Teaching and Learning about Planet Earth

Art Sussman

Teaching about global environmental issues raises a wide variety of social and political issues. For example, educators need to describe complex current and potential human impacts with scientific accuracy in ways that people can understand, and yet also need to avoid preaching "gloom and doom" messages that depress rather than motivate. The cosmic reality of the unimaginably awesome universe of time and space in which we exist provides a very different perspective for our global environmental crises. Humans today are changing the way our planet works, and we need to make major societal changes. The processes of how we educate about and discuss these issues are as much a part of our challenge as how we actually change our societies to address these issues. Sussman summarizes his approach in a four-phrase mantra, "Think Globally, Act Locally, Feel Cosmically, Be Lovingly."

Earth System Science, Environmental Education, Carbon Cycle, Climate Change, Big Bang, Stewardship

I am very grateful to the Paul F-Brandwein Institute[1] for the great honor of selecting me to present the 2011 Brandwein Lecture. I am both humbled and excited to have this unique opportunity to share with so many great science and environmental educators my practices in global environmental education and my thoughts about teaching and learning about planet Earth.

I have recently been doing education work in the Pacific Islands region, including remote U.S. territories such as American Samoa. If we were gathering in that location to discuss the local environment and our planet, we would begin with an invocation grounded in the local culture to help us experience our connections to the natural world and the importance of our conversation.

I am not of Samoan ancestry. My traditional background is Orthodox Judaism. Even though it has been many decades since I followed the rituals of my childhood religion, those practices can still be very evocative for me. So I would like to begin with a Jewish invocation that is used at the beginning of special occasions. I have somewhat altered the invocation so it more closely matches my adult beliefs.

Blessed and wondrous are the ground, the waters, the Sun, and the world that have given us life, nourished us, and brought us to *this time* and *this place*.

Religions are one major way that people are motivated to act in specific ways in their daily lives. Religions also motivate people to refrain from doing things that they otherwise might do. Even more important, religions help many human beings experience deep feelings of meaning and connection as they engage in specific activities and also refrain from other activities.

This invocation and these thoughts make me wonder whether we would be more effective environmental stewards and environmental educators if we incorporated spiritual practices and perspectives. Would my behavior be different if I said a blessing each time that I recycled or each time that I refrained from impulsively driving my car to the local shopping center? Would I recycle more? Would I consume less? Would I be more joyous?

Of course, there are many objections and potential pitfalls to including any form of spirituality in public education. Nonetheless, part of what I want to do in this presentation is to raise complex issues, consider them, and recognize that we are often immersed in situations that have no easy answers.

I selected that specific Jewish invocation because it recognizes and honors this time and this place. I will be emphasizing how a science-based understanding of the age of the Universe and of our planet can help bring a very important perspective to our environmental challenges. But I also emphasize the here and now. I think we need to celebrate this time and this place with all of its strengths and challenges. This is our here and now. Its challenges are our opportunities to define who we are and to fulfill our deepest being.

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[1] Brandwein Institute www.brandwein.org.

As a scientist, part of what I experience with awe and wonder is where this time and space came from. We have very strong scientific evidence that our Universe (the space and time in which we live) came into existence about 13 billion years ago. As a robust scientific theory, the Big Bang is based upon multiple strands of evidence from the physical world combined with rigorous, internally consistent logical reasoning based upon that evidence (Singh 2005).

The early expanding and cooling Universe had its first stable atoms when it was about 400,000 years young. There were no stars and no large atoms. Chemistry classes would have been a lot easier with a periodic table for a Universe with basically two elements, hydrogen and helium. For those of you who know about it, this is the origin time for what we experience today as the cosmic microwave background radiation, a strand of very strong evidence underlying the Big Bang theory (Balbi 2010).

The first stars began to shine when the Universe was a mere 100 million years young. This new light came from nuclear fusion reactions. Some of those stars ended their lives with spectacular explosions, seeding the expanding Universe with an entire periodic table ensemble of elements, leading billions of years later to Joni Mitchell singing, "We Are Stardust."[2]

What does that phrase teach us? "We Are Stardust" teaches us that tree huggers did not invent recycling. Not only is recycling the Earth way of life, it seems to be universal.

Our solar system and planet began about 4.5 billion years ago, formed with hydrogen from the Big Bang plus elements from lithium through uranium that were made by stars. It took life less than a billion years to get started on Earth. For the next two billion years, the only life forms were bacteria. We can thank our microbial ancestors for inventing the abilities to sense the environment, move, eat, eliminate wastes, and have sex (Margulis & Sagan 1997).

The first complex cells with true nuclei did not evolve until about 1.5 billion years ago. Our most complete fossil record dates back about 600 million years following the proliferation of animals with hard skeletons. Based upon those fossil skeletons, we know that there have been five major periods in the last 600 million years when unimaginably huge numbers of plants and animals died (Hallam 2004).

The most familiar of these "mass extinctions" resulted from an asteroid slamming into Earth with a force greater than thousands of times all our nuclear weapons (Frankel 1999). Earth's web of life recovered from all these mass extinctions, with each recovery taking millions of years.

Our species, *Homo sapiens*, dates back about 200,000 years, a mere 0.01% of Earth's existence (Leakey 2005). At the start of our modern calendar, there were about 0.2 billion of us. In the year 1950, our population had reached 2.5 billion people. In 2011 our population reached 7 billion. It took only 60 years to add twice as many people as had been added in all the previous 2,000 years.[3]

Earlier in our history as a species, humans generally respected the natural world and lived in harmony with it. We know that sometimes earlier human societies significantly altered their local environments. If they gravely harmed the local web of life, they may have perished or had to migrate. Yet, no matter what they did, their numbers were too small and their technologies too limited to affect the planet.

In contrast, we humans today have both a very large population and extremely powerful technologies. Not only do we significantly alter our local environments and food webs, we are actually changing the way our planet works. Humans currently move more of Earth's surface than all the natural erosion processes (Hooke 2002). We are on a path to triple in this century the atmosphere's concentration of carbon dioxide (Henson 2011). We appropriate about 40% of the net terrestrial photosynthesis (Vitousek et al. 1986).

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[2] Lyrics to Joni Mitchell's song are available at http://www.songlyrics.com/joni-mitchell/woodstock-lyrics.

[3] http://geography.about.com/od/obtainpopulationdata/a/worldpopulation.htm.

The global consequences of these actions are written in the sky, in the ocean, and in Earth's ecosystems.[4] Earth's protective ozone layer decreased to alarmingly low levels. Globally sea levels are rising and the pH of the ocean is decreasing. Arctic polar ice is shrinking. Global climate is changing. Everywhere we look, species are disappearing. We are changing the way our planet works.

Our new role on planet Earth requires that we behave with great wisdom and maturity. But we are a very young species that is infatuated with our new powers. Using terminology from human development, where are we as a species on a spectrum ranging from Baby to Toddler to Child to Teen to Young Adult to Mature Adult to Wise Elder?

In my seventh decade of life, I recognize in myself elements of all these stages. I am a toy-breaking toddler, a self-centered child, and a rebellious teen. But amazingly enough, I also have outbursts of maturity and wisdom. I see that same range of behavior from destructive toddler to nurturing elder throughout our social and political institutions. Unfortunately, with respect to global citizenship, our societies are predominantly in the immature areas of this spectrum.

The fact that we are changing how Earth works now requires that we truly come of age as a global species and live with greater maturity and wisdom. To become wise global stewards, we need to understand how our planet works. From one point of view, our planet is incredibly complex and challenges the thinking of even our brightest scientists. However, from another point of view, it is quite easy to understand the major ideas about how our planet works (Sussman 2000).

This knowledge is based on Earth System Science, a way of investigating and understanding planet Earth as a system (Skinner 1999; Sussman 2000; Sussman 2006). Through Earth System Science, we combine the knowledge and skills of virtually all our scientific disciplines. We measure key features of our planet, analyze all the data, and develop powerful explanations, such as plate tectonics, that reveal the inner and outer workings of our planet. We are learning how our planet works and how we are affecting it.

In my education work, I use simple simulation activities to help teach and learn three systems principles that together explain the biggest ideas about how our planet works. In this part of the presentation, I will share some of those educational activities with you.

One simple simulation[5] features three people (costumed as the Sun, a plant and a cow), a brown grocery bag (sugar), one black balloon (carbon) and three yellow balloons (energy). The same black balloon keeps circulating between the plant and the cow representing the photosynthesis and respiration parts of the carbon cycle. In contrast, yellow balloons flow from the Sun to the plant to the cow, and then get punctured. These actions represent heat energy entering the Earth system, circulating among organisms, and ultimately leaving the Earth system as heat radiating to space. By following the actions in this simple play and joining in saying the actors' lines, both the actors and the interacting audience learn three principles (Sussman 2000 & 2006):

- Earth is essentially a closed system for matter. The matter that is here stays here, and cycles within the Earth system (Matter Cycles);
- Earth is an open system for energy. Earth receives a continuous flow of energy from the Sun and that energy leaves the Earth system as heat (Energy Flows); and
- Earth is a networked system for life. Earth's organisms are interlinked with each other and with Earth's cycles of matter and flows of energy (Life Webs).

I also use a low-tech simulation to teach about the carbon cycle[6]. As with any of Earth's major cycles, we teach about the carbon cycle by exploring its reservoirs (where the carbon exists, how much is there, and its form in each reservoir). Again as with any of Earth's major cycles, we explore how the matter moves between the reservoirs.

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[4] An excellent summary of global changes is a document by U.S. EPA titled *Climate Change Indicators in the United States*. It can be downloaded at http://www.epa.gov/climatechange/indicators.html.

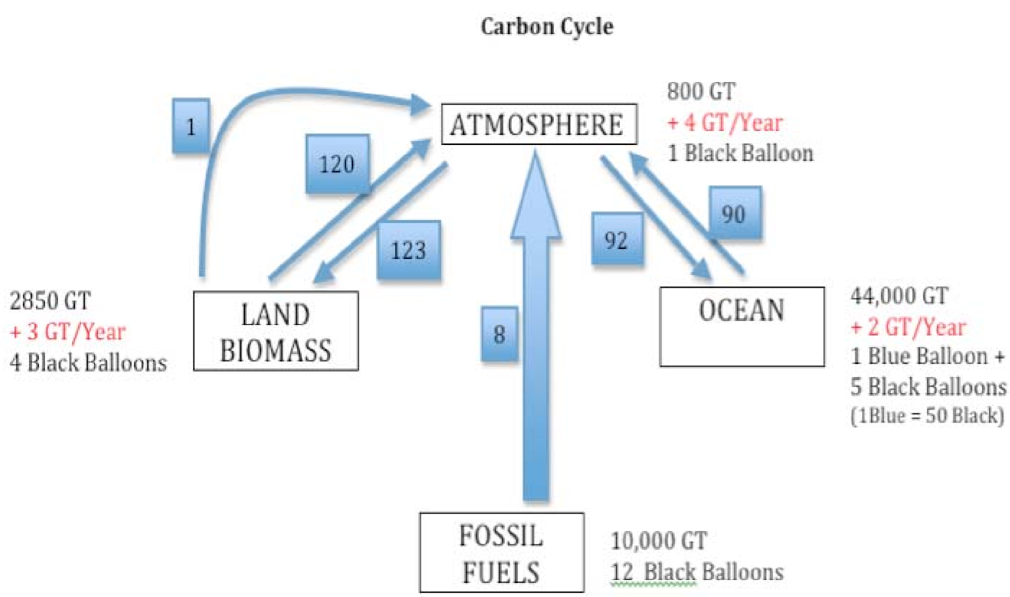
[5] Three Principles Play activity at http://www.guidetoscience.net/cs/drart/view/drart_res/40.

[6] Carbon Cycle Demonstration at http://www.guidetoscience.net/cs/drart/view/drart_res/39.

A person representing the atmosphere holds one black balloon to symbolize all the carbon in the atmosphere (mostly carbon dioxide gas). A person representing land biomass holds four black balloons for all the carbon in plants and soil (small and large biomolecules). A third person representing the ocean holds one blue balloon and 5 black balloons to symbolize all the carbon in the ocean (mostly in the form of bicarbonate salts). (You probably remember from high school physical science the important conversion factor that one blue balloon equals 50 black balloons.) A fourth person representing fossil fuels has 12 black balloons that are packed in a box to represent the carbon buried under ground in the forms of coal, petroleum and natural gas.

In the simulation, the land biomass takes the atmosphere's one black balloon to represent the amount of terrestrial photosynthesis that occurs over a period of 7 years. The atmosphere takes back its balloon to represent that over a period of 7 years, terrestrial respiration releases as much carbon dioxide as exists in the entire atmosphere. Similar interactions between the ocean and the atmosphere represent the balanced carbon cycle between those reservoirs. In contrast, our combustion of fossil fuels is putting an unbalanced amount of carbon dioxide into the atmosphere. As a result, the atmospheric concentration of carbon dioxide has increased 40%. It would have increased even more, but so far the ocean and land biomass have absorbed more than half of the extra carbon dioxide that we put into the atmosphere.

The numbers used in the simulation and in the Carbon Cycle figure below are based on research studies summarized in a workshop convened by the U.S. Department of Energy Office of Science (U.S. DOE 2008).[7] The numbers expressed are in gigatons (GT) of carbon,[8] indicating how much of Earth's carbon is in each reservoir and how much carbon moves each year from one reservoir to another reservoir.



I also use a third low-tech simulation[9] to teach about the greenhouse effect. This simulation includes a Sun icon, a big Earth balloon, a yellow balloon to represent light, an orange balloon to represent heat, and colored balloons to represent molecules of oxygen, nitrogen, water, and carbon dioxide.

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[7] The workshop report can be downloaded at

http://genomicscience.energy.gov/carboncycle/report/index.shtml#page=news.

[8] One gigaton is a billion tons.

[9] Greenhouse Efffect Demonstration at http://www.guidetoscience.net/cs/drart/view/drart_res/41.

I walk the yellow balloon moving it up and down in a wave pattern from Sun to Earth. As I do that, I say that this ray of light has traveled 93 million miles as an electromagnetic wave through empty space The ray (yellow balloon) then hits the roof of the building, is absorbed and is converted to heat energy (orange balloon). Eventually that heat energy radiates away from the roof. I walk the orange balloon with a longer wave motion away from Earth towards outer space.

First I do this balloon-switching, wave-walking dance without any molecules to represent Earth's atmosphere. Then we place balloons representing oxygen and nitrogen near the Earth ball. Repeating the yellow balloon wave-walk from the Sun to Earth, I show that the entering light wave does not interact with oxygen or nitrogen. Repeating the orange balloon wave-walk from the Earth to outer space, I show that the exiting heat wave also does not interact with the oxygen and nitrogen that are the main gases in Earth's atmosphere.

Now we place balloons representing molecules of water and carbon dioxide near the Earth balloon. Repeating the yellow balloon wave-walk from the Sun to Earth, I show that the entering light wave does not interact with the atmosphere's water or carbon dioxide. Repeating the orange balloon wave-walk from the Earth to outer space, I show that this time the exiting heat wave interacts with molecules. The water and carbon dioxide absorb the heat energy, become a little more energetic, and then release the heat as a wave. These interactions with atmospheric carbon dioxide and water vapor keep the heat energy longer in the Earth system and make our planet warmer than it would be without these greenhouse gases. This natural greenhouse effect helps make Earth habitable for its web of life.

These simulations illustrate how we can teach the biggest ideas about how our planet works. The three principles can be used to teach essentially any environmental issue (Sussman 2000 & 2006). For example, global climate change is due to the fact that humans are altering Earth's cycles of matter, particularly the carbon cycle. The extra amounts of greenhouse gases in the atmosphere change Earth's energy flows by trapping heat longer within the Earth system and thereby change our global climate. The resulting climate changes impact the web of life and also impact human systems (such as sources of fresh water, agriculture, and coastal cities) that have been designed for the previously stable climate.

People have a wide spectrum of attitudes about the changes that are happening to the natural world. On one extreme, some people think that our planet is doomed and there is no hope. At another extreme, some people think that everything is just fine and we should ignore the alarmists. In the middle, most people believe that there are serious problems and that we need to work together to "Save the Planet."

On that spectrum of attitudes, I am very concerned about our environmental situation. However, I would not say that we need to save the planet. Earth has survived much worse catastrophes than anything we can do. Life on Earth has survived much worse catastrophes than anything we can do. The planet does not need us to save it.

So what could we say? I am thinking of making tie-dyed lab coats that say "Save Earth's Current Web of Life (Including Us)." I agree it is not a highly marketable, sound-bite slogan, but that may be the price of scientific accuracy.

One problem that we confront in thinking and teaching about these issues is that while there is usually a range of possibilities, the issues are often presented only in terms of extremes. This presenting of "both sides" of issues by its very nature falsifies the reality. Global climate change will not destroy civilization this decade, but neither is it a hoax. What we need to understand and teach are the areas where there is scientific consensus and the areas of uncertainty, such as the quantity of the changes and how fast they will happen.

Educators who are concerned about the environmental impacts of human activities also have to confront the quandary of education versus advocacy. The standard approach in the environmental education community is to say that we educate students so they have the knowledge and skills to make their own choices, and that we do not advocate for specific actions (NAAEE 2010).

We want students to become global citizens because they understand the situation and consciously choose their actions, not because we have told them what to do. We favor education because we want our students to be life-long learners who can apply their knowledge and skills to the new situations and challenges that will surely confront them.

While I support this approach, I have to warn that it is easier to say than to do. The major problem is that sometimes one needs to know and understand a lot to untangle the web of information and what is euphemistically called disinformation (just think about everything that word implies). A related problem is that many things that are presented as facts are true on the surface, but also have myriad unspoken assumptions and omissions built into them. For example, the cost comparisons of generating electricity from renewable sources and from fossil fuels generally do not include tax and infrastructure subsidies, pollution costs, health costs, and costs related to international political instability.

In addition to education/advocacy, we face other complex dilemmas that have no simple answers. How do we avoid raising feelings of gloom and doom while still being accurate about the potentially very dire consequences of our actions? How can we provide students with real personal choices that make the greatest differences if our own, their parents' and the school's choices do not live up to those ideals? How do we avoid self-righteousness and cultish behavior? How do we effectively deal with indifference and political hostility? And finally, when students and people knowingly injure their own health and bodies, how can we motivate them to protect the planet's web of life?

While fear is one of our most powerful motivators, gloom and doom messages can cause people to withdraw rather than engage in positive actions. For both personal and pragmatic reasons, many educators emphasize messages of hope and opportunity. Here are some very good messages that we can promote:

- It is not too late. We can still prevent major damage.
- We already have the tools to avoid and/or solve our environmental challenges.
- Meeting these challenges will provide many new exciting and rewarding career opportunities.
- What each of us does in our daily life makes a big difference. We can each be part of the solution.

While I agree with and teach these very good messages, I also would like to send out what I think is a great message that resonates with my deepest beliefs. I believe that to cause the least damage to Earth's web of life and to ourselves, we need to fundamentally change our societies and how we live. Not only do we need to change how we live, the changes would be very good for us. If humanity can come of age on Earth as a mature, wise species that lives sustainably and equitably, I believe that we could all have lives that are potentially far more joyous and fulfilling.

To help us get there from here, I advocate the following mantra:

THINK GLOBALLY
ACT LOCALLY
FEEL COSMICALLY
BE LOVINGLY

The third phrase of this mantra returns us to the first part of this presentation. The cosmic time, energy, and space of the Universe can give us a very important perspective on our situation and actions. How we engage in our actions is just as important as what we do. The best environmental education and environmental actions avoid self-righteousness, hate, despair, and arrogance. Feel cosmically.

Deeply aware that life on Earth has existed for billions of years without us and will continue to exist for more billions of years, let us do what we can with hope, wisdom and love, but without neurotic attachment. Let us try to do the right things because they are the best and most fulfilling things that we can do in our time and our place. Let us join our hands, hearts and minds as joyous stewards of a glorious web of life on a unique planet, in an amazing solar system, amidst an unimaginably awesome Universe.

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Art Sussman may be reached by phone at 415.531.3110 or 510.525.2540 or by email at sussmanart@yahoo.com or www.guidetoscience.net.