No Simple Answers—How models and data reveal the science behind the environmental topics

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On the surface, when teaching controversial environmental topics, come down to the following simple concept: The population is exploding, and all these people are putting too much stress on the environment. It is hard to not get weighed down into the doom and gloom, or to present oversimplified, and often biased solutions. That being said, we know environmental topics are really a complex blend of science, policy, economics and human impacts. So how do we help students understand the complexities in these situations? With ongoing uncertainties with regard to climate change, energy availability, and freshwater availability, it may be a helpful strategy to focus on teaching the science, presenting it as objectively as a possible, to use it as a way to set the stage where data and models drive the understanding. It is our experience that approaching the topics this way makes students more likely to be receptive to the information and less likely to get turned off or defensive.

This article describes the Concord Consortium's High-Adventure Science: Earth Systems and Sustainability (HAS: ESS)(http://concord.org) has free online curricula in which middle and high school students use computational models, analyze real-world data and engage in building scientific reasoning and argumentation skills to learn about environmental topics and the effect of humans on Earth's systems. The National Science Foundation has funded the development of curricula that cover five topics: climate change, freshwater availability, energy use, Earth resource availability and land use management. Two curricular modules have already been developed (exploring fresh water availability and climate change); the others are in development.

Models and…

In High-Adventure Science curricula, students use computational models to explore the content. Our models are ideal for exploring Earth's systems and human impact. Every High-Adventure Science module includes a set of increasingly complex computational models that represent a particular system under study. The models are based on mathematical algorithms that approximate physical laws. Experimentation is therefore possible and encouraged. Much as scientists do, students can control conditions at the start and during a run. They can explore cause and effect and observe the changes in the models that emerge. The models have vivid graphics and run quickly, so students can run multiple experiments and gain insights by carefully observing changes to the system. The models (see Figure 1) in the *Will there be enough fresh water?* module, for example, allow students to create different cross sections through Earth's surface, saturate the layers with water, place wells, change surface layers, change precipitation rate and explore the outcomes of each change.

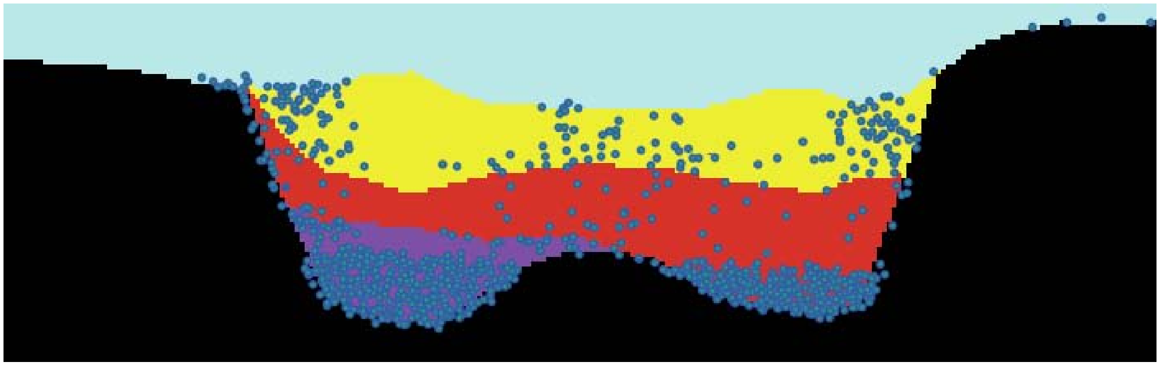

Figure 1.

In the *Modeling Earth's Climate* module, students begin by using a computer model to explore the effect of carbon dioxide on global temperature. The model helps students see how carbon dioxide traps infrared radiation, in turn increasing the temperature. Students can increase or decrease CO_2 amounts in the model and observe how the changes affect the system by interpreting the output graph to the left of the model (Figure 2). By experimenting with extremes—adding lots of CO_2 or removing most of the CO_2—and paying attention to the resulting graph, students discover for themselves the relationship between atmospheric carbon dioxide and temperature.

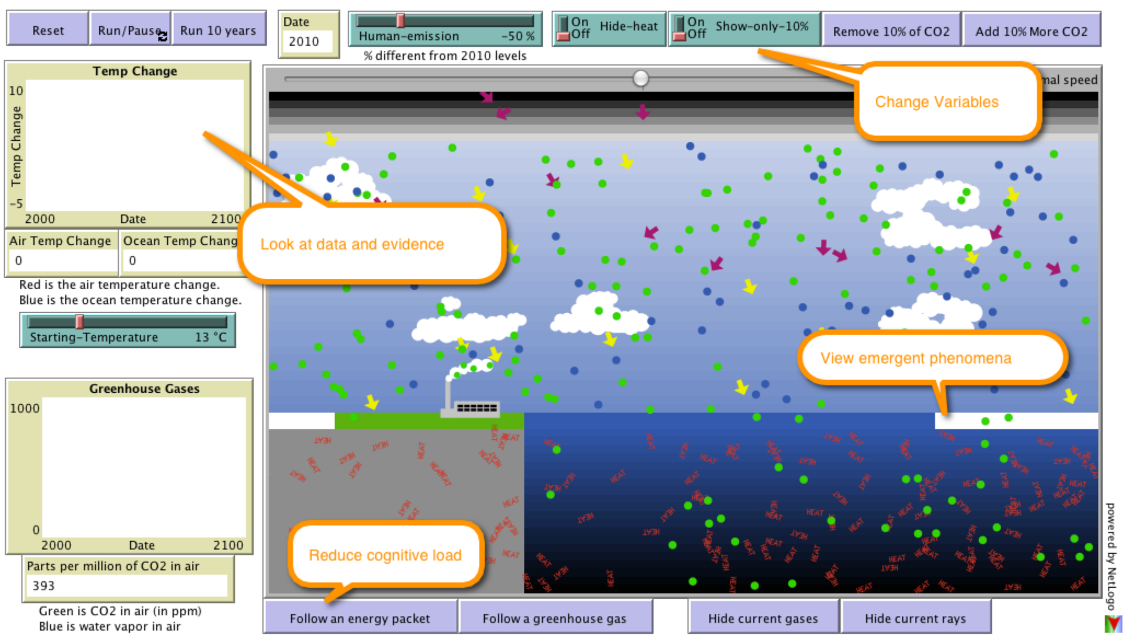

Figure 2

...data

High-Adventure Science curricula ask students to compare model output—and their own conclusions—to real-world data. By simulating climate in the past, scientists can see how well the models compare to real-world data and judge how they might predict the future. The models in the High-Adventure Science modules are not predictive like the most complex climate models. But if trends from the educational models are compared to the real-world data, then when students are presented with the data scientists are looking at, they can begin to make sense of information and the embedded complexities. The High-Adventure Science *Modeling Earth's Climate* module presents students with varied data sources: temperature data derived from Vostok Research Station ice cores, Earth temperature changes from NASA satellite monitoring, and the amount of carbon dioxide over the last 60 years in the Keeling curve. As students work through the data, they can discover the rate of temperature change and the extent of human impact. By combining this information with their own experimentation students can draw their own conclusions.

Controversy also means uncertainty

Engaging in these topics, which have no clear-cut answers, means addressing the uncertainty and sources of uncertainty head-on. High-Adventure Science curricula help students to focus on what is known, and to identify what additional information might be needed to better understand the issue. A distinctive feature of the curriculum is the use of argumentation item sets, which consist of four questions that require students to: 1) make scientific claims; 2) explain the claims based on evidence; 3) express their level of certainty; 4) describe the sources of certainty. These item sets, used throughout the curricula, encourage students to reflect on evidence from models and real-world data and to evaluate the certainty of scientific claims. Think about the controversy around hydraulic fracturing to release natural gas from shale (the focus of our energy curriculum that is in development): We prompt students to consider where natural gas is found, the uses of natural gas, the potential risks and benefits of this energy use, based on science and not the often hyperbolic rhetoric from both proponents and opponents. This makes it easier for students to see what is known, and what is still uncertain with this topic, and to begin to understand that there are no easy answers, as with all energy sources including nuclear, solar, wind, and other fossil fuels.

Conclusion

Developing this habit of mind serves students well. They can become critical consumers of information and will be able to create and rebut arguments based on evidence. High-Adventure Science curricula provide learning experiences for students to enhance their understanding of the science while confronting the unknowns and uncertainties as part of understanding potential risks and benefits of human impact. Attempting to remove the bias, as much as possible, allows students to unpack the information without feeling that they are being led to a predetermined answer while being told how to think and feel. None of these issues have clear easy solutions. but this approach can open the dialogue.