, processes and evolution.

Figure 1. Framework of Earth Systems Understandings.

Student Ideas about Global Climate Change

Educational strategies are best designed when they are based on knowledge of the learners' level of knowledge and preconceptions. Information can be selected and experiences organized to fill known knowledge gaps, enhance understanding of relationships, and remediate misconceptions. In the last part of the 20th Century a number of researchers probed student understanding of global climate change, its causes, consequences, and "cures." In general, secondary school students (ages 11 and up) know that global climate change will be associated with changes in weather patterns, and they can basically describe how the greenhouse effect works to increase temperatures in the lower atmosphere (Boyes & Stanisstreet, 1993).

Misconceptions

However, these 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, according to a synthesis by Gowda, Fox and Magelky (1997) are:

- Inflated estimates of temperature change (11^{o} F/decade, compared to estimates of 0.5^{o} F by the Intergovernmental Panel on Climate Change),
- 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), and
- Confusing weather and climate.

Specific studies among student populations are summarized in Table 1. Apparently the data reflect a general level of misperceptions, as Aron, Francek, Nelson, and Bisard (1994) found that junior high to teacher prep students had low knowledge and numerous misconceptions about atmospheric phenomena in general. It is significant to note that fewer than 3% of U.S. students have access to high school Earth science courses, where such material would be taught.

Methods of research

Recent research has identified methods appropriate for analyzing the concept relationships upon which students are basing their perceptions. For example, Boyes and Stanisstreet (1998) focused on how high school students relate skin cancer to global environmental effects. Large numbers of the students confused the action of heat rays with that of UV rays, and along that line of thinking they believed that raised temperatures (from the greenhouse effect) were guilty. Using an 11-item questionnaire, the researchers analyzed the percentage of students that linked the various concepts, and were able to diagram overlapping connections to find that only 9% selected and were confident in the correct explanation.

Rye, Rubba, and Wiesenmayer (1998) tested the use of concept maps as part of an interview schedule to explore the relationships among the ideas student hold. Despite the value of the mapping tools demonstrated in other research (e.g., Heinze-Fry & Novak, 1990), and the confidence teachers have in the techniques of concept mapping for organizing ideas, the use of concept mapping did not contribute additional insights beyond the interview notes.

The same researchers had used expert concept maps as part of teacher preparation for teaching an instructional unit on global warming (Rubba & Weisenmayer, 1993). Perhaps they were useful for the teachers in planning and organizing. The instructional unit, however, represented one of the first attempts to gauge the impact of instruction on alteration of misconceptions about global warming and ozone relationships. Rye et al. (1998) found that students' prior misconceptions "limit and confound their understanding of the nature, causation and resolution of global warming" (p. 544). Over half the students in the post-instructional study believed that ozone layer depletion caused global warming. The researchers recommended that teachers address the issues at separate times and with different materials so that confusion and overlap of concepts is not facilitated in the learning process. Of course, additional teacher preparation in the facts of physics related to these phenomena is needed as well.

Table 1. Examples of 1990s research on student awareness of global atmospheric issues.

Teacher Knowledge and Priority for Climate Change Education

Despite the evidence that teachers hold some of the same misconceptions as their students about global climate change, many place a high priority on the topic as part of their students' education. Studies conducted among teachers in the Great Lakes region (Fortner & Corney, unpublished data) found that middle school science teachers (N= about 100 per state/province in Ohio, Michigan, Indiana, Illinois, Wisconsin and Ontario) rated global climate change as a priority of 3 out of 4, but only 26% (77 out of 300) considered the topic one of their top five "highest priorities." They indicated that their own knowledge level was also at a level of about 3. A similar survey given to all secondary science teachers in the Republic of Cyprus in 1999 resulted in lower ranking for the issue among others tested. The 120 responding teachers (67% of the population) rated global warming as the 7th priority issue out of 12, but still gave it a high mark (average response 3.5 out of 4). Knowledge levels were rated at 3.2. The top issues for Cyprus teachers were ozone hole, air pollution, and acid rain. Interestingly, the ozone issue ranked 3.9 in priority and teachers' knowledge was reported at 2.8 (Fortner & Constantinou, 2000). Anecdotally, in a global data workshop conducted by the author, Cyprus teachers presented with a list of 20 Internet sites to visit chose the ozone hole site as either their first or second exploration.

Teachers and global climate change were the subjects of other studies with different aspects to offer. A group of teachers in an inservice program about global climate change appeared to feel strongly that their own behaviour serves as a model for their students. Interview and journal data demonstrated they were conscious of showing best practice regarding their personal responsibility for global climate change (Rubba & Rye, 1997). The teachers appeared to believe that "if teachers show active interest and involvement in taking citizenship action, then students are more likely to do the same" (p. 82).

Curriculum Entry Points

If we chose to include global climate change in the curriculum, where would it fit? The possibilities are numerous, and a teacher determined to include the issue will find ways to make it fit. Some caution is required based on students' mental functioning levels: concrete versus abstract understanding. Elementary students below age 12, and many who are older, are not at appropriate stages of cognitive development to deal effectively with the magnitudes of space and time encompassed by the concept of climate as opposed to daily weather. The ozone hole especially is an intangible idea that should be avoided at early ages to prevent confusion with weather experiences. There are some tangible experiences that can demonstrate the greenhouse effect, but on the whole the key concepts for understanding climate change are very abstract and beyond the mental preparation of elementary students. More instruction will not change learner readiness based on cognitive development stage.

Some of the more obvious curriculum choices for secondary science, with examples, are:

- Biology/life sciences: carbon cycle, types of producers, effects of environmental conditions on living things (proxy data such as tree rings, coral banding, etc), physical requirements of habitat, impact of previous climates in earth history,
- Chemistry: water quality changes related to quantity (dilution); precipitation analysis, CO_2 sources and testing, analysis of soils, insulating properties of CO_2,
- Physics: light spectrum, heat vs. temperature, density and distribution of gases, mechanism of greenhouse effect, energy budgets, atmospheric and oceanic movements, etc.,
- Earth/Space science: atmospheres on other planets, Earth's historic climates, ice ages, climate, atmospheric and oceanic movements, geographic relationships, land vs. water in energy relationships, foundation for support of life, proxy data from fossils and ice cores, natural contributions such as volcanic emissions, etc., and
- Environmental Science: (not a common curriculum, but full of opportunities) issue analysis, components of viewpoints, science and society issues, economics of decisions, etc.

Schools using Earth Systems Education as an organizer for learning will have little difficulty using questions about global climate change to address all of these science components in relation to each other, whereas in a standard curriculum the physics class would not consider the biology, the chemist could ignore the space science, and so on. With Earth Systems Education the topic could also be enriched with activities in other subject areas. For example the art of the Little Ice Age period is noticeably different in its composition, with more scenes of skating on rivers, iced limbs of trees, and such, than periods before and after the mid-1800s. Paintings after the eruption of Krakatoa have more red tones in the skies. It is also possible within Earth systems classes to openly discuss how decisions are made on environmental issues, and what options are available to deal with the problem. Environmental decision choices should not be suggested to students, but they should be assisted in analyzing the costs and benefits of choices.

Programs and Materials for Teaching

The materials produced by the Earth Systems Education Program at Ohio State (http://earthsys.ag.ohio-state.edu) are a starting place for teaching both global and regional aspects of global climate change. The two books of activities are:

- Activities for the Changing Earth System (ACES), produced with National Science Foundation support (Mayer, Fortner, & Murphy, 1993) with 10 activities each for middle and high schools, including some on natural contributors to atmospheric features, such as volcano explosivity and solar distance.
- Great Lakes Instructional Materials for the Changing Earth System (GLIMCES) by Fortner, Miller, & Sheaffer (1995), sponsored by the National Oceanic and Atmospheric Administration, Ohio Sea Grant. This book of activities includes terrestrial and aquatic changes predicted by scientists for the Great Lakes region.

All Earth Systems activities are based on principles of learning by becoming involved in inquiry. They begin with an important question, such as: After the maples, then what? Should we develop winter or summer recreation? How have all the species gone? When they begin with such a reason to do science, students are more eager to search for information and synthesize it. They find new ways of communicating their knowledge in group learning situations and demonstrating capability through alternative assessments. This is the way lasting learning is constructed.

Other groups have made collections of instructional activities available: the Environmental Protection Agency and the National Oceanic and Atmospheric Administration have collections, and the National Oceanic and Atmospheric Administration (through support from the Office of Global Programs) includes a listserve with teacher workshop participants receiving regular updates on climate events. Educational clearinghouses now compile lists of available materials, so any teacher wishing to address the topic may find assistance in existing publications. A few are identified in the endnotes,[1] and the hard-copy materials are of course supplemented by many excellent collections of web sites like those in Teacher Links (http://www.eecs.umich.edu/mathscience/teachers.html) and Earth Today (http://earthsys.ag.ohio-state.edu/earth_today.html).

Environmental Education Detractors

Some of those who wear the name of "environmental educators" are advocates with a mission but without substance. This is unfortunate, for it places the profession in a defensive position. Better definition of roles, and perhaps subdivisions of the name, would go far to explain motives, but the mission of real environmental education is so urgent that few consider definitions a worthy use of time. As a result, the field seems constantly at odds with detractors.

In the past few years some conservative organizations, including those whose economic base is perceived to be threatened by moves to curb CO_2 emissions, have broadcast wide criticisms of environmental education (e.g., Adler, 1992). The Internet site for EELINK.NET reviews the criticisms and responses at http://neeap.uwsp.edu/NEEAPServices/Newsletters-/1994_1998/f96re.htm. The topics of the criticism can be classified as:

1. Environmental education is often based on emotionalism, myths, and misinformation.
2. Environmental education is often issue-driven rather than information-driven.
3. Environmental education typically fails to teach children about basic economics or decision-making processes, relying instead on mindless slogans.
4. Environmental education often fails to take advantage of lessons from nature, and instead preaches socially or politically correct lessons.
5. Environmental education is unabashedly devoted to activism and politics, rather than knowledge and understanding.
6. Environmental education teaches an anti-anthropocentric philosophy that man [sic] is an intrusion on the earth and, at times, an evil.

Environmental educators can respond reasonably to each of these criticisms based on the methods and materials most practitioners use. It is easy to see from the list, however, where global change education could fit into the attacks. The environmental education community offers an additional note about why environmental education is necessary (Table 2), and the reasons clearly support climate change education. The best defense against detractors, however, is for the educator to be able to demonstrate credible scientific data behind the lessons being used.

• Builds Better Citizens	• Builds Better Workers
• Advances Excellent Education	• Develops a SoundEcological
• Promotes Tolerance for Diverse Views	Foundation • Creates a Nation of Critical and Creative Thinkers (Teachers how to think, not what to think)
• Links Disciplines	• Helps Learners Resolve Conflicts
• Links Human Health with Environmental Health	• Doesn't Shy Away from Values Education
• Works for a More Sustainable Future	• Reaches Out to All Audiences/Promotes Social Equity

Table 2. "A Dozen Reasons Our Country Needs Environmental Education," Judy Braus, World Wildlife Fund (1996).

Conclusion

Students from elementary school to college, and in a number of countries, have a general understanding of a range of environmental problems, and a set of environmentally friendly behaviours. They appear to recombine the two lists on a fairly generic basis, as if any friendly behavior is useful to counter any environmental problem. In addition, the characteristics, causes and effects of the issues get blended so that most problems seem to be interrelated.

There are ample materials for teaching about global climate change, many credible and free sources of sound scientific information, and numerous places where the topic could fit into the curriculum. However, with an overcrowded curriculum and with little interdisciplinary training, teachers may be reluctant to infuse information about a topic that is inherently intangible and uncertain. If the education of students on global climate change is left to television, as Boyes and Stanisstreet (1992) suspect, misconceptions may go unchallenged or no education may occur at all.

When teachers place high priority on a topic, as those in recent studies have done for climate change, they may generate an internal incentive to learn enough about it to teach it. Providers of teacher education should become aware of these priorities and make learning opportunities available. It is critically important to remember that today's teachers did not study this topic in school, nor were they likely to study interdisciplinary sciences. The media they use for self-education may be deficient. Teachers, like their students, are likely to possess deeply held misconceptions and confused issues, and overcoming these is difficult. For teachers and students to learn, a first step is pre-assessment of conceptual linkages. Only then can instruction be structured to counter insufficient or inaccurate information (e.g., Smith, Blakeslee, & Anderson, 1993).

Notes

[1] Cavanaugh, M. (1998). *Annotated bibliographic citations of global change resource materials*. Akron, OH: Environmental Education Council of Ohio. (ad388@acorn.net)

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Transparencies for teaching: http://www.fsl.noaa.gov/%7Eosborn/CLIMGRAPH2.html Free.

http://hepg.awl.com/weiss/e_iprojects/c08/chap08.htm is a data-use and problem solving site on global warming designed by Addison Wesley to accompany and elementary statistics text. Free.

Notes on Contributor

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