Modeling the Unknown is High Adventure Science

BY AMY PALLANT

"Very few see science as the high adventure it really is, the wildest of all explorations ever taken by human beings, the chance to catch close views of things never seen before, the shrewdest maneuver for discovering how the world works. Instead, they become baffled early on, and they are misled into thinking that bafflement is simply the result of not having learned all the facts."

— LEWIS THOMAS[1]

How did life begin? What is the universe made of? What is at Earth's core?

To celebrate its 125th year, *Science* published a special issue entitled "What Don't We Know." The issue features articles on the 25 top unanswered questions in science as identified by a panel of scientists and lists 100 additional questions. What scientists don't know is no small matter. These are big questions and there are a lot of them!

Just browsing the list is exciting for anyone with a scientific bent. But we wondered—is it possible to generate similar excitement and motivation in middle and high school students? Teens seem to value facts and certainty over doubt and curiosity. And while there are no guaranteed answers, the unknown offers opportunities to explore the wildest possibilities.

In the *High Adventure Science* project, funded by the National Science Foundation, our goal is to engage students in current research in the unanswered questions of science and to shift the teaching and learning process from textbook facts to the ongoing process of science. We are exploring a practical approach to motivating students and teaching science that is widely recognized but rarely implemented because of the lack of appropriate student activities and the pressure of tests. (Ironically, those tests are based on standards that emphasize the process of science as much as the content.) We are building curriculum units that show students how science truly proceeds as they learn about unsolved science topics.

Many attempts have been made to interest students in "real" science by putting them in contact with scientists or engaging them in research, but these approaches are not practical for wide scale or long-term adoption. There are too few scientists who can offer the time needed to sustain these efforts. The High Adventure Science project is bringing current research on relevant topics into the classroom in a way that is true to the spirit of science—doing authentic inquiry, experimenting with models, and exploring aspects of actual unanswered questions in science. Using modern technology and proven methods of cyberlearning, it could be easily scaled up to have a measurable impact on science teaching.

We identified 13 unanswered areas of research in earth and space sciences (see sidebar) that connect to the science curriculum and standards. We then surveyed students and teachers, explored potential modeling ideas, and narrowed our focus to three: "Climate Change: Is Earth's past a good climate model for the future?" "Space: Is there life on other planets?" and "Natural Resources: Will there be enough fresh water?" These units will simulate a current key experiment by researchers, though simplified for educational purposes. We will also include several short videos of scientists presenting their own research and how the data they are collecting is related to solving aspects of these unanswered questions. Finally, the units will include real-world data for analysis. What makes these units unique will be the way in which students are able to gather data from the models, and through the perspective of the researchers in the videos, compare their results to real-world data.

Our research will investigate the following questions: Does the curriculum increase student understanding of and interest in science? How do these materials affect student understanding about the nature of science and science research?

Is Earth's past a good climate model for the future?

Though scientists agree that global warming is occurring, there are still many unknowns about what exactly will happen to Earth and the environment as a result of global warming. Daniel Schrag, a leading researcher on climate change, states in the video *Freeze, Freeze, Fry: Climate Past, Present, and Future,* "When you hear debates about climate change it is all about whether scientists know enough, whether scientists are sure, and I kind of laugh about it. We are doing something to the Earth that hasn't been done in 35 million years. The idea that scientists like me are supposed to predict exactly what is going to happen, when no human has ever seen this ever before, is kind of crazy. The Earth is a very complicated system, and no one can make perfect predictions of the future. You can't trust your weather forecaster out more than five days. So why do they think we should be able to predict what climate is going to be more than 100 years from now? Especially when nobody has ever seen such

REFERENCES

1. Kennedy, D., & Norman, C. (2005). 125 Questions: What don't we know? *Science*, 1 July 2005, http://www.sciencemag.org/sciext/125th/
2. Schrag, D.P. (Producer). (2007). *Freeze, freeze, fry: Climate past, present, and future* [DVD]. Available from http://www.classroomencounters.org/

high levels of CO_2 on the Earth. It's an experiment. It is a terrifying experiment, but it is an experiment."[2]

Students will study some of the many variables scientists are exploring, such as changes in CO_2 and other greenhouse gases, albedo, ocean temperature, and cloud cover. The models will enable students to alter the levels of each of these variables and observe the shift in the model's climate temperatures. In addition to the modeling interactivity, the unit will set the context for exploring climate variation by looking at Earth's climate history and in particular comparing today's changing climate with the climate of the Eocene, when atmospheric CO_2 was high and the last thermal maximum occurred. Students will explore light-matter interactions, in other words, what happens when sunlight enters Earth's atmosphere and encounters clouds, greenhouse gases, and land.

Additionally, students will learn about the distribution of Earth's continents over time, and how changes in ocean currents are closely related to global climate over time. Finally, students will discuss how scientists recreate models of past climates and why this work is important in predicting future climates. By addressing earth science content, these explorations will fit into existing secondary science classes and meet both content and inquiry standards.

Student scientists and the power of models

Of course, scientists spend entire careers researching one question, so we do not expect that students will solve the big questions. However, students will be able to explore aspects of the research by using interactive models; their data will come from manipulating model parameters and studying the emergent behavior. Just as discoveries are made at local and national science fairs every year by young scientists doing original research, our students will have the opportunity to explore their own questions about the unknown.

By combining the motivation of unanswered science questions with the pedagogical potential of robust inquiry supporting models in geosciences, we hope to provide students with compelling views of how science is done while engaging them in today's most vital science content. There is no doubt that there will be a new set of questions for *Science's* next list, but with the help of modeling simulations some of the current questions may be closer to being answered.

LINKS *High Adventure Science*

High Adventure Science
http://has.concord.org

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Questions for Exploration

What causes mass extinction? In geologic history there have been at least five times when more than half of the world's species died. What caused these events?

Is there life on other planets? Scientists have found over 400 planets around other stars. Could life exist somewhere out there?

How hot will Earth get? Global warming will affect our world in profound ways. What predictions can be made about future trends that account for natural cycles and anthropogenic factors?

How are solar systems formed? The conventional theory of solar system formation examines only our own solar system as a test case, but our solar system is not typical. How were others created?

How does Earth's interior work? The convection of Earth's core produces a magnetic field, which may influence surface conditions. Mantle convection is related to volcanoes, seafloor spreading, and mountain creation. How do these motions in Earth's interior really work and in what ways do they affect Earth's surface?

What is dark matter? Most scientists believe that there must be "something" to account for missing mass in order to obey the theory of gravity. Dark matter has mass, but is invisible, so what exactly is it?

What causes lightning? New research has discovered that lightning emits large bursts of x-rays. Could cosmic rays from outer space be involved?

Will there be enough water? The green revolution has brought many lands into self-sufficiency, but essential water pumped from the ground is not being replenished by precipitation. Can countries feed future populations when they are running out of water?

What if the ocean's conveyor belt changed? Deep ocean currents distribute heat around the planet, affecting climate. Could global warming shut down the ocean's conveyor belt with devastating effects on weather patterns, collapse of plankton stocks, and a depletion of oxygen?

What causes ice ages? Changes in solar radiation absorbed by Earth due to periodic orbital fluctuations are one factor in the creation of an ice age. What are other factors?

Is human space travel likely? How can humans be protected from the harsh radiation, cold, and vacuum of space? Is space travel about science or human exploration?

When will an earthquake hit? Earthquake forecasts of the locations and magnitudes of future large earthquakes could save lives. Yet, making a precise prediction has eluded scientists. Is it possible?

Will hurricanes become stronger? Hurricanes Katrina and Rita in 2005 were the worst in many years; their strength was attributed to warmer sea surface temperatures caused by global warming. Can we predict hurricane seasons of the future?