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**The Concord
Consortium**

Perspective:

Defined by Data

By Chad Dorsey

There is little denying that we live in a world defined by data. When historians view this era, the explosion of data and the ways in which it shapes our lives may turn out to be one of its most distinctive characteristics. The growth is staggering: the amount of worldwide data doubles every two years.

This data revolution is inexorably entering all aspects of our modern lives. New approaches to gathering and analyzing data define winning political candidates, generate new techniques for tracking criminals and drive decisions about responding to disease outbreaks. Data produced by our everyday actions inform everything from television programming to product development. Data and its proliferation touch our lives in countless ways, from viewing an online ad or considering the privacy implications of Internet traffic monitoring.

This data revolution has immense ramifications for education. The students we are preparing today will enter a world very different from the one in which we were educated. They will be thrust into a small world filled with big data, and will need to be able to succeed at careers whose titles don't even exist today. They will need the knowledge to comprehend the math and science that drive these data and the skills to navigate oceans of information fluently. As this future becomes clearer, we are beginning to understand how we might prepare students for this new, data-rich age.

In many ways, however, the most important revolutions spurred by big data are already present. Today's rapidly evolving technology and recent advances in research on teaching and learning usher in a new, deeply digital realm of education. While any use of data must also address concerns about protection and careful application, when taken in total, the entrance of data offers a wealth of opportunities within education: redefining the places where education occurs, the ways we understand student performance and the nature of the underlying pedagogy.

Places of learning

As technology continues to break down barriers, new opportunities for learning open up across time and space. With ubiquitous access to technology—from desktop computers to smartphones—learning can happen in places that were scarcely imaginable before. Divisions between formal and informal education fade away as we access learning on the go, providing new opportunities to understand how learning evolves in this fluid world.

Our Learning Everywhere initiative is beginning to examine this question by offering connected learning opportunities that complement and extend museum experiences into after school or at-home settings. Students can design an energy-efficient building in an after school program, then modify and test it at a museum-based design competition. Or they can begin an investigation in a museum and continue the experimentation with models and simulations they can access from home. By gathering in-depth data on the use of these materials, we will be able to see precisely how learning takes place across these environments.

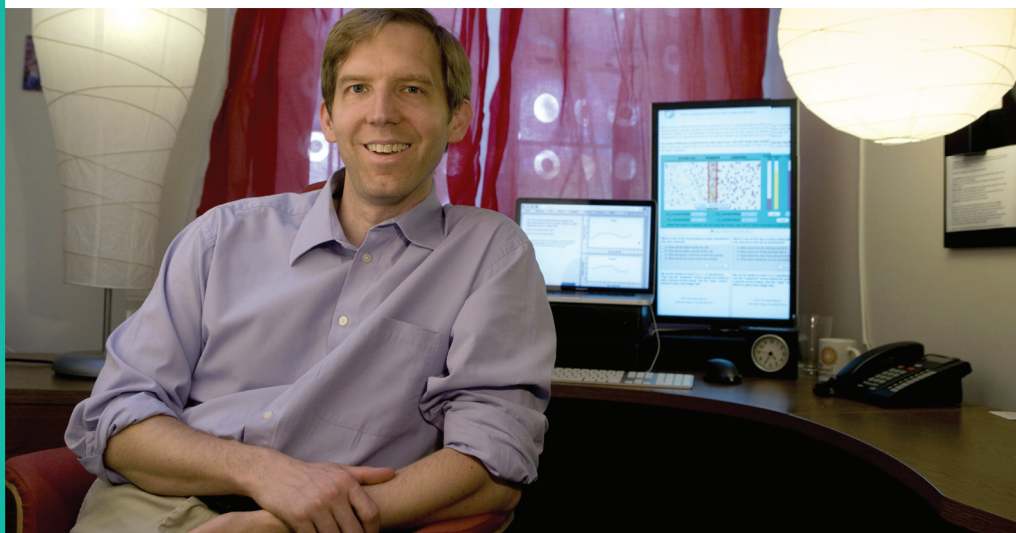
Process of learning and design

Through the use of data and its applications via technology, we are able to gain new insight into processes and concepts. Understanding how students learn engineering and design skills is vital to knowing how to increase student interest in engineering. But these skills are difficult to characterize and even harder to quantify and measure. New technologies offer the opportunity to gather huge data sets, however, and bring forth a new dimension of understanding.

Our Energy3D software, developed by Charles Xie and Saeid Nourian, is a computer-aided design environment with powerful data-driven features. The software offers students a simple and engaging way to create and test energy-efficient house designs. At the same time, it generates detailed logs of the design process that unfolds with every mouse click. These logs are gold mines of unprecedented detail about how students undertake and learn the process of design. They have already uncovered many novel insights about student design patterns and gender-specific design processes. In a new project, we are building next-generation analysis tools to characterize the data from these design processes and extend the experiments to thousands of students at a time, a potential transformation of engineering education propelled by the data revolution.

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Students will need the knowledge to comprehend the math and science that drive these data and the skills to navigate oceans of information fluently.



Performance assessment

The potential that data offer for understanding student learning is by no means limited to the process of engineering and design. Data hold great potential for assessing student learning, both assessment of content understanding and more complex assessment of the practices of science and engineering. By bolstering tools such as models and simulations with logging capabilities and carefully designing opportunities for learning and assessment, we can gain new views into student learning that can be much more informative than current, traditional assessments. With technology, we can peer over a student's shoulder virtually and observe as she undertakes the process of scientific inquiry.

These capabilities offer the potential for designing performance assessments that truly capture the essence of these scientific practices. We are now working with some of the country's leaders in content learning and assessment design to create the next generation of performance assessments, aligned with the Next Generation Science Standards. Big data is setting the stage for an entirely new paradigm of assessment. The multiple-choice test may one day join the overhead projector and mimeograph machine as a relic of a former era.

Pedagogical opportunities

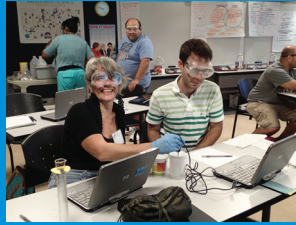
Teachers make implicit use of data all the time. They watch students, grade papers and ask questions that inform them about student thinking and understanding. These pedagogical methods are tried and true, but incomplete: student learning happens through many actions that are invisible, allowing many “teachable moments” to slip by unnoticed in the hidden fabric of daily learning. As we move toward new forms of learning made possible by digital technology, data offer increasing opportunities to identify and make use of these moments.

By capturing data about nascent student learning and providing those data to teachers as they make decisions about how to usher learning forward, the teaching experience evolves from a series of educated guesses to a process of informed decisions. Already, our software is collecting and providing near real-time data on student performance, carefully honing data sources to increase insight for teachers. Through judicious application of technology, we can suggest promising pedagogical paths for teachers—from helping them understand the thinking of their students mid-class to providing a detailed picture of the misconceptions their students harbor.

Possibilities for the future

With the rush of new data come huge and unforeseen opportunities. Many of these can be anticipated, but not yet fully envisioned. Mobile devices generate huge data sets that could be tapped to understand how learning evolves. Apple's new iPhone contains an entire chip devoted to using motion data in unexpected ways, from sending information about your activity levels to health apps to remembering your location when it senses you parking your car. Other smartphones contain up to a dozen sensors, from gyroscopes to barometers to radio and magnetic field sensors.

With these devices, students worldwide now carry mature mobile laboratories in their pockets, generating data whose promise for learning remains almost entirely unrealized. Similarly, data about learning will evolve in new and unexpected ways as technology continues to proliferate in the classroom and beyond.



Rhode Island Students Score High on Inquiry

By Frieda Reichsman and William Day

The Rhode Island Technology Enhanced Science (RITES) project has been fomenting change in educational and institutional practices, and most importantly, in student learning across the small but diverse state of Rhode Island since 2009. Funded by the Math and Science Partnership program at the National Science Foundation, the RITES project is a unique collaboration between Rhode Island institutions of higher education, public schools, the state Department of Education and the Concord Consortium.



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Figure 1. Each investigation—addressing one or more learning goals in Earth and space science, life science and physical science—consists of a sequence of activities that engage students in collecting and analyzing data using embedded simulations, sensors and more. Activities include embedded graphical data collectors, interactive models and tables, drawing tools, prediction graphs and multiple-choice and open-response questions.

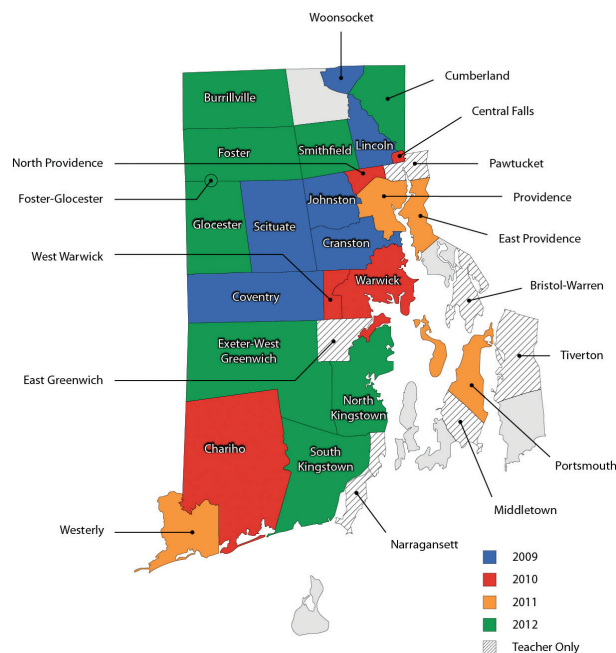
Through the RITES project, teachers are able to offer their middle and high school students an exciting collection of free, highly interactive online educational resources called investigations (Figure 1), created using Concord Consortium’s RITES software. The investigations are assembled, developed, customized and evaluated by teams of Rhode Island faculty, teachers and educational experts who work in pairs on discipline-specific resource teams. Students of teachers participating in the project have achieved significantly higher scores on statewide inquiry assessments than their peers taught by teachers who were not part of the project.

Each spring a new cohort of Rhode Island school districts has been recruited for a two-year period of formal participation. Over the course of the project’s five-year lifespan, most Rhode Island school districts have joined the project (Figure 2). And thanks both to new districts and veteran districts, the use of RITES curriculum materials has steadily increased (Figure 3).

Web portal

Students and teachers access investigations through a Web portal that saves and tracks student progress. A class can begin an investigation one day by reading, answering questions and collecting experimental data, and return to the investigation the next day, picking up where they left off. The portal also allows students, teachers and RITES researchers to gauge student progress. Teachers with varying access to technology in their classroom—from one computer per class to one computer per student—can successfully use the investigations by accessing either collaborative or individual student modes in the Web portal.

Figure 2. Each year, a new cohort of Rhode Island school districts has been recruited. Teacher participation was also open to districts that had not formally joined the project, indicated by the striped districts. The project has achieved its target of reaching a majority (approximately 75%) of the science teachers in 75% of the state’s school districts.



Opportunities for educators

RITES offers educators across the state multiple ways to get involved—from participating in summer short courses and presenting at project conferences to developing student investigations and leading professional development courses as members of resource teams.

Teachers learn how to use the investigations to foster inquiry during two elective summer courses in each of their two consecutive years of participation in RITES. Each short course focuses on a specific investigation, giving teachers time to reflect on addressing student misconceptions and enhancing student engagement and discourse. Course instructors, usually the authors of the investigation, model best practices in instructional methods. Teachers work collaboratively with colleagues from their own and other Rhode Island school districts and share strategies for reaching all learners.

on their practice. A poster session is held at the spring conference for teachers to share their research.

RITES partnership model

NSF’s Math and Science Partnership program calls for a genuine working relationship between higher education faculty and classroom teachers. A hallmark of our approach is that within each discipline-specific resource team, we pair a higher education faculty member with a master classroom teacher to develop an investigation and a corresponding summer short course. In contrast to a top-down approach, RITES puts the expertise of classroom teachers on equal footing with the deep content knowledge of college and university faculty.

While lecture-style teaching is predominant in many college courses, master classroom teachers in middle and high

At the RITES spring and fall conferences, teachers exchange ideas and showcase their students’ learning as well as their own. They receive curricular and pedagogical support through a series of breakout workshops ranging from “Engineering Practices in the Science Classroom” to “Thinking Like a Scientist.” They also lead sessions and present to one another, using student work and other classroom data to reflect on student learning and

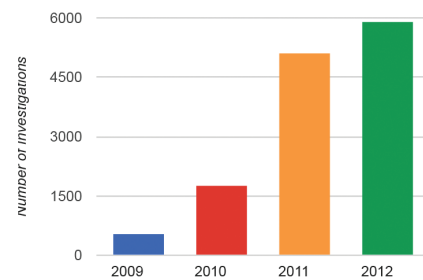
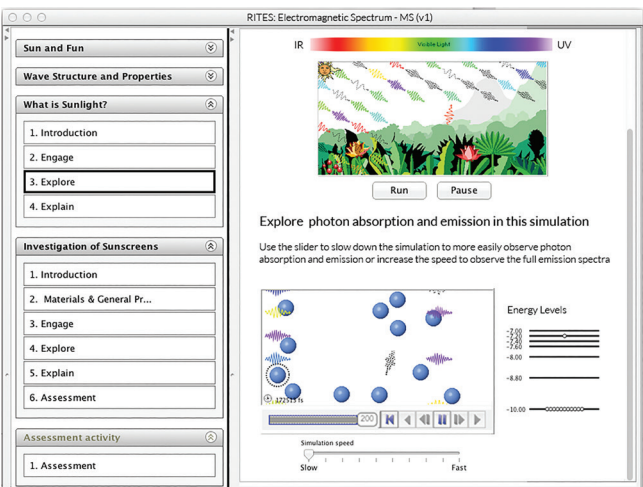


Figure 3. The number of investigations used by students has risen due to new districts joining and to the continued use of RITES investigations by districts that have completed project training.

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school often use much more interactive and pedagogically modern approaches: fostering collaborative classrooms, supporting small group work and utilizing a variety of scaffolding techniques such as eliciting student thinking prior to addressing a topic, as well as “jigsaw” and other exchanges between small groups of students. Bringing deep content knowledge together with deep pedagogy means that both members of a pair have expertise to share.

An overarching goal of the expertise pairing is to build sustainability, so the program’s effects continue post-funding. RITES funding has established permanent tenure-track faculty positions at the University of Rhode Island and Rhode Island College that bring together education, science and technology with the mission to foster a two-way connection between higher education and classroom teaching.

Positive effects on educators and education

A team of RITES collaborators researched the effects of resource team participation

by surveying the individual team members on their experience with RITES materials and course development. Ninety percent of classroom teachers and 80 percent of higher education faculty responded that working with a resource partner was an enriching and valuable experience. Faculty and classroom teachers both responded that they would like to engage in similar professional development efforts in the future, and the vast majority of college and university faculty indicated that the approaches to learning in the investigations and summer courses could be adapted for use in their courses. Teachers reported that they were increasingly using technology in their classrooms and many were now seen as a science education resource in their schools. Many participants reported that one year later they still had regular communication with their partner.

Positive effects on students

In 2012, RITES researchers compared the performance of students of RITES and non-RITES teachers on the New England Common Assessment Program’s (NECAP)

standardized tests, which are given in 8th and 11th grades. The researchers targeted three RITES districts for which data were available at the time. Since the content questions on the test change each year and are not valid for comparison purposes, the researchers focused on the science inquiry portion of the test. The results indicate that students of RITES-trained teachers scored higher on the science inquiry tasks than students of teachers who did not receive RITES training (Table 1). Significant differences for the RITES program were found in an urban school district (Providence) serving predominantly African American and Hispanic students, as well as in urban ring communities (Cranston and Johnston). The results were statistically significant even after controlling for the effects of poverty, minority group membership, special education and Limited English proficiency status.

As more schools are able to harness their demographic and NECAP data, RITES researchers will continue to study additional Rhode Island districts.

Table 1. The summer short courses were first taught in the summer of 2009. The data shown for 2010 are from the NECAP tests administered in the following academic year. The results showed no significant differences between students of RITES and non-RITES teachers. In 2011, following the second summer of the two-year training, students of RITES-trained teachers obtained significantly higher scores, suggesting either that the changes to teacher practice were manifest only after the full training, or that the evolving RITES professional development model was maturing, or both. In 2012, following the first summer of participation for Providence and Cranston, student achievement was significantly higher for students of RITES teachers. These data reinforce the idea that the RITES professional development model was evolving to support greater teacher improvement following the first year of teacher participation.

Grade 8 Results — NECAP Inquiry Subscore Improvement RITES vs Non-RITES												
District	2010				2011				2012			
	Total	RITES	Δ	p	Total	RITES	Δ	p	Total	RITES	Δ	p
Johnston	295	101	-4%	n.s.	238	182	20%	<0.01				
Cranston									808	46	29%	<0.001
Providence									1755	1387	106%	<0.001

Total = Total number of students tested
RITES = Number of RITES students
Δ = Percent improvement between RITES and non-RITES students
p = Significance of the p-value (n.s. is not significant)

Grade 11 Results — NECAP Inquiry Subscore Improvement RITES vs Non-RITES												
District	2010				2011				2012			
	Total	RITES	Δ	p	Total	RITES	Δ	p	Total	RITES	Δ	p
Cranston	813	149	-1%	n.s.	853	191	20%	<0.001				
Providence									1435	1053	10%	<0.05



LINKS

RITES portal
<http://investigate.ritesproject.net>

Monday's Lesson:

Dragons in Social Media

By Trudi Lord and Paul Horwitz

The power and appeal of social media like Facebook and Twitter is tremendous, especially to young minds. We've found a way to harness that fascination and turn it to learning!



Whyville is a popular social networking environment intended to give tweenagers (the typical "Whyvillian" is 8–15 years old) the opportunity to learn STEM concepts through collaboration and exploration. In a project we call "GeniVille," we incorporated Geniverse, a Concord Consortium computer program designed to teach genetics, into Whyville.

The genetics game in Whyville consists of increasingly difficult challenges involving breeding dragons for traits that help them retrieve specific treasures. For instance, a winged dragon can fly up to snatch a coconut from the top of a tree, while a dragon with arms, legs and a spike on its nose can dig for a magic chalice. Whyvillians create such dragons through selective breeding, and proudly "own" them as pets, but only if they have mastered the underlying genetics.

The dragon activities in Whyville were designed for children working unsupervised, but they are also a valuable adjunct to a middle school life science unit on genetics. The content is aligned to the Next Generation Science Standards

(NGSS) for heredity: inheritance and variation of traits. We can't think of a better place to take a virtual field trip—and admission is free!

How to prepare

It's easy! If you're a first-time user, go to the Concord Consortium GeniVille website, and then follow the Whyville link to register as a teacher by clicking the Join Now button. Once Whyville verifies you as a teacher, you'll have access to a personalized URL where your students can register. Their accounts will be tied to you in your Class Roster.

If you've already started Mendelian genetics in class, head straight to the Dragon Castle using the Destination dropdown menu on the lower left of the Whyville home page. Otherwise, begin with a brief overview of chromosomes, genes and traits.

Field Trip: Day 1

Have students log onto their own computer, go to the Dragon Castle and begin with the Tutorial. Then, working in pairs, students



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should go to the Dragon Book (linked from the Tutorial or accessible from the student's satchel icon at the top of the screen) and try the first three challenges, where they explore the inheritance of simple dominant and recessive traits. Students can move through the different dragon lairs together, scoping dragon chromosomes and searching for the alleles they need to produce a winning dragon. Encourage them to chat—online and in person—about their choices.

If students get stuck, have them visit the labs in the Dragon Book. In these game-like activities, students can change a dragon's genotype and see its phenotype change or watch meiosis in action. The labs help students learn how to identify lair parents with the gametes needed to produce treasure-hunting offspring. When students return from their field trip by logging out of Whyville, start a class discussion on dragon traits and how they are inherited.

Field Trip: Day 2

Students return with their buddies to Whyville, ready for more advanced challenges focused on incomplete dominance, sex linkage and polyallelic traits. There are 9 lairs and 21 labs for experimentation and inquiry.

Your students can become Whyvillian dragon geneticists and discover that social media and STEM learning go hand in wing. Join them, and let us know how their online adventures go. Send your feedback to dragons@concord.org.

LINKS

[GeniVille](http://concord.org/geniville)
<http://concord.org/geniville>
[Whyville](http://whyville.net)
<http://whyville.net>

Molecular Modeling

in Cyberspace

By Chad Dorsey



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of the Concord Consortium.

The 2013 Nobel Prize in Chemistry was awarded to Martin Karplus, Michael Levitt and Arieh Warshel “for the development of multiscale models for complex chemical systems.” According to the secretary of the Royal Swedish Academy of Sciences, “This year’s prize is about taking the chemical experiment to cyberspace.”

Our Molecular Workbench software was developed over the past decade by Senior Scientist Charles Xie, whose own postdoc co-advisor Georgios Archontis was advised by none other than the new Nobel Prize winner Martin Karplus! Georgios was an early contributor to CHARMM, a widely used computational chemistry package. Charles collaborated with both Georgios and Martin Karplus on a study that used CHARMM to calculate binding affinities among biomolecules involved in the metabolism of glycogen.

Molecular Workbench (MW) is built on the fundamental physical principles that govern molecular dynamics. This ensures the accuracy and depth of the visual simulations, and many of its computational kernels were inspired by CHARMM. We’re proud of this legacy and honored by the academic genealogy. Now, with funding from Google, we’re transforming the Java-based Classic MW software to run on the Web using HTML5 and JavaScript. With this, we’re taking the chemical experiment to cyberspace, this time for education.

A microscope for the molecular world

Understanding the world around us is an elusive prospect. From events as simple as melting ice and boiling water to those as subtle and complex as the interplay between light and matter, mysterious rules and invisible processes seem to rule every aspect of life. Understanding science demands a thorough familiarity with them. Or does it?

Formulas and algorithms are perfect for experts already familiar with them. To students, however, they are a foreign language. More often than not, they obscure the phenomena they attempt to describe instead of making them more accessible. But this doesn’t need to be the case. Models and simulations can make the invisible visible and explorable for students, turning a mysterious and obscure world into one that is tangible, conceptually available and ripe for student experimentation—all without a single equation.

Transforming Molecular Workbench for the web

Our Classic Java-based Molecular Workbench has been making this possible for students for nearly a decade. In 2011, Google awarded the Concord Consortium funding to bring MW software to the next stage. Over the past two years, our Next-Generation MW project has worked to bring the already popular Molecular Workbench to a wider audience via the power of the Web, with a goal of exposing real-world phenomena for student learning through exploration. We have created a series of tools that allow students to experience both microscopic and macroscopic phenomena in new ways. These are part of a new generation of learning—web-based and accessible on all manner of devices—that will permit millions of students around the globe to investigate scientific phenomena and help redefine teaching and learning for years to come.

Molecular Workbench brings a stunning range of phenomena to students’ laptops and tablets. Students can investigate

fundamental molecular processes underlying everyday phenomena—from phase change to diffusion through membranes—and understand the variables that control them. Computational models unveil the interactions between light and matter, demonstrating how plants harvest light for photosynthesis or how different wavelengths of light interact with CO₂ in the atmosphere. Models of DNA reveal how encoded information is translated into the proteins that govern processes in all living things and how small mutations in this code can cause large changes, or no changes at all. Demonstrations of basic chemical reactions show how a single spark and a series of random molecular motions can result in an explosive cascade of molecular changes.

Macroscopic phenomena governed by fundamental physical equations are equally accessible using these same modeling engines. Molecular Workbench makes physical phenomena such as the motion of a pendulum or the vibration of a mass on a spring available for intricate investigations, with linked graphs that help expose the subtleties behind these seemingly simple systems. And other simulation engines make even more phenomena accessible. Students can also explore the motion of the planets, governed by the very same equations but on a vastly grander scale. Simulations inspired by Charles Xie's Energy2D software bring the world of fluid dynamics, energy and heat transfer alive, permitting students to see conduction, convection and radiation, and to perform experiments to understand engineering principles involved in concepts such as solar house design.

Simulations make these phenomena and many more available to students around the globe. Perhaps some day one of them will be inspired by Molecular Workbench to win a Nobel Prize in Chemistry—molecular modeling certainly has more awards in its future.

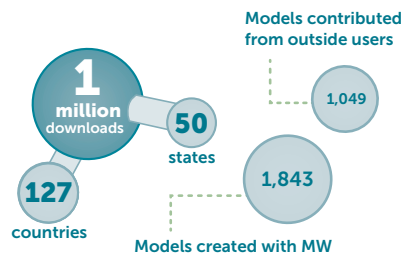


Molecular Workbench

1 million and growing

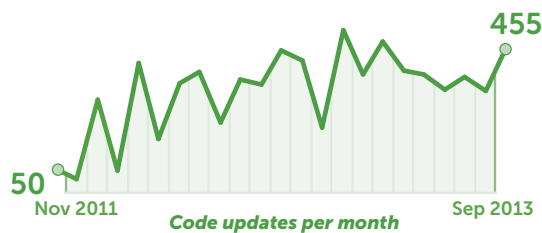
If you build it...

Molecular Workbench has been downloaded **over 1 million times**. We're on our way to reaching millions more students!



Developing for the future

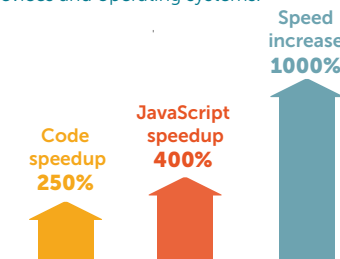
Thanks to **Google**, we're transforming our award-winning, Java-based Molecular Workbench to run on the Web using **HTML5** and **JavaScript**. This is the **Next-Generation Molecular Workbench** for the 21st century classroom.



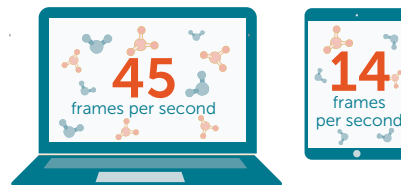
Lines of code: 50,475
Github commits: 7,216
User stories: 1,043

Speeding things up

We're **optimizing** for different devices and operating systems.



Optimized simulation speed for 200 atoms:



We've created almost **100,000 atoms** on the Web and we're making more all the time!

Developers, get the **open source** code¹ and join the conversation².

Key partners

With our collaborators, we're **embedding** Next-Generation Molecular Workbench simulations **throughout cyberspace**. Nearly 45,000 students have encountered these models in edX MOOCs.



Collaborate with us: nextgenmw@concord.org

¹ <https://github.com/concord-consortium/lab>

² <http://groups.google.com/d/forum/lab-models>

LINKS

Next-Generation Molecular Workbench
<http://mw.concord.org/nextgen>

Understanding Graphs

Step by Step

By Andy Zucker and Carolyn Staudt

To guide student learning, the Common Core State Standards for Mathematics and the Next Generation Science Standards emphasize instructional practices that require more than recalling facts or applying familiar procedures.



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Carolyn Staudt
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Why? Because increasingly teachers, parents, employers—all of us—expect students to become flexible thinkers and problem solvers who flourish in the face of rapid changes in the workplace, university and global society.

The new STEM standards pose challenging goals for students: making sense of unfamiliar problems, using tools strategically to solve problems and design solutions, constructing viable arguments and explanations, critiquing the reasoning of others and asking the right questions. For many schools, achieving these goals—which are more complex than old definitions of “basic skills”—will be difficult.

There are already reports (e.g., in New York and Kentucky) of students scoring significantly lower on state tests aligned with the new standards. It will take years for schools to update curricula, instruction and assessments, and for students to achieve these ambitious new STEM education goals. Our mission at the Concord Consortium is to use technology in deeply digital ways that transform education in support of the new standards.

Our free Web-based SmartGraphs and Graph Literacy activities help students make sense of graphs by providing questions that lead to understanding, step by step, and by showing students visual hints on the graph as well as explanations. Students interact with graphs by drawing on or annotating them using a computer mouse or touchscreen.

SmartGraphs

The new math and science standards assert that students should have a more fluent understanding of graphs. Students are already taught to graph points, lines and functions, but now they are asked to understand unfamiliar graphs in textbooks, newspapers and scientific journals. Whether students look at graphs about climate change, the national debt, planning for retirement or many other phenomena, we now have higher expectations that they can “read” these graphs and make sense of them, in the way they are expected to read unfamiliar texts.

Textbooks, it turns out, do not do a great job of teaching “graph literacy.” Decades of studies have shown that even undergraduate students studying science find it difficult to interpret unfamiliar graphs. Like mathematical formulas, graphs pack a great deal of information into a small space. They may look simple, but looks may be deceiving. Graphs often convey complex information, so students must develop general graph literacy skills.

We’ve created a suite of free activities that cover a wide range of graph-related topics. Plus, teachers or other curriculum writers can create their own activities by completing online forms without any special programming skills.

Graph literacy

Learning to read graphs is a skill that transcends any particular subject, just as learning to read is important beyond any one subject. For example, virtually all students, even those in upper elementary school, should be able to draw a graph representing simple motion, such as walking forward and backward at different speeds on a straight path. Understanding this type of position-time graph requires understanding the graph title, the axis labels, grid lines on the graph, what it means to connect points and so on—fundamental graph literacy skills that can be applied to any graph.

In one example, a student reads a short story about someone walking to the bank, to the store and back home again, and then, using a mouse or touchscreen, draws a graph representing that story. The student’s graph, in red, is then compared to the correct graph, in blue (Figure 1). Repeated trials, including visual feedback from SmartGraphs, provide students new ways to understand how a graph can represent a word story, and vice versa.

Figure 1. Connecting a story to a graph.

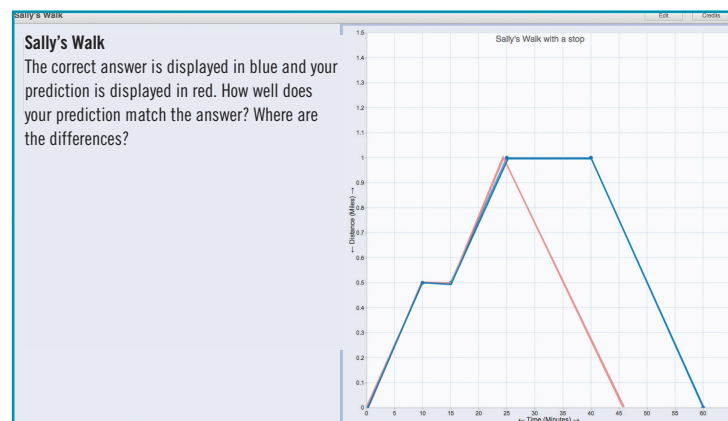


Figure 2. Labels help students understand the meaning of a graph.

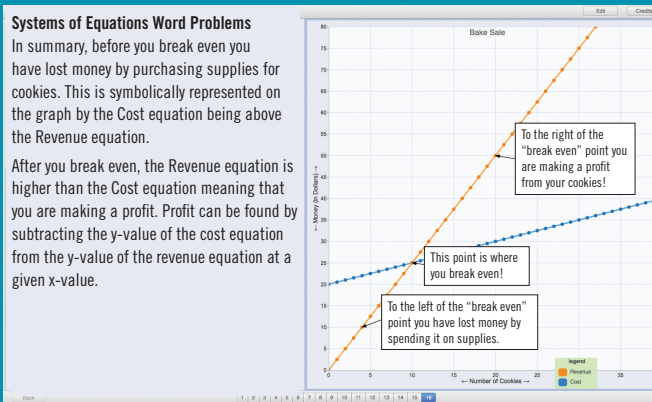
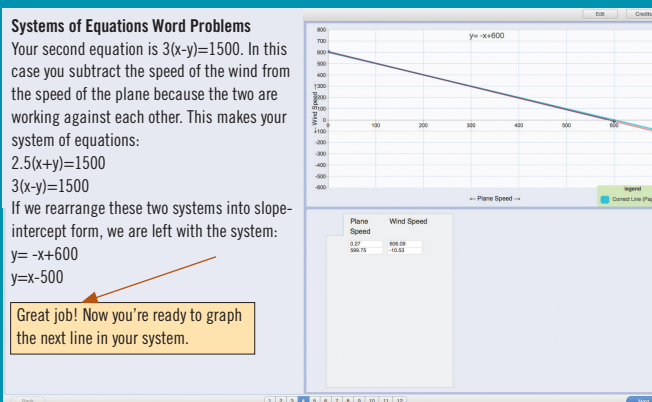
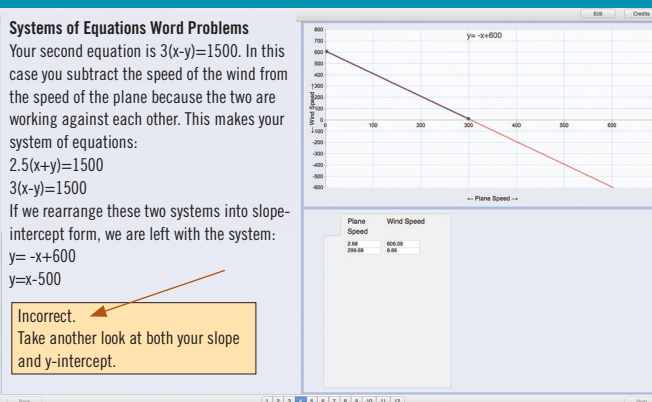
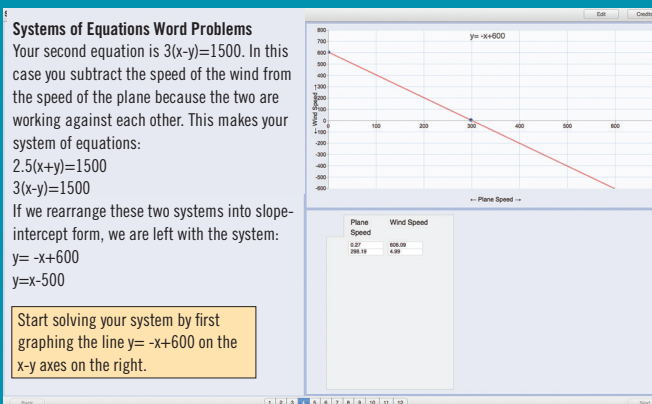


Figure 3. A line construction sequence, with hints for students.



Graphs in algebra

High school algebra is filled with graphs, but the course is a serious trouble spot in many schools. Requiring algebra for all students is becoming common in the U.S. For instance, while more than 60% of California students take algebra in grade 8, thousands fail or repeat the class because they are not prepared. At the national level, too, test scores for 17-year-olds on the National Assessment of Educational Progress (NAEP) math test have been flat from 1973 to 2012, despite growing pressure on schools during those forty years to improve achievement in math and science. We believe our graphing software can help teachers and students do a better job in algebra and other high school math courses.

Constructing lines based on equations is a common task in algebra. Figure 2 shows a page in a SmartGraphs activity that helps students understand systems of two equations. Important points or regions on the graph are labeled to help students understand their meaning. Questions posed to students can also require an answer in the form of a label the student constructs on a graph.

In another algebra activity, students are asked to construct a line for an equation based on a word problem. Figure 3A shows that a student has constructed the line (by clicking two points, which are then connected by a line) and is about to submit the answer. The software tells the student that the line is not correct and provides hints (Figure 3B). (The author of the activity can allow any number of trials for the student.) When the student tries again, the software recognizes the student's line is now correct (Figure 3C). This is one of many ways in which students can interact with a graph using SmartGraphs.

Deeply digital textbooks

Publishers have the opportunity to embed meaningful and interactive content into a new breed of digital textbooks. We hope that SmartGraphs and other tools become part of a new generation of deeply digital texts that provide practice problems, hints, tutorials and scaffolding.

LINKS

- SmartGraphs
<http://concord.org/smartgraphs>
- Graph Literacy
<http://concord.org/graph-literacy>

Intermolecular Interactions

are Key to Understanding

By Dan Damelin

Have you ever played the game where the goal is to determine how a series of items is connected?



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Try this:

- Why does water form on the side of a cold glass?
- Why does global warming mean there will be bigger and more powerful hurricanes?
- How can a tiny change in a gene cause a major disease like sickle cell anemia?

The answers to all of these questions can be found in how molecules attract to each other. This one foundational concept can link what appear to be disparate topics into a coherent framework for understanding the world around us. Indeed, much of what we observe can be explained as emergent phenomena based on the interactions of atoms and molecules.

Richard Feynman, Nobel laureate in physics, said that if he could only pass on a single concept to a world bereft of scientific knowledge it would be the atomic hypothesis: “that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.” From this idea we can begin to explain the answers to the questions above.

The Interactions project, funded by the National Science Foundation as a partnership between the Concord Consortium, Michigan State University’s CREATE for STEM Institute and the University of Michigan, is developing a semester-long interdisciplinary science course based on this fundamental concept. Four units cover intermolecular interactions from various macroscopic and submicroscopic perspectives, providing the foundation

for subject-specific courses that follow—from physics to chemistry and biology.

Unit 1: Why do some things stick together while other things don’t?

Students explore basic electrostatic attractions between macroscale objects, then drill down to the atomic level to understand the particulate nature of matter and how atoms provide an underlying mechanism for many phenomena.

Unit 2: How can a tiny spark cause a huge explosion?

Students look at electrostatic attractions and energy transformations involved in chemical reactions. They move from studying single atoms to more complex groupings as molecules form.

Unit 3: Why don’t all liquids boil at the same temperature?

Students investigate the structure of molecules and the electronic distribution within them to understand bulk properties of materials, like boiling point, solubility and viscosity that are due to intermolecular attractions.

Unit 4: How do my genes really work?

Students combine everything they’ve learned about molecules, attractions and energy, and apply this to understanding the biochemical nature of life, including everything from the formation of the first cell to DNA replication and protein function.

The units engage students in the practices of science as outlined in the Next Generation Science Standards, including developing and using models, analyzing and

interpreting data and engaging in argument from evidence. Curricular units incorporate research-based methods for engagement and exploration.

Coherence

Research has shown that coherence of curriculum is a dominant predictor of student learning.¹ By using the atomic world as a lens for understanding the macroscopic world we experience, science becomes a more connected whole. Instead of memorizing many specific rules tailored for understanding particular phenomena, students build a framework based on fewer fundamental scientific concepts and apply that framework widely.

Contextualization

Each Interactions unit is based on a driving question, providing students with a meaningful context for exploration. A good driving question has the following characteristics:²

- **Feasibility:** Students should be able to design and perform investigations to answer the question.
- **Worth:** Questions should deal with rich science content and process that match district curriculum standards.
- **Contextualization:** Questions should be anchored in the lives of learners and deal with important, real-world questions.
- **Meaning:** Questions should be interesting and exciting to learners.
- **Ethical:** Questions should not harm living organisms or the environment.
- **Sustainability:** Questions should sustain students’ interest for weeks.

The classroom maintains a Driving Question Board with the driving question, as well

as additional related questions generated by students. To help answer those questions, students generate data, including results from hands-on experiments, annotated computational models, student illustrations of consensus models developed by the class and everyday observations from inside and outside the classroom, and post these data to the board. The teacher's role is to foster an environment of collaboration, active discussion and student discovery.

Multiple representations

The curriculum links hands-on experiments to Molecular Workbench models, allowing students to explore the same phenomena at different scales. Because atoms are too small to experience firsthand, the abstract world of molecular interactions and motions can be hard for students to grasp. The Molecular Workbench computational modeling platform provides a concrete visualization of the atomic realm and a way

Why does water form on the side of a cold glass?

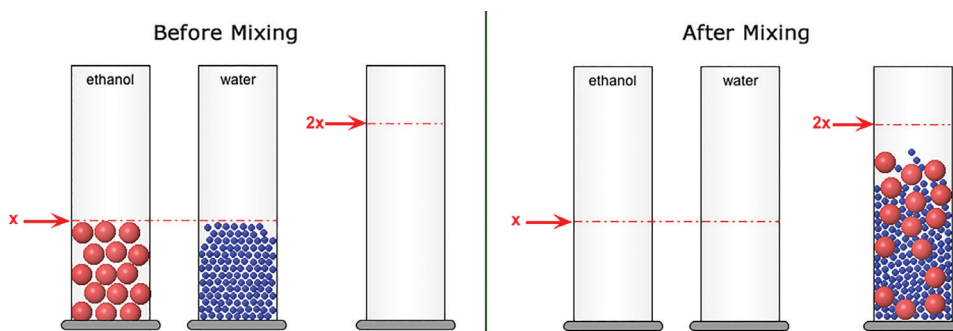
Air contains many separate water molecules, all attracting each other. If they move fast enough they can overcome those attractions and remain a gas mixed in with the air. When water molecules touch the cold glass, they slow down enough that the attractive forces between them cause them to condense on the side of the glass.

Why does global warming mean there will be bigger and more powerful hurricanes?

Warmer air evaporates more water molecules. During evaporation, heat energy from the air is absorbed by liquid water molecules, which use that energy to overcome their intermolecular attractions. That same energy is released when the water molecules condense back into liquid droplets. The energy released during

For too many people science just doesn't make sense: it seems like a collection of unconnected facts that are difficult to apply to everyday experiences. Our goal is to help students achieve a level of confidence in their ability to learn and apply science, to experience what it means to do science and to begin their journey in using atomic-level reasoning to achieve a deeper understanding of the world in which we live.

Figure 1. The particle model provides a possible explanation for why mixing ethanol and water results in a solution that takes up less volume than the liquids measured individually (<http://concord.org/links/particle-mixing>).



for students to see the results of experiments at this level; students get a feel for how atomic-level behavior results in the emergent properties of the systems they experience at the macroscopic level.

For example, when students mix liquids to explore the particle theory of matter, they do both a hands-on experiment and a virtual one (Figure 1). By marrying the macroscopic world of students' everyday experience with the submicroscopic world, the curriculum helps bridge the abstract and the concrete, forming links to the underlying atomic interactions that connect so many different phenomena.

Answer key

So, how do intermolecular attractions provide an explanation for the questions posed at the beginning of this article?

condensation is what powers hurricanes. More evaporation results in more condensation, resulting in bigger and more powerful hurricanes.

How can a tiny change in a gene cause a major disease like sickle cell anemia?

Genes are a blueprint for making proteins (a type of large, complex molecule). One of those proteins is hemoglobin, which carries oxygen in our blood cells. There is a gene mutation that results in a small change in the hemoglobin protein, causing hemoglobin molecules to stick to each other, forming fibers that distort blood cells into a sickle shape.

Intermolecular attractions are key to understanding these seemingly dissimilar phenomena ... and a great deal more.

- Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies*, 37(5), 525-559.
- Krajcik, J., & Mamlok-Naaman, R. (2006). Using driving questions to motivate and sustain student interest in learning science. *Teaching and learning science: An encyclopedia*, 317-327.

LINKS

- Interactions
<http://concord.org/interactions>
- Molecular Workbench
<http://mw.concord.org>

Under the Hood:

In-browser Image Capture with Shutterbug

By Noah Paessel



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A new suite of our online STEM activities includes challenging web-based interactives that model physical phenomena—from diffusion to protein folding and pendulum motion to climate change. Students run the model, testing different variables, then answer questions about the model's behavior by taking and annotating snapshots.

Because we couldn't find any open-source web technology for image-based questions and answers—and we didn't want to install special software on a student's laptop or tablet—we created Shutterbug, a versatile open-source JavaScript and Ruby project that captures screenshots in a variety of web applications.

Technical overview

Shutterbug is distributed as a Ruby Gem. It's a Rack service that can deliver its JavaScript to the browser. The JavaScript library sends HTML fragments back to the service, which generates images from these fragments using PhantomJS. In Figure 1, `getDomSnapshot()` triggers a request to the Shutterbug service. The response from the POST request contains an image tag that points to a newly created image on the server.

That's it! Now, you can browse the demos running on your local machine at <http://localhost:9292/index.html>.

Integration

If you'd like to integrate Shutterbug into your project and host Shutterbug on your own server, start by downloading it. (The project's README also includes step-by-step instructions for setting up a free Heroku Shutterbug service.)

Once you have a Shutterbug server setup, integrating it into a web page is simple—just include the following somewhere in your page's markup:

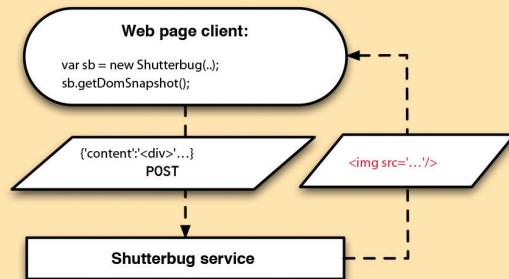
```
<script  
src='http://<yourhost:port>/  
shutterbug/shutterbug.js'  
type='text/javascript'></script>
```

The Shutterbug constructor `new Shutterbug(...)` takes a few arguments to tell Shutterbug what dom element to snapshot, and what to do with the resulting image tag. In this case `$("#sourceselector")` identifies an HTML tag as the source we want to capture. We also tell Shutterbug to update `$("#outselector")` with an `` tag that will be returned by Shutterbug.

You can even specify custom callbacks or have multiple Shutterbug instances work together across iframes.

Shutterbug is a new project, and we welcome help and feedback. Please join our mailing list.

Figure 1.
Shutterbug
client server
communication.



Getting started

With three simple steps you can download and test Shutterbug locally. First, you'll need to have Ruby and a recent version of the Bundler Gem installed. (All links to download sites are listed at the end of this article.)

1. Download Shutterbug from github, or clone it using git.
2. Install bundler. Run `bundle install` from your shell.
3. Start a rack server `bundle exec rackup`

You'll have to replace `<yourhost:port>` with the actual address of your server.

In your page's JavaScript, create a new Shutterbug object like this:

```
var shutterbug = new Shutterbug(  
'#sourceselector',  
'#outselector'  
);
```

Elsewhere in your JavaScript, bind some event to call `getDomSnapshot()`:

```
$('#button').click(function() {  
  shutterbug.getDomSnapshot();  
});
```

LINKS

- Shutterbug
<https://github.com/concord-consortium/shutterbug>
- Download Shutterbug
<https://github.com/concord-consortium/shutterbug/archive/v0.0.11.zip>
- Heroku
<https://www.heroku.com/>
- Bundler Gem
<http://bundler.io/>
- Rack
<http://rack.github.io/>
- Phantom JS
<http://phantomjs.org/>
- Mailing List
<https://groups.google.com/forum/?hl=en#!forum/shutterbug-dev>

Innovator Interview:

Andy Zucker

azucker@concord.org

Q. Tell us about your background.

A. I grew up in Manhattan in an apartment building near the American Museum of Natural History. My father was an internist and psychiatrist and my mother was a world expert on platelets and blood clotting, so I was surrounded by science early. I became interested in computers in high school, and started programming with punch cards. After college, I became a math and science teacher, and I directed the computer center at Milton Academy—before there were microcomputers. I then earned a master's in science education from Stanford and a doctorate from the Harvard Graduate School of Education.

Q. Can you describe your career.

A. I've had the opportunity to play many different roles in education—from strategic planning to program evaluation to video and software development. As a Fellow in the Education Policy Fellowship Program, I administered federal grants for novel uses of telecommunications in health, education and welfare. At the U.S. Department of Education, I wrote congressional budget justifications. My bailiwick included children's TV, so I got to know Frank Withrow, one of the fathers of Sesame Street, and I became a huge supporter of children's television.

Later, I worked at SRI International for 17 years, almost always in the Arlington, Virginia, office. SRI is a fascinating place—with 25,000 projects over the years, they've done everything from helping Walt Disney decide where to put Disneyland to creating Tide, the first artificial detergent, as well as developing speech recognition software and Siri, the iPhone assistant.

Q. Tell us about your book *Transforming Schools with Technology*.

A. Larry Cuban was a vocal and often thoughtful critic of computers in school. And for a time there was not enough pushback that technology was important, so I wrote *Transforming Schools with Technology*. I always felt that having been a teacher was incredibly important to all the other things I did because I learned some of the ground truth about what it is to be a teacher. One myth I was fighting in the book was then fairly common: that teachers resist technology. That's not true.

Q. What are your thoughts on the evolution of 1:1 programs?

A. *Never Mind the Laptops* is the title of one book about laptop schools. The technology enables other things and it's the other things that count. The price of computers keeps coming down, so it's inevitable we'll get to 1:1. But getting computers in schools

is slower than everyone had wished. Social institutions are slow. Technology is fast. That's the story of the world's big problems in a nutshell.

Q. What are some of your hobbies?

A. I'm trying to shift gears as I approach retirement. I've been working with the Greater Boston Interfaith Organization, which is working to control health care costs in Massachusetts, and I'm interested in what psychology means for public policy. My wife and I also love movies, theater and music.

Q. What makes the Concord Consortium special?

A. The Concord Consortium has been a wonderful place to be for the past eight years. One of the great strengths is teamwork, which is key for innovation. Thomas Edison was not alone; he had a staff of 30. That's the way it's done!

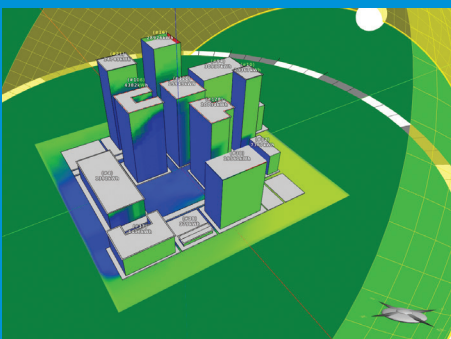
Q. What projects are you working on?

A. Our team has been developing SmartGraphs, which is web-based software designed to help students understand graphs and the STEM concepts represented in graphs (such as velocity or population growth). We also developed an online authoring system for non-programmers to create and publish new activities. We'd love to see SmartGraphs get used very widely.



The Concord Consortium is happy to announce the following new grants from the National Science Foundation.

Mining Large Data Sets from Energy3D



With our open source Energy3D CAD tool, students design energy-efficient buildings while the software automatically logs the process. Now we will be able to mine large data sets from thousands of secondary students solving engineering design challenges with Energy3D.

In collaboration with Purdue University, we will use this “big data” to 1) identify common patterns of engineering design behaviors and habits of mind, 2) gauge the extent and effect of inquiry actions in a design process, 3) detect iterative design cycles, 4) measure the volume of the design space explored by a student, and 5) characterize a student’s divergent-convergent thinking process, which is critical to the development of creativity and innovation.

Constructive Chemistry

One of the most effective pedagogies in science education is to challenge students to design and construct something that performs a function, solves a problem or proves a hypothesis. Learning by design is a compelling way of engaging students. Our new “Constructive Chemistry” curriculum, based on our award-winning Molecular Workbench software, provides a graphical user interface for students to author scientifically accurate simulations. Students at Bowling Green State University and Dakota County Technical College are creating their own molecular simulations in response to questions and challenges.

New SimBuilding Game

The Concord Consortium and Santa Fe Community College (SFCC) are developing SimBuilding, an innovative set of simulation games for teaching building science. The software—available in English and Spanish—will support diagnostics, construction and operation games, each mapped to science concepts and practical skills related to real-world jobs. An intelligent tutor will offer instant feedback to direct gameplay based on student inputs.

Pilot tests will be conducted in four community colleges in New Mexico through SFCC’s Center of Excellence for Green Building and Energy Efficiency. Student data will be automatically logged and analyzed to reveal details of their learning.

Physical Science Assessments for NGSS

We are developing next-generation assessments that address a core idea in physical science—matter and its interactions—by integrating middle school chemistry content with two NGSS scientific practices, constructing explanations and developing and using models. Assessments will be iteratively designed and administered in middle school science classrooms to ensure usability. The work will include expert reviews of alignment with the NGSS to examine construct validity; cognitive analyses to examine cognitive, construct and diagnostic validity; and psychometric analyses to examine empirical validity.

Telepresence Opens Research Opportunities

A new project combines expertise in ethnography, education and technology at the Concord Consortium, the Woods Hole Oceanographic Institute, the Harvard Kennedy School and the Monterey Bay Aquarium Research Institute. We are investigating how telepresence can transform STEM research and education by bringing meaningful research experiences to scientists and students otherwise unable to participate.

Early career scientists pioneering the use of remote robotic vehicles (ROVs) and sensors will work with undergraduate students to explore greenhouse gases released from the ocean floor. Engineers aboard a ship in the Caribbean will support the ROVs while scientific observations, data analysis and research decisions will be conducted on shore.