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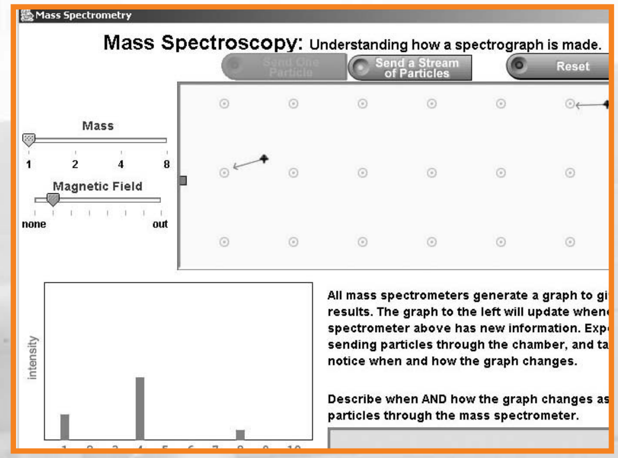
A Tale of Two Revolutions



A researcher and student use a mass spectrometer. With the Molecular Workbench modeling software, which simulates atomic-scale interactions, students can practice a simulated laboratory procedure, such as mass spectroscopy.

By Boris Berenfeld, Dan Damelin, Amy Pallant, Barbara Tinker, Robert Tinker and Qian Xie

Two revolutions are on the horizon. Every era seems to be associated with a revolutionary technology that reshapes society. In the process, each technology attracts massive investments, demands new infrastructures, and creates vast new employment opportunities. Each also requires education to focus on new skills and understandings. In the 19th century it was steam and railroads. Then came electricity, the automobile, telephones, airplanes, and chemistry. While in the 20th century digital electronics were ascendant, two coming revolutions – biotechnology and nanotechnology – promise to dominate the 21st century.

Biotechnology and nanotechnology are close cousins. These two revolutions are related across the organic-inorganic divide, operate at the same scale, and are both based on the capacity of molecular machinery to provide the answers to practical challenges. Both revolutions demand that students learn more about the world of molecules and their interactions.

Biotechnology has already become an enormous enterprise. Where only several decades ago, just a handful of companies were based on this technology, now at least 1,500 firms are employing drug-related researchers. In fact, the number of employees doubled between 1993 and 1999, rising to 115,000 (see note 1). Work in this sector promises to deliver more and better food crops for the poor, more effective and economic medicine, and improved detection of disease.

Nanotechnology has the potential of becoming as important as biotechnology. The field focuses on making tiny, useful things that are as large as a tenth of a micron (100 nanometers) or as small as ten Angstroms (one nanometer, or roughly ten carbon atoms). Understanding the behavior of atoms and molecules on the nano-scale allows the creation of materials and devices from the "bottom up" by placing the right atoms in the right places.

To illustrate how nanotechnology differs from today's manufacturing, Dr. Ralph C. Merkle, one of the pioneers of nanotechnology, explains: "Casting, grinding, milling and even lithography move atoms in great thun-

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Perspective

Technology to the Rescue

Robert Tinker

Nationwide, student achievement in technical fields – mathematics, science, and technology – is unacceptably low, highly inequitable, and headed downward. Scores of students in the class of 2003 on the ACT test provide the latest indications of the problem. Only a quarter of students taking the test reach a level that predicts a satisfactory grade in college science, and this figure is down from previous years. The scores for under-represented minorities are unacceptable, with only one in twenty African-Americans reaching this level. Only college-bound students take these tests, so national averages are certain to paint a more depressing picture.

Educational technologies are part of the solution

Although technologies are increasingly available in schools, mathematics, science, and technical (MST) educators make insufficient use of technology,

> Information and computer technologies can help more students achieve and surpass the current goals of MST learning.

one of one of the few new resources at their disposal. Information and computer technologies (ICT) should be an integral part of MST teaching. Better use of ICT is urgently needed because technology can be used to greatly improve learning and it is an essential part of modern science. ICT is called for in teaching standards and numerous reports from government, business, universities, and academics.

Not all uses of ICT are equally important for improving MST learning. Multimedia, drill and practice, Internet searches, and student-generated reports are increasingly commonplace and do have some role in teaching and learning, but these applications skirt the periphery of education. The core of math and science is about investigating, exploring, asking questions, analyzing, and thinking – activities that ICT is uniquely able to facilitate and deepen. ICT can enhance this kind of learning through student investigations of real events with probes, investigations of highly interactive models, electronic communications about investigations, and assessments embedded in learning activities.

Achieving current MST goals

Information and computer technologies can help more students achieve and surpass the current goals of MST learning. To do this, we make extensive use of substitution units that can be used in place of other instructional materials and require about the same amount of classroom time. Teachers can, for example, substitute a unit on phase change based on exploring the Molecular Workbench for a comparable unit taught using traditional approaches. (See “A Tale of Two Revolutions” on page 1.)

Most of the really hard concepts in introductory science can be addressed with substitution units and there is strong evidence that doing so will increase student learning. Our research already has promising data for substitution units for kinematics and dynamics, genetics, physical science, and plate tectonics.

Policy makers rightly require more rigorous data, however. For example, a dean or district superintendent needs to know whether these materials are reliably better than other approaches, whether they will be effective in colleges or schools like their own, using technology and professional development that they can afford. They also need data on a complete range of content, because their decisions might involve technology purchases for an entire course, not for just a unit on one topic. The Education Accelerator that we recently launched is designed to

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The Concord Consortium

The most exciting capacity of ICT goes beyond simply finding better ways to meet current educational goals. Technology can fundamentally change what is taught in introductory science.

provide applied research data that can answer these policy questions. (See "The Education Accelerator Becomes a Reality" on page 11.)

Transforming MST education

But we need to do more than simply get more students up to the present standards for MST education. The most exciting capacity of ICT goes beyond simply finding better ways to meet current educational goals. Technology can fundamentally change what is taught in introductory science. For instance, linking genetics and biomolecular models might permit a treatment that connects classical to modern genetics in middle school. Similarly, molecular modeling might give beginning students deep intuition for atomic explanations of the states of matter. New tools and models could allow nanotechnology to become a topic in introductory physical science, or genomics to be taught early in biology, or calculus concepts to be taught in physics. These advances would not be just for advanced students, because this kind of learning depends on explorations of the real world and models that any student can undertake. Unlike most MST teaching, these explorations avoid mathematical formalism, a barrier to most students.

This kind of curriculum change is difficult to justify to decision-makers, and extensive data will be required to convince skeptics of the value of making such changes. Any school willing to experiment with these approaches would need to find the courage to go well beyond the current standards. Careful research, of the kind planned by the Education Accelerator, will be needed to document the value of all the changes needed.

Ultimately, the kind of accelerated learning that we expect to document will give rise to a fundamental re-evaluation of the science education standards. Our long-term goal is to generate sufficient data to demonstrate that the science standards could profitably address a few core concepts more thoroughly, downplay the thicket of minor concepts that follow from a deep understanding of the core ideas, be more focused on cause-and-effect relationships, and include far more modern, interdisciplinary content.

As a nation, we are not protecting our technological lead by producing a technically literate population, nor are we training adequate numbers of MST leaders. We are squandering the contributions that could be made by large segments of our population, including women and under-represented minorities. The new capacities for learning that ICT creates could address these challenges by fundamentally changing what is taught and how learning takes place. @

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Interdisciplinary science

An example can help illustrate the possibilities. An introductory interdisciplinary science course could start with our molecular models of atoms (see http://workbench.concord.org). By exploring what happens to two elastic atoms that collide, students will learn about the energy conservation laws and, because the atoms have an attractive van der Waals force, potential energy. Extending this to many atoms gives rise to the idea of temperature, which is simply the average kinetic energy. At low temperatures these atoms condense into a liquid and a crystalline solid, releasing potential energy that can be measured and compared to the attractive forces between atoms. The atomic basis of diffusion, entropy, phase change, latent heats, the distinction between heat and temperature, conduction, crystal structure and faults, evaporative purification, and many other phenomena are immediately obvious and open to exploration.

Similar experiments can be done with molecules that can break apart at sufficiently high temperatures. Experiments with these lead to a deep understanding of chemical reactions, equilibrium, reaction constants, and that mysterious free energy. The atoms in these molecules can be charged, enabling learning experiments with ions, polar molecules, and solvents. Finally, with smart surfaces and some other constructs, molecular biology concepts such as conformation, surface binding, and self-assembly can be subjects of inquiry.

A course with this structure is a blend of physics, chemistry, and biology. It would give students unprecedented ability to understand the fundamental ideas of all three subjects. It could be taught without a single equation to beginning or liberal arts students, or it could be used as the conceptual core of a highly mathematical treatment. By treating topics such as the physical basis of latent heat and giving students rich mental models of sophisticated topics like thermodynamics, such an interdisciplinary course would enable students to learn a few ideas more deeply and be able to apply these ideas to a very wide range of situations. Science would appear less as a miscellaneous collection of facts and more as a coherent set of powerful concepts.

A Tale of Two Revolutions

→ PAGE 1

dering statistical herds. It's like trying to make things out of LEGO blocks with boxing gloves on your hands. Yes, you can push the LEGO blocks into great heaps and pile them up, but you can't really snap them together the way you'd like. Nanotechnology promises to let us inexpensively arrange atoms in most of the ways permitted by physical law, getting essentially every atom in the right place" (see note 2). As we develop better techniques for creating objects this small, there will be many applications, from the ability to manufacture sub-microscopic robots traveling through our body, detecting illnesses and killing viruses, bacteria or cancer cells, to making new generations of super powerful and inexpensive computers that can store all the information of the Library of Congress into a memory the size of a sugar cube!

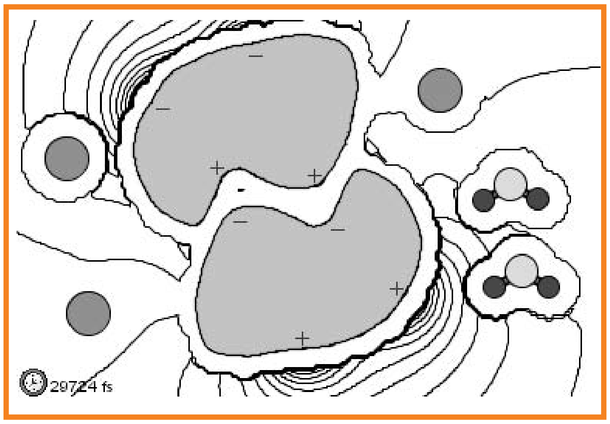

Figure 1. Smart surfaces. This is a model of molecular recognition between polymers. Each bead represents an amino acid. By changing the properties of amino acids, students can alter the effectiveness of the recognition.

Biomimicry

An important strategy in nanotechnology is to learn from biology and to mimic the design of cellular machines. For example, researchers try to mimic the way living cells assemble their protein-based machines one amino acid at a time in the sequence dictated by the genetic code. This "bottom up" manufacturing allows cells to obtain materials of an exact desired shape, using simple principles of self-assembly and help from molecular "chaperones." As scientists understand biology better at the molecular level, they are emboldened to take further, and we hope, careful, steps to make new molecular products.

The challenge to education

William James described the world of a newborn infant as a "blooming, buzzing confusion." The molecular world, that universe in which large and small molecules jostle each other randomly and continuously, exchanging energy and undergoing dynamic changes in three-dimensional conformation, can appear much the same to our students – and to us! Yet this vibrating universe underpins the incredible stability of living beings, the regularity of crystals, and the functionality of modern electronics.

How can students get a sense of the influence of random motions and fluctuations that are a manifestation of temperature? How can they discover the order that emerges from it?

Over the last half-century biology has employed a progression of metaphors, drawings, and microphotographs to provide students with a glimpse of the molecular world. Although microphotographs present a realistic view of molecules, they do not permit students to gain a feeling for the dynamic nature of colliding and interacting molecules. Computer-based dynamic molecular modeling, previously the province of academics using supercomputers, now can be made available to them.

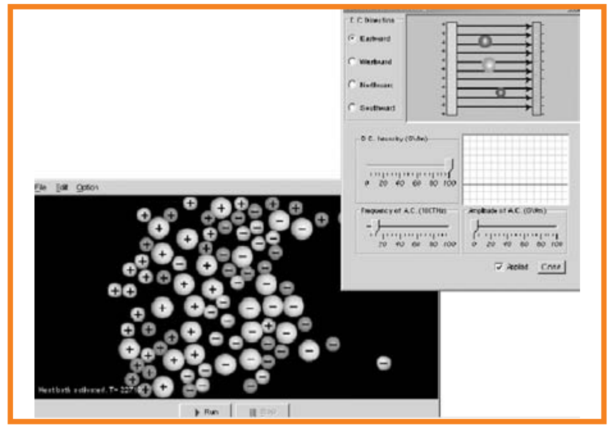

Figure 2. Simulated electrophoresis. Using a control panel, students can change the direction and strength of the electric field, the temperature of the system and properties of the particles.

Expanding our models to accommodate the new revolutions

Several National Science Foundation grants have allowed us to develop the Molecular Workbench, software for creating molecular simulations that we use in high school and college science and technology courses. At the heart of the Molecular Workbench is a simulation that models the motion of atoms that results from forces that act on atoms: mutual repulsion and attraction, bonds, and charge. These models all show random thermal motions and, therefore, help students gain a deep understanding of thermodynamics. The basic models can help explain phase change, diffusion, thermal conduction, solutions, crystal structure, and many other properties of materials.

In order to expand the utility of the Molecular Workbench into chemistry, biology, biotechnology, and

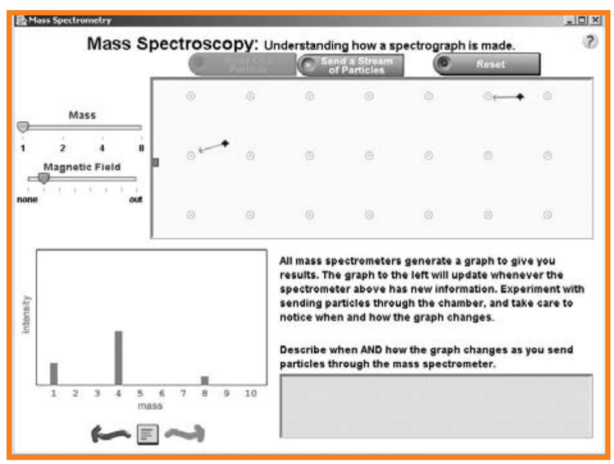

Figure 3. Fragment of the simulated mass spectrometer activity. Students explore how the mass of particles and the strength of the magnetic field affects the deflection angle of moving particles. Their task here is to manipulate the magnetic field so that the particles hit the detector.

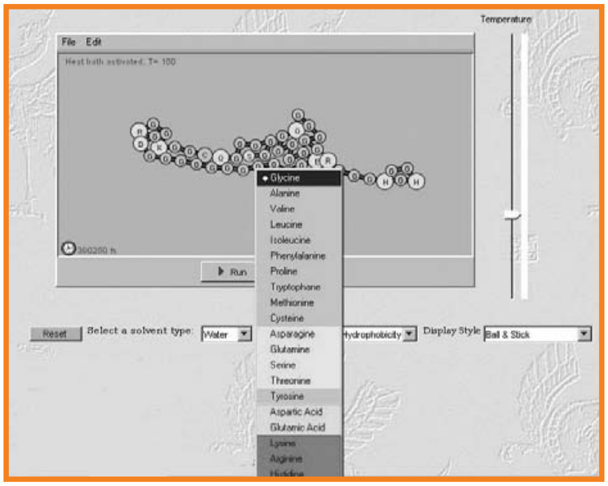

Figure 4. Exploring protein conformation. Students work with a model protein made of 46 amino acids. Each amino acid can be replaced by another of the 20 different amino acids. They can then observe the effect of polar and non-polar amino acids on the resulting protein shape. Students also can test the stability of the structure by increasing the temperature.

nanotechnology, we have added some unique innovations. By introducing effective hydrophobic and hydrophilic forces, we can illustrate protein conformation in solution without having to explicitly put in numerous solvent molecules. By combining the collision theory of chemical reactions and molecular dynamics, we can model chemical equilibria and reaction energetics. By supporting "smart surfaces" and "splines" (see Figure 1), we enable student investigation of the interactions of larger biomolecules, in which their molecular surfaces play a decisive role. We are now exploring educational applications of these expanded models in nano- and biotechnology.

Sample explorations

Several key investigations can give students a "hands-on" feeling for molecular manipulation. For example, students can compare the subatomic structure of charged, polar and neutral molecules and then practice a simulated laboratory procedure of molecular separation, such as electrophoresis (Figure 2) or mass spectroscopy (Figure 3), in which these concepts are used. Students are then in a good position to understand the role of polar and non-polar amino acids in shaping protein structures (Figure 4) and continue on to discover the effects of temperature on protein folding.

"DNA to protein" (Figure 5) allows students to experiment with changing codons in DNA responsible for the primary structure of a protein, and explore mutations that change the shape (and possibly the function) of a protein. "Smart surfaces" (Figure 1) permits students to design simple 2D approximations of proteins shaped as antibodies, receptors or pore components. They can then go on to explore interactions between "smart surfaces" or between them and a small molecule, thus modeling receptor-ligand interaction and other aspects of molecular recognition.

These illustrations cannot do justice to the models, which are in continual motion due to the effect of temperature. Because our models are based on molecular dynamics, they automatically incorporate an accurate model of thermal motion and they exhibit temperature effects. Unlike software that might simply allow students to assemble molecular designs, the Molecular Workbench incorporates thermal motions, which must be considered in any nano-scale design.

Dynamic molecular modeling is a simple, yet central tool

What challenges will the bio- and nanotechnology revolutions pose for educators? It is impossible to know in detail the educational needs of specific bio- and nanotechnologies, but it is easy to know on what science they will depend. Students will need to know about atoms and molecules, the forces that act on them, and the properties that emerge from collections of them. Experiences like those illustrated above could lead to a better understanding of both natural and designed "molecular engineering." Simulations like the Molecular Workbench that model these systems will be central to any instructional strategies, because of the technical difficulty of doing actual experiments, and the mathematical difficulty of understanding these systems analytically.

We are looking for high school and community college science teachers interested in testing our software. We offer a small stipend, as well as community support. Please contact Amy Pallant (apallant@concord.org). @

Figure 5. DNA to protein. Students can substitute or delete any nucleotide in the model gene that codes for the protein above, and explore how this mutation affects the resulting shape of the protein.

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are members of the larger Concord Consortium molecular modeling team

ARTICLE LINKS & NOTES

Note 1. http://www.gene.com/gene/features/25years/biotech-backgrounder/employment.jsp

Note 2. Silicon Valley Chemist. American Chemical Society. Vol. 23, No 5.

See examples of biomimicry. – http://www.biomimicry.org

National Science Foundation – http://www.nsf.gov

Molecular Workbench – http://workbench.concord.org

Download the Molecular Workbench. It runs under Windows and OSX. – http://xeon.concord.org:8080/modeler/webstart/index.html

Monday’

Teachable Moments w

By Eric Brown-Muñoz

Great educational “gadgets” beg to be explored. When I was teaching, I had a set of iron puzzles on my desk that both students and fellow teachers found impossible to resist. The most compelling gadgets are simple objects that have profound ideas behind them; they spark curiosity and often lead to “teachable moments.”

Highly interactive software models can provide the same “feel” and learning opportunities. Computers provide engaging models that are difficult, if not impossible, to set up in real life. Learners of all ages are naturally drawn to short, discrete programs that are fun to play with. Software programs thus greatly extend the range of things that can be learned by “gadgets.”

The challenge is to design activities using computer-based models that lead to successful learning experiences. For example, scientific games that involve setting the velocity and elevation of a cannon to hit a target are very popular, but not very effective. Students solve the problem by tweaking variables to find the correct answer, but they are not challenged to understand the underlying physics or mathematics.

Teachable Applets

I define a “teachable applet” as a focused computer program that is both fun and educational. Teachable applets have three things in common:

- They are simple to use.
- They provide a challenge that is interesting and relevant.
- They have one profound idea at their core.

Teachable applets exist to present one concept in a way that is both powerful and simple. The most effective applets are those you use once or twice to help master a concept, and then throw away.

The best applet captures the imagination of the students. It shows the deep ideas in ways that are inherently interesting and provoke curiosity. If the interface is simple, the technology and the procedures are transparent and the concepts take center stage.

I judge the best applets with a fairly demanding standard: the interest of my nine-year-old son. I give him an applet and a few minutes of help. If he is still exploring it 30 minutes later, the applet passes the test.

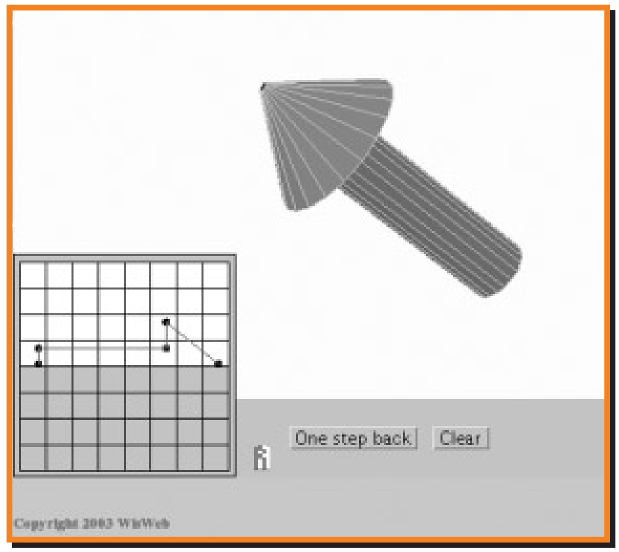
The Shodor Foundation and the Freudenthal Institute each have collections of applets well worth exploration. Start with the following (or try them out on your son, daughter, niece, nephew, friend, or student).

Lathe

The Lathe applet from the Freudenthal Institute is an engine for “revolution.” For the student, it’s an interesting way to make “cool” three-dimensional objects.

Point your browser to:

www.fi.uu.nl/wisweb/welcome_en.html



The Lathe interface is wonderfully simple, though the applet illustrates a fairly complex concept.

Click the applets button on the left, and select Lathe from the list.

You are presented with three controls: a grid to draw on (half is grayed out), and two buttons – “One step back” and “Clear.”

Click points on the grid to create a two-dimensional segmented line. The applet draws the related three-dimensional object in the main display window (this is a solid of revolution). Use your computer mouse to click or twist the resulting 3D object for easier viewing.

The idea behind the applet is profound: the two-dimensional diagram in the grid is half of a cross-section.

So how is it educational?

My son saw this applet on my computer as I was reviewing it. Immediately, he wanted to play with it. A good first sign!

’s Lesson

ith Teachable Applets

His first inclination was to click in the box to see what came up. After playing for a while, he made several things that appeared to him like “airplane jet engines.” He was exploring on his own, but I knew a challenge would help him figure out what was happening.

“Miguel, can you make a spear?” I asked. He started out drawing a spear in the middle of the grid. The result was something shaped oddly like an airplane jet engine.

I continued, “let’s start with the stick. Can you make a thin stick?” Miguel soon discovered that he wanted a horizontal line. Then he figured out that the lower the line, the thinner the 3D stick.

That was all of the prompting my son needed. After several minutes, he figured out that the bottom of the grid mapped to the center of the object. The rest was easy. He soon had a pretty convincing spear with a nice sharp point.

Plop It!

The Shodor Statistics applet “Plop It!” has the same advantages: it is engaging and focuses on one concept. It is designed to teach basic statistics.

Point your browser to:

http://www.shodor.org/interactivate/activities/

Look at all the great software and select Plop It!

This applet presents a histogram. Click inside the graph, and an object (represented as a blue box) falls into one of the columns. This is equivalent to adding a data point to a sample.

This type of applet is effective because it allows the student to focus on only one thing. The applet performs the calculations, freeing the student to think about what the calculations mean. (Of course, the mechanical act of calculating the average is important, and the student should have experience making this calculation. But students can do these exercises elsewhere.) Here, the student can wrestle with the more profound ideas about the meanings of “mean,” “median,” and “mode.”

There are several ways to use this applet. For example, you can use this in a classroom discussion to introduce the three Ms (mean, median, mode).

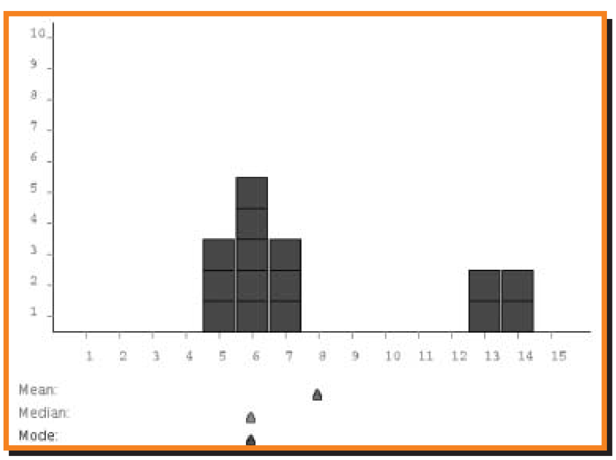
Once students are familiar with the concepts and the tool, present a challenge. For example, “create a set of 15 items that has a mode of 6 and a median of 6, but a mean of 8.” This is not an easy task. Students will have to understand what these terms mean on a fairly deep level to attack this problem. This elegant applet allows students to focus exclusively on the important math concepts.

Using Applets in the Classroom

Applets like Plop It! make great classroom demonstrations. With a projector, you can demonstrate the computer model and use it to spark classroom discussion.

Applets also are great for small group or individual work. The key is to give clear tasks with objectives that students can measure themselves. For example, if the task is to find factors, the applet should make it clear when the students have the correct answer.

When the applet and the task are interesting and relevant, the computer model naturally captivates students. The teacher then has the opportunity to walk around the classroom to help, prompt students with a question, or present them with new challenges. Students are engaged. And they’re learning. @



Plop It! is a simple tool that is engaged, focused, and effective.

Eric Brown-Muñoz (ebrownmunoz@yahoo.com) is an independent Java programmer who is developing interactive materials for teachers.

ARTICLE LINKS & NOTES

Shodor Foundation – http://www.shodor.org

Freudenthal Institute – http://www.fi.uu.nl

Ready to Teach:

A scalable support program for uncertified algebra teachers

By Robert Tinker

Teacher quality is one of the most important determinants of student success. But certified teachers are in short supply in low-wealth schools. More than 70% of mathematics courses in high-poverty, high-minority middle schools are assigned to teachers who lack even a minor in mathematics (see note). Thus, the consequences of the shortage of qualified teachers in schools serving high-poverty, high-minority communities are predictable: lower performance of students from these schools. The glaring gaps in achievement between students in these schools and students in other schools will continue until the teacher certification gap is closed.

> The overall goal of the joint Ready to Teach program is to develop, implement, evaluate, and disseminate an affordable, scalable support program for uncertified algebra teachers.

Drastic and immediate efforts are needed to address the problem of uncertified teachers in high-poverty and high-minority schools. There is new urgency for solving this problem because "No Child Left Behind" is now federal law that requires schools to have "highly qualified" teachers in all classes by 2006 to continue to be eligible for federal education funding. New ways of dealing with this problem are needed that can leverage available resources quickly and effectively.

Robert Tinker (bob@concord.org) is President of the Concord Consortium.

The Ready to Teach program

The Concord Consortium's Seeing Math Telecommunications Project and the PBS (the Public Broadcasting Service) Teacherline Project have joined together to create a program called "Ready to Teach" that will address the problem of under-qualified secondary mathematics teachers. The overall goal of the joint Ready to Teach program is to develop, implement, evaluate, and disseminate an affordable, scalable support program for uncertified algebra teachers. By joining together, the two projects can pool their resources to create a powerful new strategy for addressing the problem of under-qualified teachers: economical, effective teacher professional development that is delivered online. The solution could be expanded to encompass most disciplines.

The core innovation of the Ready to Teach program will be online Close Support™ courses for algebra teachers that will address both content and pedagogy needs of participating teachers. Close Support courses will provide content-specific, just-in-time assistance to teachers of Algebra I and II. Each teacher participating in a Close Support course will, at the same time, be teaching the same topic to students. Our goal is to ensure that each participant gets content and teaching support that will pay off immediately in the courses that the participant is teaching. This should maximize the impact of the teachers' professional development and result in measurable gains in their students' learning.

Creating Close Support online courses that are synchronized with classroom teaching is a major challenge. Teachers use a wide range of textbooks that have different approaches and even teachers with the same text cover the content at different rates, emphasize different sections, and bypass different chapters. In addition, we do not want to be too closely tied to textbooks, because their treatment is often chaotic and fails to incorporate what has been learned about how students learn.

Our design for Close Support courses for teachers begins by dividing the online Algebra I or II course into three-week modules, each of which focuses on one major topic. A module will not attempt to cover every detail of the different texts. Instead, the modules will be organized around a limited number of central ideas and will provide many ways for learning and teaching these ideas. Each module will include video of classroom teachers addressing the core ideas. The video provides a powerful stimulus for online discussions about teaching strategies and class organization. Each module also will have interactive applications for guided explorations of the key ideas. Teachers will be encouraged to use the online activities with their students, provided they have adequate technology support in their classrooms. Embedded assessments will allow us to provide ongoing assessment of student progress in classrooms that choose to use the software. Offline activities and assessments also will be available.

The modular structure of the Close Support Algebra content will allow us to craft online professional development course sections that match the needs of small groups of teachers. We are developing 22 modules that cover the core content of traditional Algebra I and II courses. A full-year course, that carries graduate credit and counts toward accreditation, will be composed of eight to ten of these modules. We will group participating teachers into sections of 20 teachers who have approximately the same classroom schedule. The appropriate modules then will be fitted to the consensus schedule for each section. Some teachers may have to make minor adjustments to their schedules so that all participants in a section will be synchronized.

This design will ensure that every participant has a community of about 20 peers following the same schedule. They will be able to try out ideas and software together, share what they learn about their students, and gain a deeper understanding of the mathematics and the pedagogy through these discussions. Each section will be led by a trained facilitator who will guide the conversation and ensure full, thoughtful involvement of all participants.

Are you ready to join?

The Ready to Teach program needs help from professional development programs, pre-service teaching institutions, and schools to meet its tight development and implementation schedule. Algebra I modules will be tested in the spring, beginning in February 2004. Complete courses for both Algebra I and II will be tested during the 2004-2005 academic year. After revisions, the materials will be widely available in the fall of 2005.

We currently are recruiting a variety of organizations to test materials and course modules. In order to obtain quantitative results, we will need to randomly assign Algebra I and II teachers to two different kinds of teacher professional development. We also will need schools that have enough technology to use our software in their algebra classrooms, because the assessments embedded in the software will be used to track student progress. Participating schools will need to administer our standardized test to their algebra students and teachers at the beginning and end of the year. Finally, we will need access to records of student progress in prior years. (Data will be kept in strict confidence; no one outside the project will be able to identify specific students, teachers, or schools.)

Teachers in the study will enjoy free, high-quality professional development that will carry graduate credit toward accreditation. All teachers completing their professional development will earn a stipend. A part-time project coordinator at the school site also will be reimbursed.

If you are interested in joining the Ready to Teach program, contact Raymond Rose (ray@concord.org). @

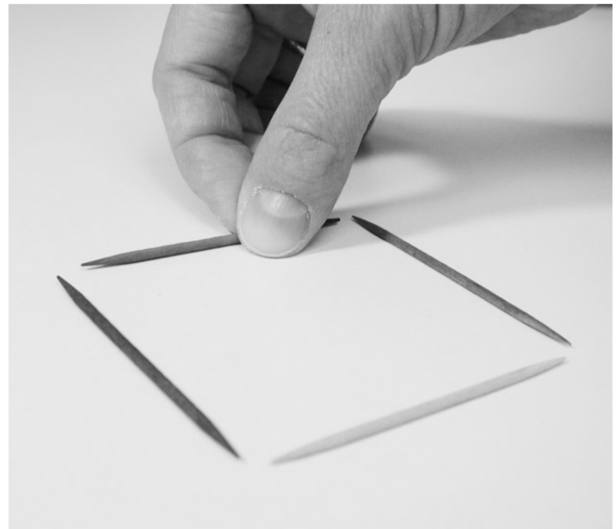


Figure 1. One-by-one square.

Toothpick challenge

In this activity, you're going to build squares using toothpicks. The challenge is to figure out a rule or rules for determining the number of toothpicks needed to build a square of any size.

Ready?

OK. Let's start with the first few squares in a sequence.

The first square has a 1 x 1 dimension. That's four toothpicks, one for each side. (Figure 1, above.)

The second square has a 2 x 2 dimension. How many toothpicks do you count? (Figure 2, below.)

What will the third square (3 x 3) look like? How many toothpicks does it take?

Continue to build subsequent squares and determine the number of toothpicks needed in each case. Finally, determine the number of toothpicks needed to build an 8 x 8 square; a 21 x 21 square; and an n x n square where n is any positive integer.

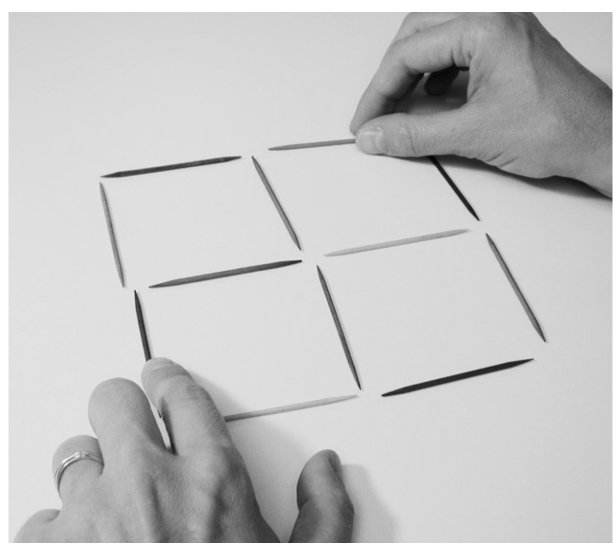


Figure 2. Two-by-two square.

ARTICLE LINKS & NOTES

Note: Ingersoll, R. M. (2002). Out-of-Field Teaching, Educational Inequality, and the Organization of Schools: An Exploratory Analysis. University of Washington Center for the Study of Teaching and Policy.

Seeing Math Telecommunications Project — http://seeingmath.concord.org

Public Broadcasting Service — http://www.pbs.org

Teacherline — http://teacherline.pbs.org

The Concord Consortium Portal

Making student performance reports available

By Paul Horwitz

Imagine that you're a science teacher and someone is trying to sell you a new piece of educational software. After pointing out how powerful the software is, how flexible the interface, how compelling the graphics, the salesman adds, "Of course, you won't be able to tell what your students are doing with this program, since there are far too many students for you to observe them all carefully. The program doesn't record what they're doing either, so you won't be able to use it to figure out whether they've learned anything."

Unfortunate as that sounds, that is exactly what we have been telling teachers for years: Just put the technology in front of the kids. If you want to know what they're doing, give them worksheets to fill out; if you want to know what they've learned, give them a paper and pencil test.

Why don't educational computer programs routinely keep track of what students are doing and produce high level, descriptive reports that can guide both student and teacher? In short, it's difficult!

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In order to keep track of what a student has done, the software must first know who the student is, and while schools do maintain student information on computers, that information is not readily available to instructional applications. Moreover, few schools are set up to store and maintain large databases of student performance data, much less execute sophisticated analyses of that data for assessment purposes.

Enter the Concord Consortium Portal. Over the past couple of years, mainly under the auspices of our Modeling Across the Curriculum (MAC) project, we have developed technology that will give teachers, students, parents, and administrators access to a wealth of data related to students' learning. We will use this rich data source to assess deep conceptual understanding of a domain far more effectively than previous methods allowed. We currently are working on ways to analyze all these data in order to deliver informative reports that can give teachers an instant "snapshot" of how a class or a particular student is progressing. As we collect more and more information from classrooms across the country, our software also will enable educators to compare the performance of students within their own school, as well as between schools. (In order to guarantee the security and confidentiality of the information we gather, we do not use names to identify students; instead, we assign each student a unique identification number, and we encrypt individual students' names so that they can be read only by school personnel and the students themselves.)

When students use software in the CC Portal, information is uploaded to our server in the form of log files, which are automatically parsed and inserted into a global database. Authorized students, teachers, and administrators can request any of a set of pre-defined reports. As we continue our research, our analysis of these data will become more sophisticated. The reports will become more insightful and useful to students as well as to teachers. Eventually, we envision an interface that will enable users to obtain customized reports.

The CC Portal grew out of the data collection and analysis requirements of the MAC project, but it will serve many projects and be an important part of the Education Accelerator (see page 11). Several Concord Consortium projects, sponsored by the Department of Education and by the National Science Foundation, are developing interactive curriculum materials in the form of structured activities based on manipulable models. This technology, which promises to deliver radical improvements in the teaching of math and science, also uses the CC Portal to generate detailed descriptions of students' interactions with the models.

The Internet has made it easy for us to collect detailed data from students using sophisticated applications in many classrooms simultaneously. The Concord Consortium Portal makes it easy for schools to participate in educational research of global importance. @

ARTICLE LINKS & NOTES

Modeling Across the Curriculum – http://mac.concord.org

Download software, access the CC Portal to view reports

Point your browser to http://mac.concord.org. On your first visit, you will need to register as a member. After registering, join the Concord Consortium Demo School and download the Modeling Across the Curriculum software to try out the activities. After completing an activity, login to the CC Portal and view student reports. You can freely download the software for your use at home or at school.

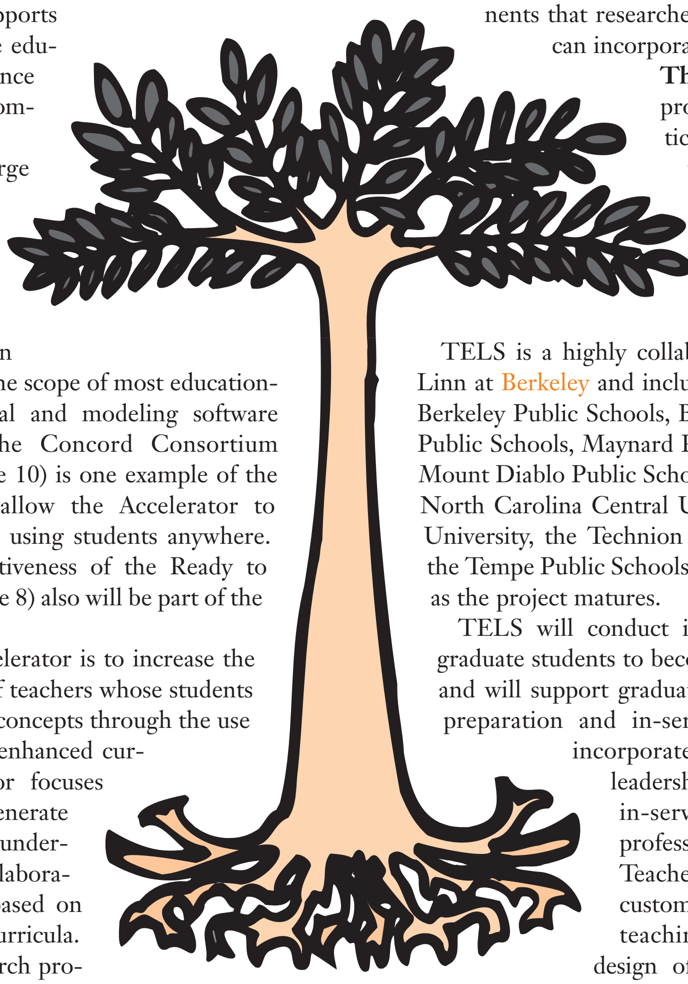
To use the software effectively with many students and teachers in a school, you should enroll your school in the Portal and specify an administrator. The administrator has the authority to register additional teachers, classes and students directly or to delegate the responsibility by creating custom Express Registration codes.

Whenever your students run an Accelerator activity, the software will track not only their answers to specific questions, but also the strategies they use to investigate the model: how long they take, which choices they make, whether their investigations appear focused or erratic, the number of times they ask for help, and how they react to that help. You can see reports based on these data. Please let us know what you think of these reports and how we could improve them.

The Education Accelerator Becomes a Reality

By Robert Tinker and Paul Horwitz

The Concord Consortium is one of the founders of the new Technology Enhanced Learning in Science (TELS) Center, a Teaching and Learning Center funded by the National Science Foundation at $2M per year for five years. By providing major funding for the Education Accelerator (see note), TELS supports applied research on the educational impacts on science of information and computer technologies.



Modeled on the large research institutions that do "big science," the Education Accelerator will do "big education" – projects requiring collaboration and resources beyond the scope of most educational research. The portal and modeling software described in the "The Concord Consortium Portal" article (see page 10) is one example of the technology that will allow the Accelerator to undertake large studies using students anywhere. Research on the effectiveness of the Ready to Teach program (see page 8) also will be part of the Accelerator effort.

The goal of the Accelerator is to increase the number and diversity of teachers whose students are learning important concepts through the use of proven, technology-enhanced curricula. The Accelerator focuses on research that will generate the required proof by undertaking large-scale, collaborative applied research based on technology-enhanced curricula. The Accelerator's research projects use powerful software tools and simulations embedded in online curriculum-based activities. These are designed to teach central topics in math, science, and technology through student inquiry and collaboration. Using sophisticated online assessment strategies, the curricula will be tested in numerous schools serving diverse student populations. All Accelerator software will be free and open source, and the supporting curricula and teacher professional development materials will be available free online for any non-commercial educational use.

Accelerator technology is aimed at fostering close contact between the researcher/developer community and the nation's K-12 schools. A useful metaphor to describe the Accelerator is a tree, where the leaves are the schools, the roots are the researchers, and the trunk is a growing collection of educational software. Here's how the Accelerator will nurture all three parts of the tree.

The leaves. The Accelerator will maintain a website where any school can go to obtain educational software and curriculum material, as well as detailed and timely reports on the academic progress of its students.

The trunk. The Accelerator will continually add to a library of inter-operable models and software components that researchers and curriculum developers can incorporate into their scripts.

The roots. The Accelerator will provide researchers with sophisticated tools that will simplify the implementation of scripts. It will link the researchers with testbed schools, enabling them to conduct projects on a national scale.

TELS is a highly collaborative effort led by Marcia Linn at Berkeley and includes Arizona State University, Berkeley Public Schools, Boston University, Cambridge Public Schools, Maynard Public Schools, Mills College, Mount Diablo Public Schools, Norfolk State University, North Carolina Central University, Pennsylvania State University, the Technion Institute of Technology, and the Tempe Public Schools. Other partners will be added as the project matures.

TELS will conduct internships that will prepare graduate students to become educational professionals and will support graduate faculty involved in teacher preparation and in-service delivery. Partners will incorporate the TELS materials into leadership programs, workshops for in-service teachers, and teacher professional development programs. Teachers will critique materials, customize curricula, test materials in teaching assignments, and shape design of new materials. TELS will provide graduate training for 20 Ph.D. students and 100 Certificate students. It also will provide teacher professional development for 1,000 pre-service students and for 500 teachers who will be engaged in Center workshops and online courses.

If you are interested in joining TELS as a student, post-doc, a research partner, or as a school, please contact TELS@concord.org. @

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Paul Horwitz (paul@concord.org) directs the Concord Consortium Modeling Center.

ARTICLE LINKS & NOTES

Technology Enhanced Learning in Science – http://www.telscenter.org

National Science Foundation – http://www.nsf.gov

Note: In the spring 2003 issue of @Concord, we dreamed out loud about the Accelerator. See http://www.concord.org/newsletter/2003-spring/perspective.html

Berkeley – http://www.berkeley.edu

Inside @concord for Fall 2003

Realizing the educational promise of technology

Concord Consortium News

Technology in Peru – The Education Development Center and the Concord Consortium will collaborate in Peru with the government's Huascaran Project to integrate technology-based components with local learning environments. We will work with three teacher-training centers and twelve rural elementary schools to improve educational practices with the support of information and communication technologies. The goal is to increase the capacity of participating schools to use technology to strengthen student-centered, intercultural, inquiry-based and collaborative learning environments. USAID's Alternative Development Program and the government of Peru fund the DOT-EDU initiative. Alvaro Galvis is the project leader from the Concord Consortium.

Students as Scientists – We have long advocated engaging beginning science students in research, and one of our favorite topics has been measurement of air quality. The strength of sunlight at different wavelengths is an easy way to monitor atmospheric haze and UV. Scientists need haze data and there are many experiments that require accurate measurements of sunlight. For instance, there may be a correlation between decreased UV and increased mosquito-born disease. Now the critical instrument for studies of this sort is available inexpensively from Radio Shack. Designed by Forrest Mims, a collaborator on many of our projects, the $29.99 Sun and Sky Monitoring Stations and its accompanying 64-page manual is an excellent way to get started.

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