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Perspective:
Distributing Innovation

By Chad Dorsey

There are 99,000 public schools in the United States. And there are thousands of software applications and technologies shown by research to help students learn. But despite these numbers, we face an enormous disconnect—much of this good technology is not widely adopted by teachers and schools.

A recent National Research Council (NRC) report* on using gaming and simulations in science learning noted that for a single software application, commercial educational game companies sell only an average of 200-300 site licenses to schools, a number representing a minuscule fraction of the available schools. With results like this, and in light of the marketing dollars these companies often have to woo potential customers, it's no wonder that research-based software products developed with federal funding frequently reach very few schools.

Ignoring this problem runs the risk of leaving innovations by the wayside, discarding valuable solutions and lessons, and squandering taxpayer dollars. As computers and technology platforms become widely available in schools, it is incumbent upon us all to ensure that this technology is used in the best possible ways for as many students as possible, encouraging wide support of deeply digital learning rather than settling for shallow or piecemeal solutions.

But how do we do this? Rapidly changing technology combined with the complexities of education has long created a truly wicked problem, one we won't quickly crack open. We can, however, identify some of the core barriers that stand in the way of our vision. Two of the most central of these barriers are the difficulty in establishing distribution of software to schools and the complex transition from initial research and development projects to products that teachers can use effectively.

The distribution problem

One of the principal problems complicating the question of scaling educational technology innovations is the basic question of distribution. Though the new ideas derived from federally funded work have very important impact on their own, it's hard to sidestep the argument that federal funding supports many quality educational software applications every year, and that teachers and students can benefit most by actually using them. This, of course, requires getting the software into their hands. Federally funded projects developing educational technology are required to disseminate their work and results, but precious few dollars in any budget are designated or approved for marketing these projects or supporting their wide distribution.

This dilemma hits at a seminal point in the history of distribution. Dramatic changes in recent years have ignited an explosion of convenience and availability, as mobile platforms have driven the development of app stores and marketplaces and turned once complex installations into simple—even enjoyable—single click processes. The success of these stores can't be ignored. The iTunes App Store and the Android Market each have hundreds of thousands of apps. The pervasiveness of this model is its true importance. The revolution has brought the concept far beyond the mobile platforms that launched it. Internet-connected television players such as Roku or Google TV bring easy-install processes straight into your living room, while Ford's SYNC system brings connections to app store products onto your car's dashboard. Recently, this revolution has expanded to the realm of desktop and Web-based applications. The Google Apps Marketplace enables administrators of its productivity software to install new Web applications easily across many users, and the recently launched Mac App Store brings this same experience to desktop software.

While there would certainly be no shortage of devilish details, an app store-like distribution channel for educational technology applications would be a distinct boon for independent developers and groups. Such an avenue would bring these groups together into a single location where teachers could easily discover, try, and adopt vetted simulations, games, or technology-based curricula. In its report, the NRC identified the lack of distribution channels as the primary barrier to widespread use of educational simulations and games in science education, suggesting the app store concept as a useful model to consider. Implementing this idea effectively would indeed be no small feat, but for as many potential roadblocks as we might list, we can uncover an equal number of valuable opportunities:

Teachers and schools could discover new applications and curriculum quickly and easily. Busy teachers and schools need easy access to quality materials and curricula that support identified learning goals. A distribution channel could help gather these in one place.

Software could be deployed more easily across multiple schools and classrooms. A modicum of standardization in such a distribution channel could help clarify system requirements and possibly even facilitate the process of deploying desktop-based software in schools. This could also help address the concerns of school or district information technology staff, who are charged with keeping school computers safe and reliable.

Professional development and support could be purchased together with software. New technologies require teachers to

Chad Dorsey
(cdorsey@concord.org)
is President of the Concord Consortium.

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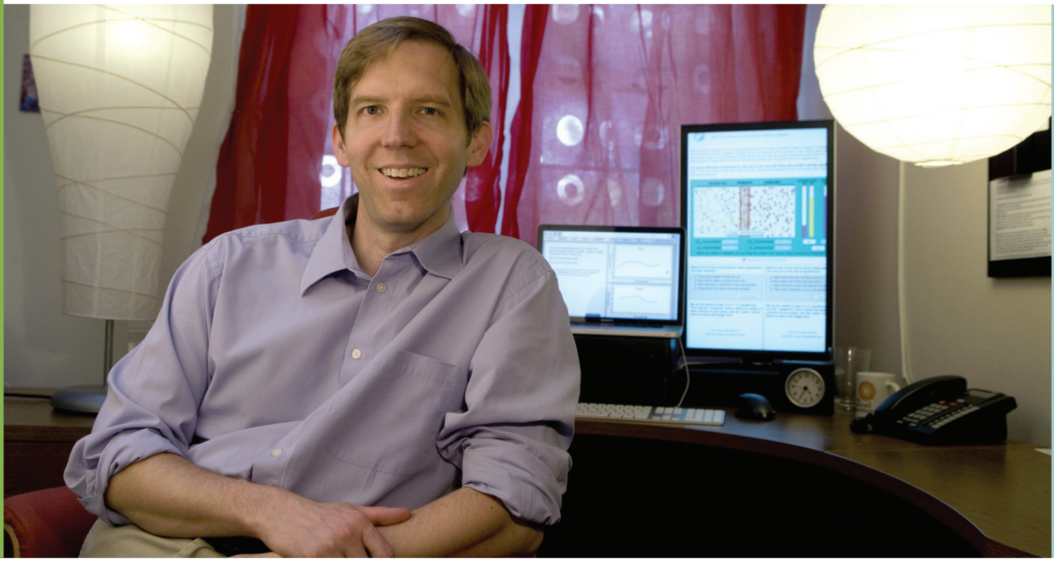


learn the ins and outs of software and frequently demand new thinking about pedagogy or the teacher's role in the classroom. With a central distribution channel for software, districts or schools could purchase professional development packages together with software, increasing the odds that teachers would receive this needed training. Such professional development could even be supplied online within the same channel.

Educational research could benefit and teachers could be better informed. With a central hub for educational technology, research data could find a central home as well. Participating teachers and students could provide secure and anonymized data for ongoing research. And reports on student use of resources could help provide up-to-the-minute information to guide teachers' decisions about instruction.

A community gathering place could be self-reinforcing. Many examples have shown the benefits of gathering interested communities online. Efforts in educational technology have begun, but have not yet gained critical mass. A central hub for distribution could provide a useful impetus to spur this community, leading to a wider range of development, improved quality of open source work, and a natural location for exchange and development of ideas, applications, and platforms.

Supporting scale-up

Such a grand vision needs to be ushered forward by multiple organizations, and it has no chance to become reality without a source of sustained support and funding. Ideally, a vision would encompass more than simply a distribution location, but would instead concentrate on the larger underlying problem: supporting quality projects in making the transition from initial research and development work to widely established educational products. A center or location with resources and time dedicated to this could help ensure that federal educational technology investments are given a fighting chance to be discovered and implemented. It could gather our best knowledge about how to scale innovations, supply blueprints for success to projects in their infancy, and match academic or nonprofit developers with partners to drive commercialization. A center could reach far beyond distribution, spurring innovation and establishing an entire new sector merging education and technology. Eventually, it could attract ongoing industry support or venture capital investment to help ensure sustainability.

The recently proposed Advanced Research Projects Agency for Education might provide one means of supporting such goals. Or federal sources such as the National Science Foundation could define and fund a locus for researching and supporting the scale-up of federally funded projects in educational technology. With strong support behind a solid vision, high-quality, research-based projects could gain footing and distribution alongside current commercial options, open source software could be easily distributed to many thousands of schools, and a burgeoning community could rally to improve education. Our nation's dedicated schools, teachers, and students deserve nothing less.

* National Research Council. Honey, M. & Hilton, M. (Eds.). (2011). *Learning science through computer games and simulations.* Washington, DC: National Academies Press.

Looking at the Evidence

What we know. How certain are we?

Here's a simple true or false quiz:

1. **Science is a static body of facts.**
2. **Science is a dynamic, evolving process that tests questions and makes conclusions.**

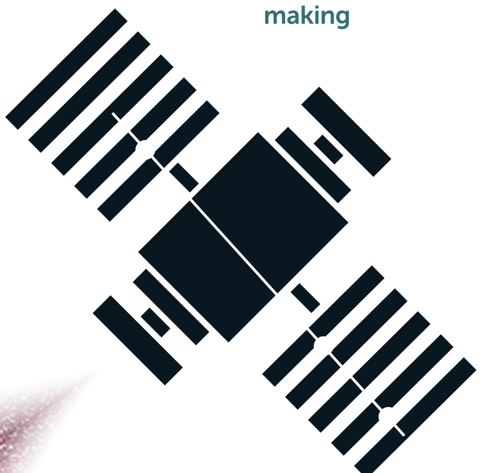
By Amy Pallant

Amy Pallant (apallant@concord.org) directs the High-Adventure Science project.

Scientists and science teachers talk a lot about things they know, things that have been established in the scientific community beyond a doubt. DNA carries hereditary information. The Earth's surface is made up of many constantly shifting plates. Gravity is the force of attraction between two objects.

But everything that is known began as a question. Through the gradual accumulation of experimental data, model building, and the discussions (and disagreements) among scientists, scientific explanations and theories were proposed, tested, and ultimately accepted by the scientific community.

Scientists—and, indeed, the field of science—move from the unknown to certainty, gathering and analyzing data, making



observations, and drawing and testing conclusions. Some of these conclusions hold up for a very long time as continued experimentation verifies original theories. Other times, contradictory evidence or results force a revision of what was previously "known."

So, referring back to the true or false quiz that introduced this article, science is clearly a dynamic, evolving process, not a collection of static facts. And we should teach it that way.

The Concord Consortium's High-Adventure Science project, funded by the National Science Foundation, is bringing the excitement of scientific discovery to students by letting them explore pressing unanswered questions using the same methods that practicing scientists use. The goal of our research is to determine whether the active exploration of these questions helps students come to view science as a dynamic, evolving process.

Uncertainty in science is a feature

Although there is a very large body of agreed-upon scientific explanations of the way the natural world works, scientists continue to explore new areas. This doesn't mean past experimental results are wrong. It simply means there is more to discover, more to learn, more to articulate. Through careful consideration of the evidence and examination of the process of science, students can sort out what scientists are certain about and where they are looking for more evidence.

The High-Adventure Science project is creating three investigations for middle and high school students that focus on current, compelling, unanswered questions in Earth and Space Science:

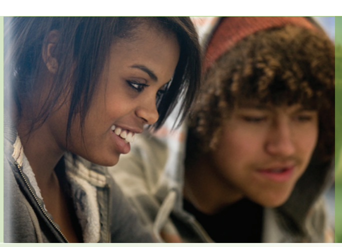
- **What will Earth's climate be in the future?** Students investigate past climate changes and learn how mechanisms for positive and negative feedback can affect global temperature. They think about how scientists use this information to make climate change predictions.
- **Is there life in space?** Students learn how scientists use modern tools to find planets around distant stars as they consider the probability of finding extraterrestrial life.
- **Will there be enough fresh water?** Students evaluate whether the vast underground stores of water will be sufficient to support a growing human population.

Each investigation incorporates interactive computer models combined with real-world data, plus video of scientists who are currently working on the same unanswered question. Students use the models, interpret the data, and draw conclusions just as scientists would. What makes these investigations unique is the way in which students begin to develop scientific argumentation skills and explore the issues of certainty with the models and data. Throughout the investigations, students are prompted to define their levels of uncertainty about the science, the data, and the models.

Developing scientific analysis and argumentation skills

Our investigations present a unique challenge to teachers: helping students embrace the idea that all cutting-edge scientific research is characterized by uncertainty, but at the same time instilling confidence that widely accepted scientific knowledge based on multiple sources of evidence is reliable and not likely to be overturned.

Those engaged in scientific research understand that science is a continual quest for knowledge. Understanding in science is an incremental increase in confidence as conjectures become hypotheses and ultimately scientific theories. Our goal is to help students to interpret data and scientific evidence while explicitly considering three questions: a) what is known? b) how do scientists know that it



is known? and c) what is still unknown?

To develop students' skills—in particular, to develop their ability to interpret data, models, and experimental results—we include in our investigations a set of tools called "explanation-uncertainty item sets" that couple students' explanations with certainty rationale items (see below). When students draw conclusions, they are consistently asked to justify their claims, rate their uncertainty levels, and explain what influenced their uncertainty.

An explanation-uncertainty item set about finding life in outer space

[Claim] 1. There are many billions of stars in the Milky Way galaxy. One of those stars is our Sun, which has eight planets orbiting around it. Scientists have just started to identify planets outside our solar system. So far they have discovered nearly 500 planets outside of the solar system. To date, scientists have not found proof of life outside of Earth.

Based on the information, is it probable that life exists outside of Earth?

☐ yes
☐ no

[Explanation] 2. Explain your choice in question #1.

[Uncertainty] 3. How certain are you of your answer about the probability of life outside of Earth?

☐ 1 Not at all certain
☐ 2
☐ 3
☐ 4
☐ 5 Very certain

[Uncertainty rationale] 4. Explain what influenced your certainty in question #3.

These item sets are designed to reveal a more complete picture of student understanding. Following a scientific claim, students must answer a question and explain their reasoning; their explanations help us understand how they think about both the evidence and the claim. The uncertainty rationale items measure whether or not students recognize the uncertainty of claims.

Students are encouraged to use this tool set throughout the curriculum. Through repeated exposure, we hope to encourage them to reflect on both the evidence they generated from using the models and the real-world data, and to evaluate how certain they are about their own claims, as well as the claims of scientists.

The following are examples of students' uncertainty rationales from pilot tests of the items with non-High-Adventure Science students.

One student who was very certain (level 5) said:

"Due to the fact that there are billions of stars within one galaxy, and there are many planets orbiting each star, and there are thousands of galaxies, the odds of Earth being the only planet capable of sustaining life are incredibly small."

Another student chose level 3 (exactly halfway on the certainty scale, between "not at all certain" and "very certain") said:

"I always believed there were other life forms on different planets, but it has not been proved that there are other life forms."

Our initial work shows that students were more likely to be uncertain about their claims and justifications when they cited personal reasons on the uncertainty rationale, while students were more likely to be certain when they cited scientific reasons. Our research will look at how their uncertainty rationales change after using the curriculum.

The High-Adventure Science project is attempting to bring frontier science to the classroom. We hope that when students hear something in the news—or in their science class—they will weigh the evidence. Students should no longer look for "answers," but begin to distinguish between what is known, what is suspected, and what is still being researched.

High-Adventure Science's Latest Investigation

In the "Is there life in space?" investigation, students learn the techniques scientists use to look for planets outside our solar system. These "planet hunters" use powerful telescopes in their search.

With the wobble method, scientists have located hundreds of planets. Students explore how a planet's diameter and mass might cause a star to wobble or move. Students also observe how the movement of a star affects the wavelength of light observed. Finally, students discover the importance of angle of orbit as it relates to scientists' ability to locate planets orbiting stars.

Using another technique—the transit method—scientists look for the dimming of stars caused by planets moving between the star and our telescopes. These eclipses, however, are rare. Students look at graphs of light intensity as planets pass in front of stars (Figure 1) and again explore how the angle of orbit affects the perceived dimming a scientist would observe through a telescope.

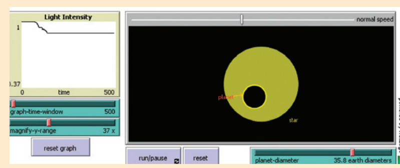


Figure 1. NetLogo model of the transit method.

In this investigation, students use both models and real-world data, and are asked to weigh in on the certainty of finding life "out there."

Follow our blog

The High-Adventure Science project is focusing on some of the current unanswered questions in Earth and Space Science. This frontier science is in the news all the time. Visit the High-Adventure Science blog at our website for easy-to-read articles that connect to our investigations—and share your thoughts, too.

LINKS

High-Adventure Science
http://concord.org/high-adventure-science

Monday's Lesson:

Digital Inquiry in the One-Computer Classroom

By Dan Damelin

Dan Damelin
(ddamelin@concord.org)
directs the RI-ITEST project.

The Rhode Island Technology Experiences for Students and Teachers (RI-ITEST) project contains some of the best deeply digital resources for doing inquiry in the high school science classroom. What exactly does it mean to "do inquiry" with digital resources? And what does it look like, especially when you have just one computer?

The RI-ITEST activities were created by the Science of Atoms and Molecules project, which developed 24 short instructional units in physics, chemistry, and biology that were built around interactive computer models with embedded assessments. Though these activities were originally designed for an individual or pair of students, there are several reasons why a teacher may want to use them in a one-computer mode with the whole class. Numbers of computers, reliability of available computers, or the timing of when computers are available may limit student computer access.

Even when technology access is not an issue, best practices call for bringing the class together for discussion after students work with models on their own. But doing whole class inquiry can be difficult, especially with interactive models displayed from one computer at the front of the class.

To facilitate inquiry in a whole class mode, try these strategies:

Brainstorm. Start with questions that allow every student to contribute (e.g., ask students to simply describe what they see). Since most students will be able to contribute, they will be more likely to chime in to later discussions.

Have students manipulate models. Ask the whole class what to do with a model. Try taking a vote (e.g., "Should we increase the concentration or decrease it?") or calling on individual students to try out their ideas by inviting them to the front of the class to set up the model.

Use models to back up claims. When students make a claim, have them set up and interpret the model. Invite discussion and have students come up with counter examples (or present a counter claim yourself, if necessary).

Now, let's see how this works in the "Diffusion, Osmosis, and Active Transport" activity (http://ri-itest.portal.concord.org/diy/view/68/type/ExternalOtrunkActivity/).

- Set up the model on page 2 of the activity with a high CO_2 concentration on one side of the cell membrane and low CO_2 concentration on the other. Run it and ask students what they see. If they say CO_2 is going from the high to low concentration area, ask them to demonstrate this in multiple ways.
- Reset the model and highlight the molecules in the low concentration area by dragging the mouse over them (Figure 1). When you run the model again, students should see some molecules move from the low to high concentration area. Ask: How is equilibrium reached if molecules are moving both ways?
- Since most students think that equilibrium is defined by equal concentrations on both sides, challenge their notion of equilibrium by running the model on page 5 of the activity with and without hemoglobin. Ask students to debate whether the "with hemoglobin" option reaches equilibrium (Figure 2). The hemoglobin causes a new equilibrium with a higher concentration of oxygen inside the cell. This highlights the fact that equilibrium means equal rates of exchange into and out of the cell, not that there are equal concentrations.

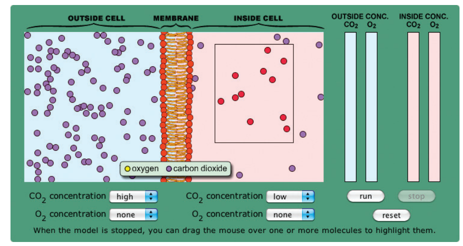


Figure 1. Highlight the molecules in the low concentration area so students can see that some will move to an area of high concentration.

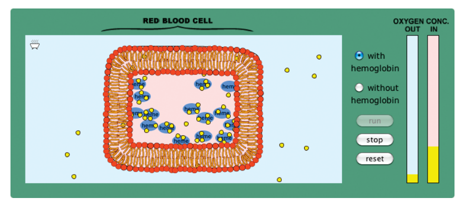


Figure 2. Equilibrium without equal concentrations. The high affinity oxygen has for hemoglobin keeps the concentration inside the cell higher than outside at equilibrium.

Try it out

Most interactive models can be adapted for the one-computer classroom and used as an effective means for engaging students in scientific inquiry. Give it a try! Some of my best classes have been done this way.

LINKS

RI-ITEST
http://concord.org/ri-itest

Inspiring Young Scientists with **Innovative Tools**

By Carolyn Staudt, Edmund Hazzard, and Charles Gale


Carolyn Staudt
(cstaudt@concord.org) directs the ITSI-SU project.


Edmund Hazzard
(ehazzard@concord.org) is a senior science curriculum developer.


Charles Gale
(cgale@his.com) is an independent science curriculum developer.

Do little seeds make little plants? Do big seeds make big plants? Do your feet heat up when you run? Is the inside of my dog's mouth the same temperature as my sister's mouth? Do bugs see the same things we do?

The list of questions from young children is virtually endless, unlimited in scope, and free of convention. Kids are curious, which makes them natural scientists. "Start Science Sooner," a recent *Scientific American* article*, called for quality science teaching to start earlier in elementary school. But teachers shouldn't simply supply answers; they need to provide students with the opportunity and tools to explore their own questions.

In the Innovative Technology in Science Inquiry Scale Up (ITSI-SU) project we are excited to add 50 activities for elementary students to our existing collection of over 100 middle and high school activities. The elementary activities will use three computer-based tools:

Models. Students test variables on computer simulations (for example, changing a playground slide's surface from aluminum to carpet or the slide's angle from 20° to 40°) and observe what happens.

Probes. Students take measurements—using temperature, motion, voltage, force, and light sensors—and get a hands-on feeling for real-time data collection and the underlying science concepts.

Digital microscope. Students see the world up close. A new, inexpensive digital microscope allows magnification between 30x and 130x—enough to see everything from a bug's eye to a pollen grain or a growing crystal.

Units for grades 3-4 (Table 1) will include engineering, life science, and physical science, while those for grades 5-6 (Table 2) will focus on earth and space science, life science, and physical science. All activities will be aligned to national science standards.

More teachers, more features, more activities

Funded by the National Science Foundation, ITSI-SU is in the process of scaling up our highly successful ITSI project, bringing even more online activities to teachers and their students. In the first year of the project, ITSI-SU trained 45 middle and high school teachers from Alaska, Iowa, Kansas, and Virginia to use our online activities in their classrooms. Teachers participated in a weeklong face-to-face workshop last summer and two online courses during the school year. They learned how to enroll students in classes and monitor student progress in the online activities. As a signature part of our project, teachers also learned how to customize existing activities, for example, by adding more models or probes or changing questions.

Beginning in the summer of 2011, a second group of teachers—including eight elementary, eight middle school, and eight high school teachers from each of the four collaborating states—will be recruited. We will increase teacher recruitment each year throughout the five-year project.

We recently added new software functionality to the ITSI-SU portal, our online repository of all activities and classes. We are currently enhancing the portal to include more metatags and search functions, plus teacher blog and discussion areas that will encourage peer review for activities customized by teachers.

As exemplary elementary activities emerge from other Concord Consortium research and development projects, ITSI-SU will continue to grow. Our goal remains to enable teachers to use deeply digital activities with their students, engage learners of all ages in scientific inquiry, and monitor their progress. When you teach children to inquire—and give them the tools they need—you create future leaders in science.

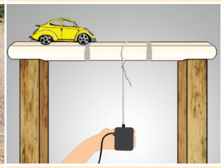
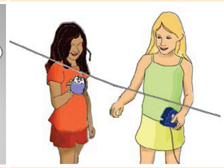
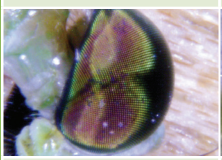
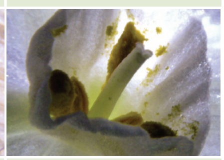
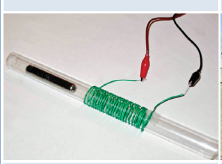
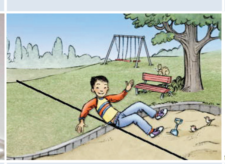
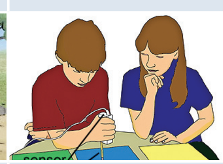
Try a free activity

Visit the ITSI-SU website and click the "Go to the Portal" button. Then click the "Activities" link to view middle and high school activities. Elementary activities will be added by June 2011 as they are developed.

Note: You can preview an activity in a Web browser. To run an activity (using models or probes), you'll need the Java Runtime Environment version 5 (1.5) or later with Java Webstart. You can download it at http://java.com.

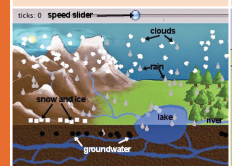
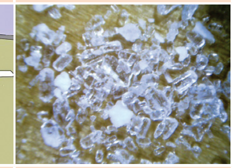
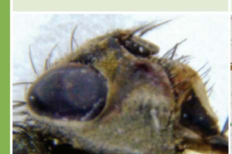
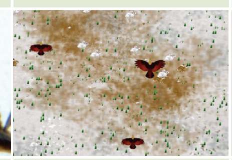
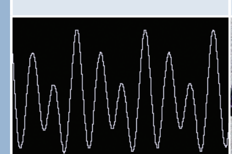
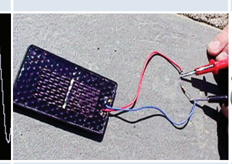
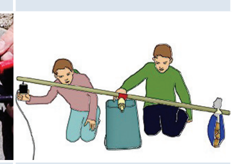
* *Scientific American Magazine. (2010, February 18). Start science sooner: Excellence in science education must begin in kindergarten. http://www.scientificamerican.com/article.cfm?id=start-science-sooner*

Table 1: Grades 3-4 activities

ENGINEERING	**Energy Production (sensors)**	**Structures (sensors)**	**Playground Design (sensors)**
	Students build and test model wind generators and solar ovens.	Students build and test model bridges and playground structures.	Students build and test playground equipment.
			
	Solar ovens*	A bridge built of file folders	A simple zip line
LIFE SCIENCE	**Senses (models & sensors)**	**Plants (models & sensors)**	**Habitats & Life Cycle (models & microscope)**
	With a microscope students study the different ways insects sense their environment.	Students study plants under a microscope and learn how they reproduce. Students also watch seeds sprout.	Using a microscope, students observe life in a drop of water. They study habitats with simulations.
			
	Compound eyes of a housefly (130x)	Flower with pistil and pollen (130x)	Virtual field of flowers
PHYSICAL SCIENCE	**Electricity & Magnetism (models & sensors)**	**Friction (models & sensors)**	**Light (sensor)**
	Students use a voltage sensor to study electricity and magnetism.	Students investigate sliding friction using sensors and models.	Students use a light sensor to measure reflected light.
			
	Magnet wrapped with a wire coil	Model of a playground slide	Light sensor over colored paper

* "Solar cookers made by children," courtesy of coconino on Flickr www.flickr.com/photos/coconino/1385983127

Table 2: Grades 5-6 activities

EARTH SCIENCE	**Water Cycle (models & sensors)**	**Planets & Stars (models & sensors)**	**Soil & Rocks (sensors & microscope)**
	Students investigate the water cycle using models and a temperature sensor.	Students use models to study the path of the sun and the phases of the moon.	Students use a microscope to study organic and inorganic material in soil. They also grow crystals.
			
	Water cycle model	Model of light from sun to earth	Epsom salts (30x)
LIFE SCIENCE	**Small Critters (microscope)**	**Living Environments (models & sensors)**	**Human Body (sensors & microscope)**
	Students study insects and brine shrimp by viewing them under a microscope.	Students manipulate a predator/prey model and use sensors to monitor different biomes.	Students observe hair and skin under a microscope. They use sensors to study the effect of exercise on their bodies.
			
	Common housefly (30x)	Model of hawks hunting for rabbits	Three types of human hair (130x)
PHYSICAL SCIENCE	**Cycles (models & sensors)**	**Energy Transformations (sensors)**	**Forces & Motion (sensors)**
	Students study cycles in nature using a motion sensor with pendulums and a microphone for sound.	Students use sensors to study how energy can be changed from one form to another.	Students use a force sensor to investigate simple machines and a motion detector to study falling bodies.
			
	Sound waves	Solar cell	Lever, weight, and force sensor

LINKS

ITSI-SU
http://concord.org/itsi-su

By Andy Zucker and Carolyn Staudt

Andy Zucker
(azucker@concord.org)
is a senior research scientist and co-directs the SmartGraphs project.

Carolyn Staudt
(cstaudt@concord.org)
directs the SmartGraphs project.

SmartGraphs Software

Helps Students Learn Using Graphs

Graph interpretation is a central skill in all fields of science, mathematics, and technology. For members of the public, understanding significant scientific and societal concepts—such as global warming, the stock market, or housing price fluctuations—often depends on making sense of graphs. Nonetheless, students of all ages demonstrate difficulties interpreting graphs. Students need to repeatedly explore, create, manipulate, and explain graphs in order to learn how to use them well. It's the same process as learning the three R's, and equally fundamental.

The SmartGraphs project is designed to help. It was funded by the National Science Foundation to follow up on seminal work in making science activities accessible to all learners through our Universal Design for Learning (UDL) Science project. We are developing free, open source software designed to help secondary math and science students become comfortable with graph interpretation.

SmartGraphs help students to learn about graphs and the concepts represented in graphs by interacting with them. Hints and scaffolds—such as visually highlighting portions of graphs, stepping students through calculations of slope, reminding students about units of measurement, helping them understand and use scales, and pointing out links between representations (such as a table and a graph)—are used only when needed. Pilot teachers tell us that this individualized assistance to students is invaluable, saving the teacher time while offering practice to students who can benefit from it.

The Boiling Water activity

To experiment with some of these features, try our demonstration activity on the Curriculum tab at the SmartGraphs website. The "Boiling Water" activity starts by describing water being heated on a stovetop. A thermometer immersed in the water reads 90 degrees Celsius. Five minutes later, when the water begins to boil, the thermometer reads 100 degrees. After reading this scenario, students are asked to sketch a graph showing the temperature over a ten-minute period, starting when the thermometer reads 90 degrees.

Page 3 of the multi-page activity shows three panes: text and student responses on the left, the student's prediction on the bottom right, and the actual temperature graph, created by the activity's author, on the top right (Figure 1). The student is asked to compare his or her prediction to what was recorded. In this example, the student incorrectly predicted that the temperature would continue rising after the water boiled—a common misconception.

Students must then click on a point depicting the temperature one minute or more after the water has started to boil (Figure 2). Since the student's selection (a red point) is incorrect, SmartGraphs highlights a section of the graph corresponding to the student's choice, and the text reads, "Incorrect. In the highlighted section of the graph the water was not yet boiling. Try again." Students must respond with a correct answer before they can move on to the next page of the activity.

At each stage, students get feedback about their graph interpretation skills—in other words, they learn to understand the "story" of the graph. The goal is that with repeated exposure to key features and processes—and the ability to interact with a graph and get individualized feedback—students will become more adept at graph interpretation and rely on scaffolding less over time.

In the Boiling Water example, students are learning both about graph interpretation skills and about an important physical science concept, the boiling point of a liquid. Other SmartGraphs activities will focus on graphs and concepts applied to algebra, forces and motion, and eventually other topics. The activities can make use of sensors attached to a computer, so that, for example, as part of the lesson students can use a motion sensor to learn about position-time graphs, velocity, or acceleration.

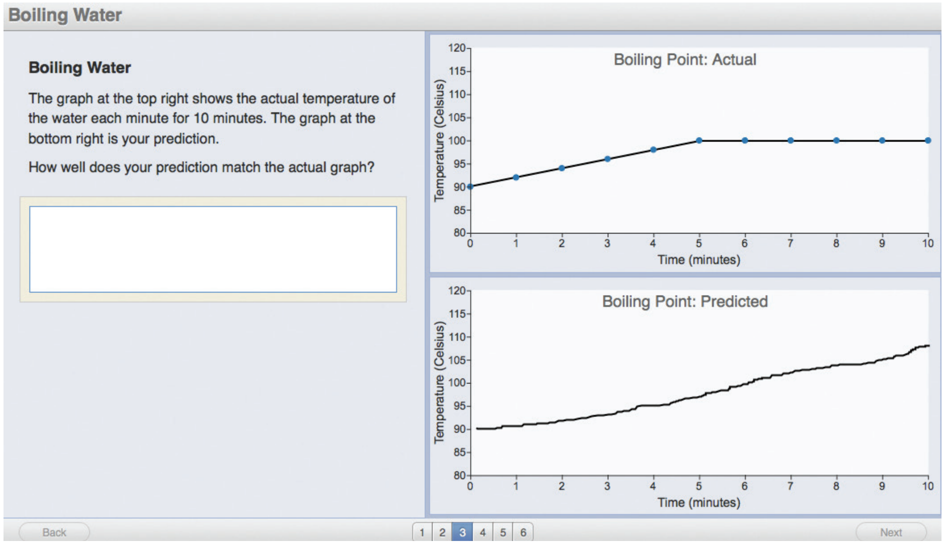


Figure 1. Boiling Water. Text and an open response question are in the left pane; the recorded data points for boiling water, top right; and the student's graph prediction, bottom right.

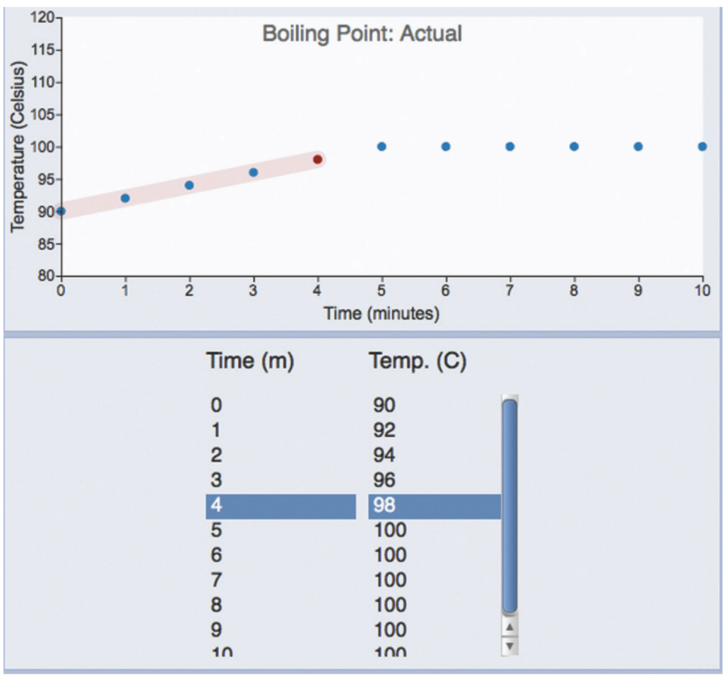


Figure 2. Interacting with a graph. The student-identified point is red (top) and correlates to the highlighted data point (bottom).

The Future of SmartGraphs

Prior work in schools using software that requires large downloads has shown that the existence of firewalls, proxies, or limited bandwidth can bring a class lesson using computers to a standstill. To mitigate these technology problems, SmartGraphs activities run directly in any modern Web browser without the use of Java, plug-ins, or software installation (with one exception: the use of sensors in SmartGraphs calls up an invisible Java applet). Our goal is to make SmartGraphs activities easy to use, so teachers will not need technical support staff to make the software run.

SmartGraphs activities will soon save data during a session so that students' predictions, graphs, open-ended answers, screenshots, and multiple-choice responses can be reported at the end of a lesson. These reports of student work could be emailed to the teacher or printed for teachers to use when assessing student performance.

One Concord Consortium project, the Innovative Technology in Science Inquiry Scale Up project (see pages 8-9), already allows teachers to customize existing exemplary activities directly within a Web browser using a template. The SmartGraphs project is expanding this type of Web browser authoring environment for teachers to permit not only textual or graphical changes, but also the capability of teachers to scaffold questions and add hints to their lessons, as illustrated in the Boiling Water activity. Eventually teachers will be able to create new SmartGraphs lessons from scratch. As authors outside the Concord Consortium create lessons, more and more free activities will be available, which will be distributed through a project portal where teachers can select and assign specific activities to their classes.

Research in Classrooms for the Future

During the 2011-2012 school year, six to eight physical science lessons will be tested in Pennsylvania as part of a randomized experimental trial with several dozen teachers who are part of the state's Classrooms for the Future (CFF) initiative. (CFF has provided more than 140,000 laptop computers to high schools across Pennsylvania.) The hypothesis of the research study is that students who use SmartGraphs will achieve more of the key learning goals in the physical science unit than students in comparison classes where SmartGraphs activities are not used. Will SmartGraphs make students smarter about graphs? We think so.

Learn more

Visit our website in the coming months to find free activities using innovative software to help students learn graphs and the concepts represented in graphs. Please contact us at smartgraphs@concord.org if you would like to be on our email list.

SmartGraphs
http://concord.org/smartgraphs

Connecting Energy

Across the Curriculum

By Vanessa Svihla, Kelly Ryoo, Marcia C. Linn, and Chad Dorsey

Vanessa Svihla
(vsvihla@hotmail.com) is a Postdoctoral Scholar at the University of California, Berkeley.

Kelly Ryoo
(khryoo@berkeley.edu) is a Postdoctoral Scholar at the University of California, Berkeley.

Marcia C. Linn
(mclinn@berkeley.edu) is Professor of Cognition and Development at the University of California, Berkeley.

Chad Dorsey
(cdorsey@concord.org) is President of the Concord Consortium.

The importance of energy and energy use is evident in all corners of our lives. From the food we eat to the cars we drive, energy plays a central role in our political and social lives. Similarly, energy is one of the most central ideas in science. The flow and transformation of energy ties together concepts across all disciplines.

Many existing science curricula present a disjointed view of this vital aspect of energy, however. Students encounter science and energy concepts in isolation, making it difficult or impossible for them to build an appreciation for how energy bridges topics and links ideas. New tools and integrated curriculum units developed at the University of California, Berkeley and the Concord Consortium are aimed at helping students make these critical connections.

The Cumulative Learning using Embedded Assessment Results (CLEAR) project, funded by the National Science Foundation, is studying the effects of these tools on sixth and seventh grade student understanding of energy. Topics include thermodynamics, plate tectonics, global climate change, and photosynthesis. Students are encouraged to build on their ideas about energy as they encounter the concepts in multiple activities.

The activities are presented in the Web-based Inquiry Science Environment (WISE), which provides scaffolding and embedded assessment (Figure 1). Students depict and process their understanding of energy relationships using a unique diagramming tool called MySystem being developed by the Concord Consortium and the University of California, Berkeley. An open source software tool for creating simplified systems diagrams, MySystem enables students to use icons (e.g., sun, plant, chloroplast, and more) connected by arrows to represent energy transfer and transformations within a system (Figure 2). Students can add color to the arrows to distinguish different types of energy or make the arrows wider or narrower to represent differing rates of energy flow. They can also indicate energy transformations and annotate icons and arrows to add more detailed information. For each diagram, students write a related narrative—called an Energy Story—as a written account of the energy within their system. These stories provide alternate representations to scaffold student understanding and additional artifacts for formative assessment of student learning.

Research results

Throughout the CLEAR curriculum, assessments, activities, and professional development are aligned using Knowledge Integration (KI) patterns and principles. KI is a constructivist view built upon 25 years of science education research[1,2]. Teaching from a KI perspective involves eliciting and adding to students' ideas about scientific phenomena, scaffolding the use of evidence to distinguish relevant and normatively accurate ideas from others, and helping students integrate ideas into promising explanations of scientific phenomena.

Students' Energy Stories and MySystem diagrams from the seventh grade photosynthesis unit were scored using

Figure 1. The Web-based Inquiry Science Environment (WISE) scaffolds student learning with inquiry maps, visualizations, and embedded assessment.

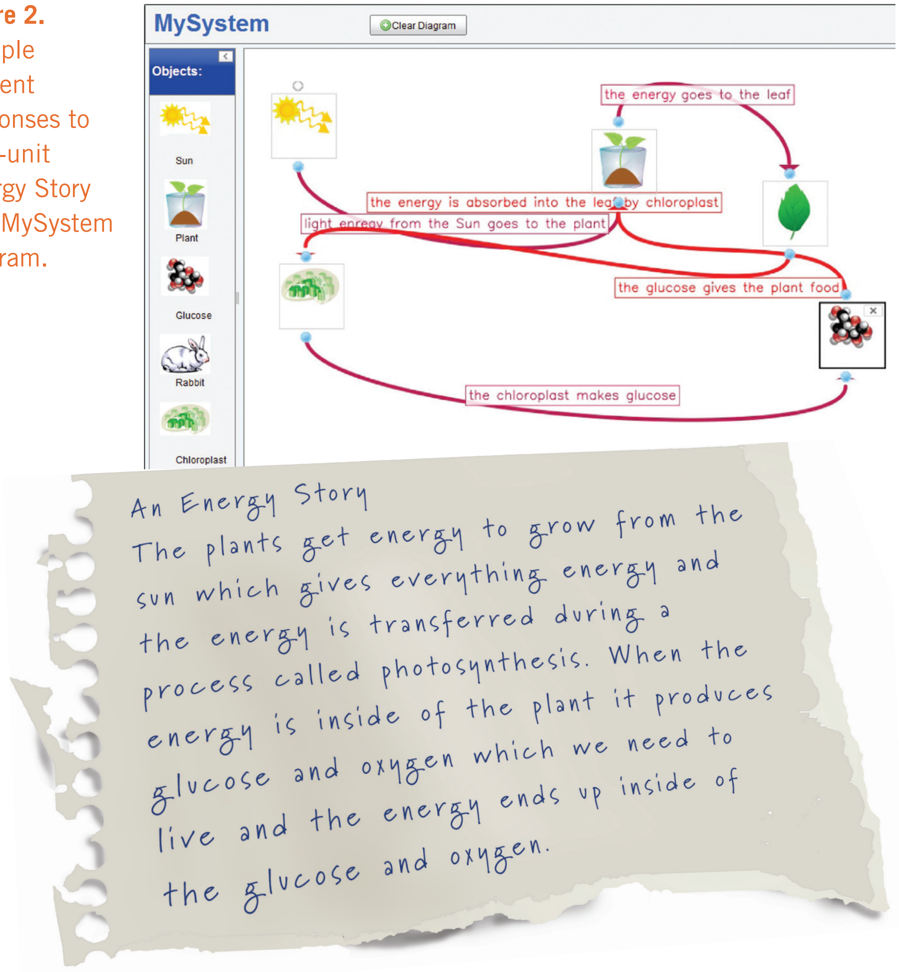


Figure 2. Sample student responses to post-unit Energy Story and MySystem diagram.

KI rubrics. Higher scores indicated that students made more scientifically valid links between energy ideas in their explanations. On the pre-unit Energy Story assessment, most students presented either irrelevant ideas or normative, isolated ideas without any scientifically valid links. Only a few students explained that plants create glucose using light energy or that energy is transferred from the plants to other living organisms. None of the students explained energy transformations at the molecular level. Using MySystem diagrams on the pre-unit assessment, most students provided non-normative ideas about the flow of energy in photosynthesis by connecting irrelevant objects, such as the rabbit and the sun icons.

We found significant learning gains in student understanding of the complex roles of energy in photosynthesis in their Energy Stories and MySystem diagrams. On the post-unit assessment, student narratives presented a more coherent explanation of how energy is involved in photosynthesis. Seventy percent of the students made the energy transformation link that light energy is converted into chemical energy in the chloroplast. Many students included details about the role of light energy in breaking up carbon dioxide and water molecules in their Energy Stories.

One student said:

"Plants get their energy from the sun. The sun shines down on them and breaks up the CO_2 and H_2O and they combine to make glucose, a basic sugar plants use to get energy."

Another seventh grade student wrote this detailed description:

"The sun rays come into the plant and the plant's chlorophyll absorbs the sun's energy, water, and CO_2. The sun energy breaks down the CO_2 into smaller molecules. Then the molecules combine to make oxygen and glucose. We breathe in the oxygen and breathe out CO_2 which is remanufactured into oxygen again. The plant uses the glucose as food to grow. Then an animal eats it and the process starts over again."

Students also used MySystem diagrams on the post-unit assessment to create more accurate representations of the flow of energy in photosynthesis with elaborated explanations on the arrows.

Conclusion

Our research shows that the combination of Energy Stories and MySystem diagrams gives students multiple avenues for clarifying their thinking. One teacher remarked that her students could gain a far deeper understanding of plate tectonics because they built on earlier ideas:

"I'm making sure that they understand what's going on in our earth that drives the plates. They tell me how heat takes energy through the earth, so they're using the information they learned in the thermodynamics unit."

The CLEAR project is helping students make connections—the cumulative effects of studying energy concepts throughout multiple curriculum units are paying off.

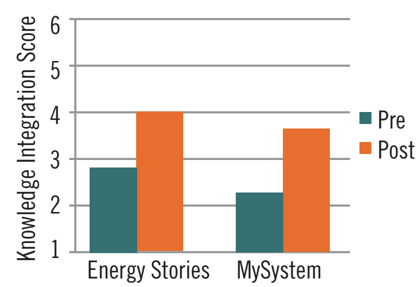


Figure 3. Student performance was significantly higher on post-unit than pre-unit assessments using Energy Stories ($t = 15.68$, $p < .001$, effect size $= 1.62$) and MySystem diagrams ($t = 16.56$, $p < .001$, effect size $= 1.60$).

LINKS

CLEAR
http://concord.org/clear

WISE
http://wise.berkeley.edu

1. Linn, M. C., & Eylon, B.-S. (in press). Science learning and instruction: Taking advantage of technology to promote knowledge integration. New York: Routledge.
2. Slotta, J. D. & Linn, M. C. (2009). WISE science. New York: Teachers College Press.

Blogging About
Breeding Evidence

By Chad Dorsey and Frieda Reichsman


Chad Dorsey
(cdorsey@concord.org) is President of the Concord Consortium.


Frieda Reichsman
(freichsman@concord.org) directs the Geniverse project.

Vocabulary. Diagrams to label. More vocabulary. More diagrams. For students and adults alike, this is the traditional vision of biology class. But biology is much more than static words and drawings: it's a living product of the work of many individuals conducting investigations and discussing the results.

In the rapidly changing world of genetics and bioinformatics, the dynamic, evolving nature of scientific discovery is clear. DNA sequencing data has continued to double every 14 months for the past 20 years. Massive databases are filled with partially analyzed data generated in high-volume experiments. These data provide new opportunities for active science to take place. Bioinformatics researchers can conduct experiments simply by examining mountains of publicly available data for clues to unanswered questions.

The Concord Consortium's Geniverse project, funded by the National Science Foundation, is a collaboration with the Jackson Laboratory, the Maine Mathematics and Science Alliance, TERC, and BSCS. Geniverse extends the Concord Consortium's long history of genetics software to build on these two ideas—the importance of understanding biology as an active, experiment-driven science and the new dynamics created by large amounts of bioinformatics data. Students conduct breeding experiments within a fanciful game-based environment and interact within an online community of fellow student scientists.

Enter the narrative world of dragons

Students work both individually and in lab groups to solve cases in a world of dragons and their model organisms called drakes, a relationship patterned after the use of mice as model organisms for studying human genetics. For example, students may encounter a disease among the dragon population and be given the task of determining where a gene for the disease is located. Students breed drakes, examine breeding statistics, and draw conclusions. While students are guided toward the right process, the game doesn't simply tell them the right answer. Instead, students must discuss and convince each other that their conclusions are correct.

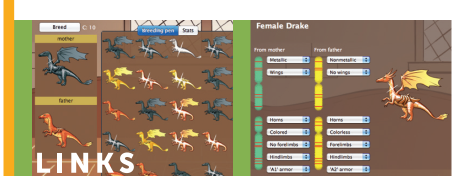
Members of a lab group gather evidence by doing a set of breeding experiments necessary to support their idea, then they post an experimental claim to the group blog. Students submit these claims through a scaffolded form that requires them to provide three important elements for their argument: 1) their claim, 2) supporting experimental evidence, and 3) their associated reasoning.

A scientific community

Blogging helps students develop scientific argumentation skills as they share ideas and comment on fellow student scientists' claims. They can link to breeding records or upload annotated screenshots as direct evidence to support their claims. Students engage in the joint development and adoption of ideas found within a thriving scientific community.

Students enter the game as trainees in the Global Guild of Geneticists, working their way through the ranks to become apprentices, journeymen, or masters as they solve increasingly complex challenges that require them to understand and apply the concepts of modern genetics. As students complete more challenges, the data from their experiments mounts, just as in current bioinformatics studies. Students who gain proficiency and enter into more open-ended challenges also gain wider access to this store of past data, so that they can eventually conduct experiments simply by filtering, examining, and processing these data themselves.

Currently students can examine the processes of inheritance and the cellular-level interaction of chromosomes during meiosis. Future strands of the game will allow students to extend their breeding experiments to involve DNA sequencing and expand the experimental database to permit analysis of DNA sequence and protein data. By providing a scientifically faithful, full-featured environment for examining genetics, Geniverse places students in the center of the action, helping them to experience biology as a much richer enterprise than yet another vocabulary quiz.



Geniverse
http://concord.org/geniverse

Innovator Interview:

Dewi Win

(dwin@concord.org)

Q. You were at the Concord Consortium from 2004 to 2005. Tell us about that.

A. I was a math major in college and was always interested in integrating video and other technologies with education. I worked at EDC developing online professional development for math teachers. When that grant ended, I came to the Concord Consortium, where I also developed online courses for math teachers with the Seeing Math project. The courses are really powerful and include interactives, classroom video, and expert commentator video. I'm thrilled that they continue to be offered at PBS TeacherLine[1] and Teachscape[2].

Q. What did you do between 2005 and 2009?

A. After Seeing Math ended, it dawned on me that it had been a while since I'd been in the classroom, since I had knowledge fresh in my head about real classroom issues, what students struggle to learn. So I went to a small teacher certification program based at the Parker Charter Essential School, then taught middle school math for four years.

Q. You've been back with the Concord Consortium since 2009. What excites you most?

A. The people, the projects, the technology we use—it's all really exciting. My own kids have been involved in pilot tests here—my seventh grade daughter came for a three-day engineering workshop and built a model solar house. My fourth grade son tested the evolution software, which is game-like and really engaging. They both love it here. I do, too.

Q. What do you see in the future of teaching math using technology that excites you?

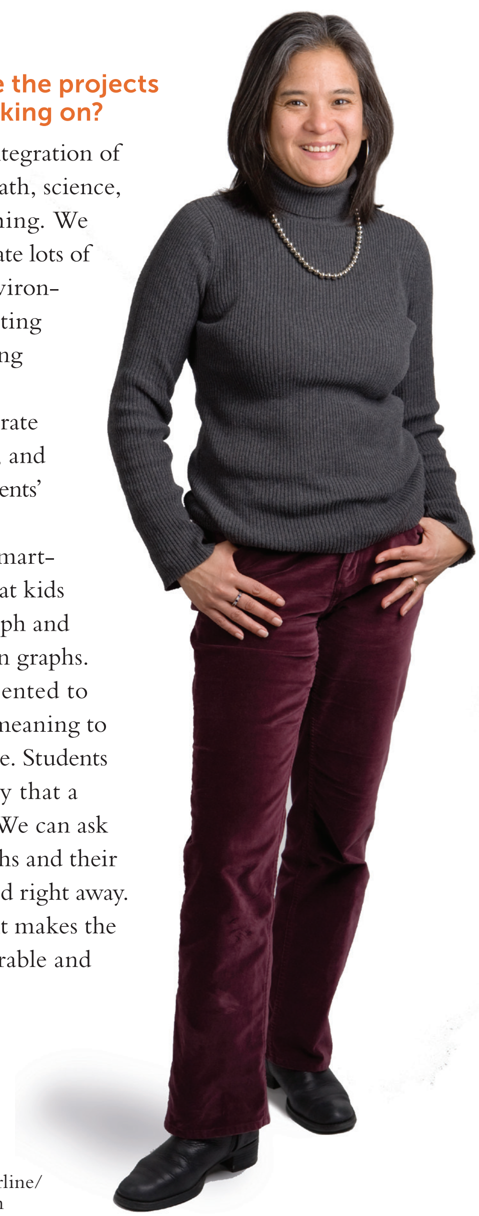
A. When I first taught years ago, we didn't even have computers. Now there are so many opportunities—from SMART boards to clickers to applets available with a simple Google search. But technology comes with its costs—kids play and there's the overhead. A carefully laid plan can fall by the wayside if the computer lab is already reserved. That's my biggest dream for future technology use—no barriers!

Q. What do you like to do outside of work?

A. I injured myself playing tennis, so I'm looking for new sports. I'm taking a tap dancing class. My kids beat me in ping pong. And for fun I drive my kids around to their fun activities.

Q. Have you done anything particularly unusual you want to share?

A. I've traveled to very remote places—Machu Picchu, Irian Jaya, Iguazu Falls. I saw the Taj Mahal as a little girl. My parents were both professors, so they had summers off and we traveled all the time. I hope to visit Sulawesi soon to see an exchange student who lived with us last year. I love experiencing other cultures.



Q. Can you describe the projects you're currently working on?

A. SmartGraphs is an integration of all the things I love—math, science, software, students, teaching. We have the ability to integrate lots of different tools in one environment. We've been collecting data with probes for a long time. Our software can now read that data, generate questions about the data, and evaluate whether the students' questions are on target.

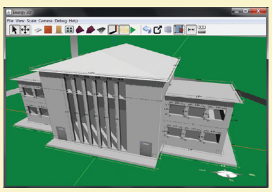
I think what makes SmartGraphs so powerful is that kids can interact with the graph and they can create their own graphs. Graphs are not just presented to them. The graphs have meaning to them—they're more alive. Students can experiment in a way that a textbook doesn't allow. We can ask questions about the graphs and their predictions are confirmed right away. If software is engaging, it makes the experience more memorable and exciting for kids.

1. http://www.pbs.org/teacherline/
2. http://www.teachscape.com

The Concord Consortium
25 Love Lane, Concord, MA 01742

NEWS FROM THE
CONCORD CONSORTIUM

Design, Build, and Test a Model House



Students can design and build their own houses and learn about energy efficiency with our new Energy3D software, developed by Drs. Saeid Nourian and Charles Xie. This WYSIWYG (What-You-See-Is-What-You-Get) computational building science laboratory allows users to design a house in three dimensions and then evaluate its environmental friendliness.

An alpha version is available at: **http://concord.org/energy3d**

The software's Blueprint Wizard automatically deconstructs a 3D structure into 2D pieces, determines which pieces are on the same plane, generates a layout of all planes, calculates the necessary lengths and angles, and prints them on a sequence of pages. Each piece is numbered and annotated with enough calculated geometric information to guide students to create their structure from paper or foam board. The deconstruction process is animated, so students can see the relationship between a house and the blueprint.

Chad Dorsey to Speak at NSTA Conference

Chad Dorsey, President of the Concord Consortium, will be a featured speaker at the National Science Teachers Association National Conference in San Francisco. Meet Chad and get free science activities on March 10 from 9:30-10:30 a.m. in Room 135 of the Moscone Center. Also, mark your schedule now to attend the Concord Consortium's other staff presentations throughout the conference. Coming out to California early for the Cyberlearning Tools for STEM Education (CyTSE) Conference? We'll see you there, too.

SproutCore Enables New Web Innovations

The Concord Consortium has started using the SproutCore JavaScript framework, an open source Web-based application framework backed by a growing community of developers and companies. Originally started by Apple, SproutCore is behind Apple's online Mobile Me and iWork.com services. Modern Web-based technologies have the ability to make it easy for teachers and students to use our interactive models and activities. With a growing collection of JavaScript methods and new HTML "tags" that are increasingly supported by modern browsers, Web-based technologies offer a wealth of promising new possibilities.

In order to build an integrated collection of models and content that make use of these possibilities and save learner data, we at the Concord Consortium need a higher-level framework upon which to build. SproutCore contains many of the parts needed for this integrated collection, handling many differences between Web browsers and providing a "data persistence API" that lets us make complex applications run easily in a browser. Most notable is how we can program reusable views of a page that are backed by a shared data model—this enables us to create a wide variety of Web-based resources all using a common set of simulations or pedagogical tools.

SproutCore is relatively new and constantly improving. We look forward to many of the planned features and tools, and are also active participants in the open source SproutCore community ourselves.
http://sproutcore.com

Concord Consortium Resources Featured in Mashable

Mashable.com has featured Concord Consortium resources in two recent articles: *8 Ways Technology Is Improving Education* and *10 Free Online Resources for Science Teachers*. Check out scores of activities in our Activity Finder at **http://concord.org/activities.**

Editor: Chad Dorsey | Managing Editor: Cynthia McIntyre | Design: Jan Streitburger | www.concord.org
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