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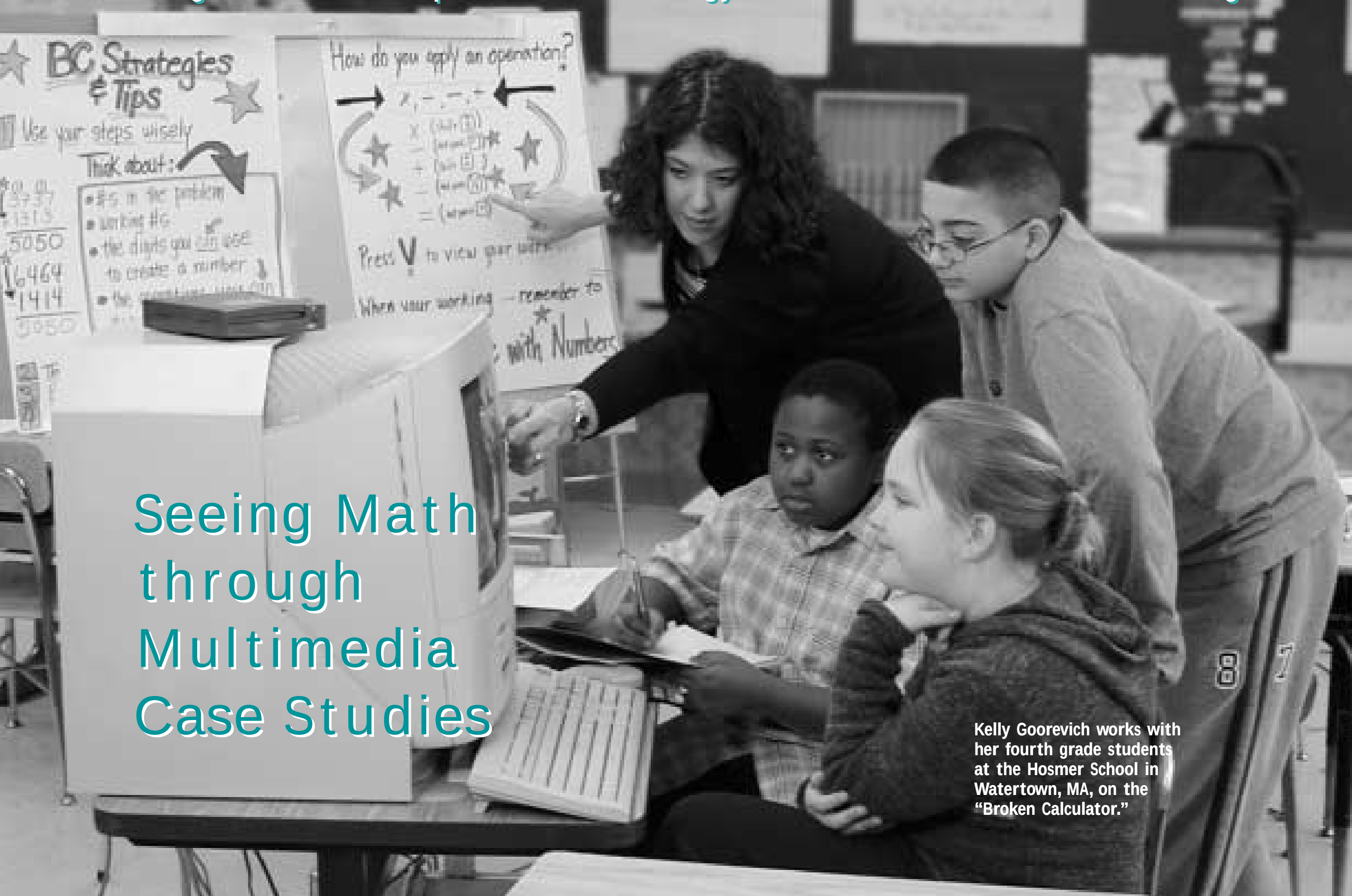

Seeing Math through Multimedia Case Studies

Kelly Goorevich works with her fourth grade students at the Hosmer School in Watertown, MA, on the "Broken Calculator."

By Joanna Lu and Raymond Rose

The case method is a powerful learning model. For years, schools of business, law and medicine have used case studies through which students explore real-life principles. By examining critical moments in a case, students enter vividly into the events and can carry the lessons learned into their professional lives.

The Seeing Math Telecommunications Project has added the force of audio, video, and interactive computer tools to the already powerful case study method. Seeing Math is developing nine Web-based video case studies that provide mathematics professional development for elementary and middle school teachers. These case studies use both real-life video narratives and guided inquiry to craft a unique learning experience. By going into real teachers' classrooms and presenting the problems they face and the solutions that grow from imperfect situations, Seeing Math provides a rich source of insight that all teachers can use to develop their own practice.

Creating the Cases

Each Seeing Math case study focuses on specific math content that is widely recognized as difficult to teach. Several months before taping, case developers from the Concord Consortium and Teachscape identified a teacher and class of students planning to study the math concept. Producers and math specialists talked with the teacher to understand the curriculum goals. The day before the lesson, the production team interviewed the teacher to understand her strategies and expectations.

Over the course of two or three taped class sessions, pre- and post-lesson interviews with the teacher, and a collection of student work, a number of stories emerged. The team decided what strands were most relevant, determined the storyline, edited the video, and shaped the Web-based materials.

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Perspective

The Educational Accelerator

By Paul Horwitz and Robert Tinker

The computer has been around for about fifty years now; the Internet, as far as most of us are concerned, for about ten. Together, these inventions have revolutionized the world of business and changed our lives forever. Yet there has been no comparable impact on schools. Why is this? Why has education, surely one of the more information-intensive sectors of the economy, failed to take full advantage of the Information Revolution? This is not a problem that can be blamed on schools or teachers; it is caused by an interlocking set of historical, economic, and policy forces.

One critical problem is that there are too few convincing real-world demonstrations that computers actually improve learning results – at least when applied to the standard curriculum and evaluated in a standard way. We know that, used well – with innovative curricula built around standards and embedded assessments – computers and software can do this. Indeed, decades of careful research have provided an "existence proof" that, combined with research-based pedagogy, computer use can result in significant improvement in students' learning.

But the unfortunate truth is that most educational research involves small-scale experiments with just a few students and teachers, often in an atypical setting. These results are not realistic enough to justify major changes in real schools. So the lack of school-based, large-scale demonstrations undermines the entire enterprise.

For this reason, we continue to urge large-scale applied research projects in schools. The required research must involve innovative technology integrated into substantial chunks of curriculum – units, courses, or sequences of courses. The approach should reinforce current teaching and address current standards, but also should exploit the power of technology to teach new things in new and more effective ways. This means developing new software, new authoring environments, and new computer-based assessments – all of which will require collaboration and innovation on a scale that is difficult for any one institution to achieve.

The Concord Consortium has been contributing to this important undertaking through projects described in this newsletter. Now we propose to expand these initial efforts into a national center that will bring the best people, theory, technologies, and instructional strategies to bear on long-term, large-scale research in educational technology. This national center – or Educational Accelerator – will include a partnership of outstanding schools and colleges, collaborating research groups, and a support infrastructure. It will foster additional collaborations between testbed schools, educational researchers, and instructional design experts. It will offer development, delivery, and assessment technologies that will make it possible to conduct research with schools and researchers located anywhere.

> Now we propose … a national center that will bring the best people, theory, technologies, and instructional strategies to bear on long-term, large-scale research in educational technology.

Educational technology is not a "frill"

Schools simply cannot afford to experiment with major innovations that exploit the power of technology, particularly innovations that require new curricula, new teacher skills, or new assessment strategies. Add to that

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Editor Robert Tinker
Managing Editor Cynthia McIntyre
Design Pointed Communications

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The Concord Consortium

> To realize the revolutionary potential of educational technologies will require large-scale research involving the collection of data from hundreds or thousands of teachers, and tens of thousands of students.

the fact that teachers and administrators still think of computers largely as machines with which to teach about computers. Few have a well-formed vision of the longer-term implications of the technology for education generally. With only rare exceptions, computer applications are seldom an integral part of texts or infused throughout a course in the current school atmosphere. Technology is viewed as an ancillary supplement that is usually left to the teacher to work into instruction. Overcoming these barriers will be a central role for the Accelerator, which will develop innovative curriculum units for full integration into course subjects.

An Educational Accelerator could:

- support the creation and dissemination of educational technology by developing, customizing, maintaining, and deploying infrastructure technology, including tools for developers
- train future leaders in educational technology through internships and summer workshops for master teachers, graduate students, post docs, and faculty
- recruit and support a network of testbed schools that will use the technology and share their experiences and data among themselves and with researchers
- acquire, store, and transmit to teachers and researchers data from the testbed schools relevant to technology use and student learning
- develop and share tools and techniques for analyzing such data, and for automating the generation and dissemination of such analyses
- host national and regional meetings on issues related to educational technology
- offer small "planning grants" aimed at the creation of new educational projects affiliated with the Accelerator, enabling the Accelerator to become self-sustaining

The Accelerator will focus on a subset of curriculum themes that can benefit most from information technology, including helping students visualize and experiment with abstract concepts that are difficult to convey by passive media such as text or static illustrations. It will adapt software tools and models developed by its partner institutions and add them to a common scripted learning environment. The Accelerator also will develop more powerful tools for automated data analysis and report generation. These technology enhancements will introduce a powerful new methodology for educational research – one that combines the capacity to capture fine details of the learning process with the large-scale dissemination required for evidence-based studies. To ensure wide adoption and continued support, all Accelerator software will be open source and all curriculum materials will be free to participating schools.

Another barrier to more effective use of computers in schools includes the cost of professional development. The best uses of computers involve relatively independent student explorations in small groups. This way of learning runs counter to the prevailing culture in many schools, particularly at the high school level. Professional development aimed at institutional change in this area is required, but funding for such services is likely to be the first thing cut by school boards and administrators in a time of fiscal constraint. All materials produced by the Accelerator will, therefore, include online, self-paced or instructor-facilitated courses intended to help teachers to use them effectively in the classroom.

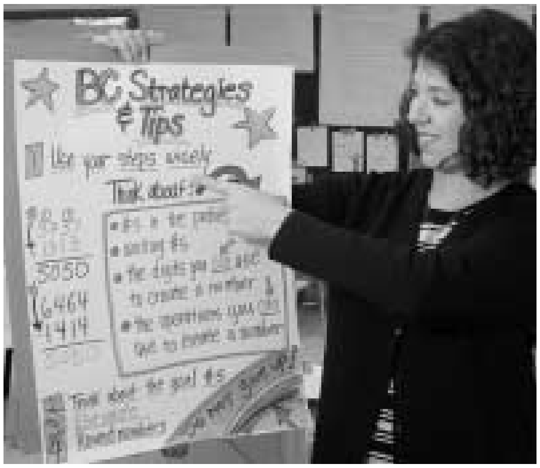
To realize the revolutionary potential of educational technologies will require large-scale research involving the collection of data from hundreds or thousands of teachers, and tens of thousands of students. A national center, such as the Educational Accelerator, can provide the volume of data that will further demonstrate the value of computers in education for all students. With this data, schools will reap the benefits and, at last, join the Information Revolution. @

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

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

→ PAGE 1

The storyline always integrates two essential elements – a math content strand that is aligned with NCTM standards, and a classroom pedagogy strand (see "Seeing Math Video Case Studies" on page 5). This integrated approach helps participants use the case as both a window into another's practice, and a mirror for reflection on their own teaching of math. Watching and analyzing the way teachers make decisions about their teaching leads participants to make better analyses and decisions about their own teaching.



The Broken Calculator case study encourages alternative problem-solving strategies.

Commentary Spurs Reflection

Video commentaries augment each case with views of the featured classroom from different perspectives – that of the teacher reflecting on the lesson she has taught, and that of a math content specialist offering additional insight. In the teacher commentary, the case teacher describes her expectations of the lesson as she envisioned it before taping. Following that, she may share her reflections about the classroom experience as it actually unfolds. Did the students "get it"? What worked and what would she change next time? Listening to a fellow teacher reflect on her practice offers a way for teachers to identify with another professional encountering the same problems and modeling a path to solutions.

Specialists from the field provide expert commentary on the case study teacher's classroom management skills, and help participants see beyond this single experience to understand other mathematical approaches to the same problem.

Inquiry-Based Professional Development

While the video narrative is the starting point, there is also a rich surround of supporting materials. The support materials answer questions about the school location, demographics, and how the featured lesson fits into the curriculum. There are examples of student work with guidelines for assessment, as well as the teacher's lesson plan. A math "diving in" activity – often using an interactive tool – helps participants understand the mathematics from the students' point of view. Teachers thus must wrestle with the same problem with which their students wrestle.

In addition, User Guides for both the course facilitator and the participants lay out a path for the course and pose activities to guide reflection on the case.

Open-Ended Presentations

Often student thought is highly original, but in real time, in a classroom, it may be difficult to understand. A video case offers the luxury of multiple chances to listen, review, and even study transcripts of what a student says. Read the transcript below and see if you can figure out what the student is talking about as he tries to explain why he concluded that 5/18 is closer to 1/4 than 1/3.

Teacher: So, how did ... tell me about the tally marks. How did you use those tally marks? How did you come about 1/4?

Student: Because first from five, you have to multiply three and it's fifteen, and then we try four ... five times four, which is twenty. So, um, twenty, is, um, two above from eighteen and fifteen is three less than eighteen so we decided 1/4...

Teacher: Oh, all right.

From Number and Operations: Fractions
Jennifer Bradley's 4th grade class
Timmerman Elementary School, Pflugerville, Texas

What was the student's strategy? Did it lead to the correct answer? Why would it work … or not work?

As any good storyteller knows, sometimes the greatest impact on learning comes not from what is told, but what is not told. Sometimes the strongest way to encourage reflection is not to resolve a problem shown in the case. Therefore, sometimes a video episode ends without a tidy resolution, and the participant is asked in the surrounding materials to reflect on how, in a similar situation, she might encourage her own students to move to a deeper understanding. In these cases, the video is a starting point for the teacher to think "what if this were my class and these were my students, what would I do?" @

Joanna Lu (joanna@concord.org) is Project Manager of the Seeing Math Telecommunications Project.

Raymond Rose (ray@concord.org) is Vice President of the Concord Consortium.

ARTICLE LINKS & NOTES

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

Teachscape – http://www.teachscape.com

Seeing Math Video Case Studies

Numbers and Operations

Division with Remainders

For 4th and 5th graders, division with remainders and the inverse nature of division and multiplication are key ideas. Nancy Horowitz and Mary Beth O'Connor present the same lesson. Students in each class build understanding about the nature of the division by creating and solving their own story problems.

Content: Division with remainders, problem solving, inverse nature of division and multiplication, division as sharing or partitioning
Pedagogy: Using effective questioning strategies, encouraging students to graphically represent abstract ideas
Location: Springfield, MA

Fractions

Jennifer Bradley's 4th grade students expand their understanding of fractions as parts of a whole to understanding fractions as numbers. They use multi-link blocks, folded number strips, and number lines to compare magnitudes of "familiar fractions" with fractions they generate from data about the classroom.

Content: Number sense, fractions, part/whole relationships, comparing fractions
Pedagogy: Using linear models of fractions to build understanding of fractions as a quantity, understanding different meanings of fractions
Location: Pflugerville, TX

Broken Calculator

Stacy Riggle's 3rd grade class explores division of large numbers using a "broken calculator" strategy: students must use handheld calculators that are limited by a division key that does not work. Kelly Goorevich's 4th grade class uses the Broken Calculator program – with various keys and operations disabled in the software – to explore addition and multiplication problems.

Content: Number sense, grouping, relationship of multiplication and division, relationship of addition and multiplication, place value
Pedagogy: Alternative problem solving strategies, communicating mathematical ideas, using technology to support learning in mathematics
Locations: Pittsburgh, PA; Watertown, MA

Geometry

2D and 3D Figures

Students in Jeanine Airesman's 4th grade class build rectangular prisms using straws and connectors, then describe and compare their constructions. They use a workbook, along with wooden polyhedral solids and other shapes, to solve riddles about faces and vertices. Students also draw 2D representations of their 3D shapes.

Content: Geometry, 3D description, 3D to 2D representation, reasoning and proof
Pedagogy: Using models to support close interpretation of text, building understanding by translating 3D models to 2D representation
Location: Pittsburgh, PA

Calculating the Area of a Triangle

Traditionally students learn to find the area of geometric shapes by using formulas. Noreen Winningham guides her 5th grade students as they build a foundation for understanding the area of a triangle and methods to calculate it before learning the standard formula.

Content: Geometry, measurement, symmetry, representation, reasoning and proof
Pedagogy: Using personal experience to inform a concept of area, applying multiple strategies to solve problems, student writing in mathematics
Location: Evanston, IL

Fourth graders Denzel, Eddie and Stephanie use alternative strategies for solving a problem with the Broken Calculator.

Pre-Algebra

Pan Balance Equations

Audrey Soglin's 5th grade class manipulates concrete representations of equivalence, using pan balances to understand the nature of equations and operations on equations.

Content: Algebra, equivalence, operations on equations
Pedagogy: Using 2D and 3D models to represent abstract processes, value of a challenging problem
Location: Evanston, IL

Functions

Leyani von Rotz's 4th grade students develop their ideas about functions, patterns and predictions by exploring linear growth patterns of tile arrangements. Using T-charts, students compare stages of growth with the number of tiles used at each stage. They generate rules that permit them to make predictions.

Content: Early algebra, functions, patterns, graphing, prediction, generalization
Pedagogy: Using patterns to support inference, understanding the difference between deductive and inductive inference
Location: Emeryville, CA

Data Analysis and Probability

Using Data to Make Predictions

This case presents ways to support NCTM standards for grades 3-5 that invite students to collect, analyze, and make predictions from data. The video shows two lessons from Rhonda Singleton's 5th grade class. The first explores mathematical fairness. The second shows the relationship between sample size and accuracy of predictions about a population.

Content: Collecting data, making graphs, data analysis, making predictions, probability
Pedagogy: Collaborative learning, games to support learning, addressing misconceptions
Location: Myrtle Beach, SC

Data Sets and Measures of Center

Students collect, organize and analyze data to determine maximum, minimum, range, mode, median, and mean. Thirty percent of Lala Sahakian's 4th grade students have arrived in the U.S. during the past 18 months. Teaching in an ESL class presents unique challenges. Not only must a teacher ensure students understand math content, but she must also assess understanding when students lack strong language skills for communicating their ideas.

Content: Data sets, data analysis, measurement, representation
Pedagogy: Teaching mathematics to ESL and ELL students, using concrete experiences to ground terminology
Location: Glendale, CA

Reflecting On Monday’

Using VideoPa

By Cara DiMattia and Daniel Cogan-Drew

Reflecting on one’s practice is an important part of teaching. The classroom, however, is a constantly moving place – it is very difficult to isolate particularly puzzling moments or review questions raised by students without stopping the flow of a lesson. Video is an excellent way to capture these fleeting but important moments. This *Monday’s Lesson* focuses on what you can do professionally as a teacher-practitioner to reflect on your teaching.

VideoPapers facilitate the use of video for reflection on classroom experiences, and the exchange of ideas through an accessible and engaging medium. VideoPaper Builder 2 (VPB2) is software designed to enable computer users of average ability to create multimedia documents, which closely link text and video, thereby grounding commentary directly in classroom data.

These primary sources of data – video from the classroom and a teacher’s written reflections – become the basis for discussion among professional colleagues. The video footage is supplemented by the use of still images captured from the video itself (notes from the board, a student’s facial expression), scanned content (student work, teacher handout), or other digital images of interest (explanatory diagrams, graphics).

VideoPapers may be published via the Internet or on CD-ROM. Educators are thus able to observe each other’s classrooms and to discuss their responses, both to the videos and to the author’s reflections in a meaningful way.

Local Teacher Professional Development

Unlike numerous professionally produced teacher development videos, the VideoPaper is produced and distributed locally within schools or across neighboring districts. The content is shot and edited by the teachers themselves, for use and exchange with each other; the video clips contain images of educators and students in the community. The context for the filming is immediate, and the strategies the film illustrates are applicable to the intended audience. The voice and message of the author is trusted; it speaks from a common experience. The authenticity of this voice earns it recognition and regard not often accorded the professional development “expert” who is typically invited to address an unknown audience of teachers.

A vehicle for presenting useful strategies to her colleagues, the VideoPaper also provides its author with an equally significant opportunity to reflect on her own teaching. The need to explain fully the theory and practice of their teaching techniques requires that teachers have a profound knowledge of their own content. The act of creating a VideoPaper becomes a process of professional self-development.

VideoPaper Builder 2

System Requirements

Windows

Windows 98, NT, 2000, or XP

QuickTime 6.0 Full Install (including QuickTime for Java)

Java Runtime Environment 1.3 or greater

Web Browser (Netscape 4.x or Internet Explorer 5.x)

Mac

Macintosh OS X 10.1 or greater

QuickTime 6.0 Full Install (including QuickTime for Java)

Java Runtime Environment 1.3 or greater

Web Browser (Netscape 4.x or Internet Explorer 5.x)

Download VideoPaper Builder 2

VideoPaper Builder 2, a new version of software originally developed at TERC, is a tool for users with moderate technology experience. VPB2 is free, open source software; it is both Windows and OSX compatible.

1. Point your Web browser to: http://vpb.concord.org
2. Click on “download,” then choose the appropriate file for your system:
   VPB2 for Windows (14.6 MB)
   VPB2 for the Mac (4.1 MB)
3. The software will download to your desktop and expand automatically. Click on the Installer and follow the step-by-step directions to install the software.

To create a VideoPaper, you will need three types of files: digital video files (.mov, .mpg), text pages converted to .html format, and images (.gif, .jpg).

This classroom episode is part of an Advar High School in Boston, Mass. Because the Creole and English, the students' gestures cussion and explanations. This VideoPaper

's Lesson

aper Builder 2

The technology skills required to use VideoPaper Builder 2 are easy to learn and useful in many other contexts. For instance, the process of shooting and editing video requires the author to become familiar with digital video cameras and to learn how to use a basic video editing software, like iMovie.

The text pages can be produced in a word processor and converted to HTML format. Word processors such as Microsoft Word have an automatic "save as HTML" function; learning to author HTML (web page) documents may be another valuable skill.

nced Algebra course at the Jeremiah Burke
e class is bilingual, speaking Cape Verdean
are important in understanding their dis-
focuses on their use of gestures.

Images used in the VideoPaper (as "slides" that are synchronized to the video) can be captured as stills from the video itself, scanned images of handouts, student work, photographs, or other graphics. The author may learn new skills with a scanner, a digital camera, or a digital image editing software (such as Adobe Photoshop).

VPB2 generates menus, links, framesets, and image slide shows in order to interconnect the author's video and text. These elements are then organized into a single multimedia presentation. The final product is viewable on a Mac or a PC, using an Internet browser, such as Internet Explorer or Netscape Navigator.

Tutorial

For a quick "10 Easy Steps" tutorial, point to the following address in your Web browser:

http://vpb.concord.org/help/tutorial.html

The VideoPaper Builder Web site also includes a complete User Guide, sample VideoPapers, and a Community area for exchanging information and ideas regarding the use of VPB2.

When you create your VideoPaper, share it with us. Post a URL to your VideoPaper in the Community area and we can all reflect on Monday, Tuesday or Friday's lesson. @

ARTICLE LINKS & NOTES

TERC – http://www.terc.edu

VideoPaper Builder 2 – http://vpb.concord.org

VPB2 Tutorial – http://vpb.concord.org/help/tutorial.html

iMovie – http://www.apple.com/imovie

Adobe Photoshop – http://www.adobe.com/products/photoshop/main.html

The VideoPaper Builder 1.0 software was originally developed as part of the Bridging Research & Practice project at TERC and funded by the National Science Foundation (Grant #9805289). VideoPaper Builder 2.0 was developed in partnership with TERC by the Seeing Math Telecommunications Project at the Concord Consortium through funding from the U.S. Department of Education (Grant #R286A000006).

Cara DiMattia (cara_dimattia@terc.edu) is a multimedia developer for the Bridging Research & Practice project at TERC.

Daniel Cogan-Drew (daniel.cogan@tufts.edu) is Administrator of the Curriculum Resource Center at Tufts University.

Through a Teacher's Lens

By Chris Mainhart and Maggie Woodcome

"Looking at the video with someone else was the most important part of the professional development experience." Maggie has expressed this sentiment over and over again as we talk to other educators about the VideoPaper case we developed together.

After collecting video in her 7th grade mathematics classroom, Maggie and I revisited the footage several times in an effort to tell a mathematical story. We had different purposes for collecting and viewing the video. Maggie saw a genuine value in the reflective process that comes from viewing the same video several times. As the math staff developer, I also relished the opportunity to share my comments and questions. I could emphasize different aspects of her teaching that contribute to student success. Trust was an essential element that allowed us to work in this manner. We devoted many hours to building the VideoPaper in an effort to analyze the teaching and instructional strategies implemented in her classroom.

The classroom story will vary depending upon the focus of the teachers involved. The issue that spoke to us was student voices – Maggie created opportunities for students to be seen as math experts. Building the VideoPaper allowed us to highlight the importance of giving students time to share their mathematical thinking. Other teachers might see different storylines.

Teachers can use this process to reflect on their own practice and to discuss the pedagogy and content with other teachers. We gained immeasurably from having focused our attention on teaching and encourage other educators to use VideoPapers to do the same.

Chris Mainhart and Maggie Woodcome
are at the Hudson Public Schools in Massachusetts.

Video Case Studies:

Grounded Dialogue Matters Most

By Alvaro Galvis and Ricardo Nemirovsky

How do teachers engage with professional development video case studies and what do they learn from them? These have been some of the driving research questions of the Seeing Math Telecommunications Project (see also "Seeing Math through Multimedia Case Studies" on page 1).

Using spring and fall 2002 data from teachers in South Dakota, Vermont, Washington, D.C., and Massachusetts, we have identified two critical aspects that make a significant difference in the depth and quality of the professional development outcomes:

- Grounding the discussion in the specifics of the video case.
- Integrating the events of the video case with actual ongoing events in the classrooms of the participating teachers.

To illustrate these points we selected the following excerpts from online postings in the Seeing Math professional development courses. We start with a facilitator's "seed" and two responses.

Facilitator: How can the questioning strategies in this case study serve all the students, not just those in the middle but the strongest and the weakest ones as well? Do the strategies offer a way to strengthen teaching and learning for all these students simultaneously?

Teacher: I think that the questioning strategies and students' responses allow the higher level thinkers to rethink their process and allows the lower level students to gather more information on different processes that were used.

Teacher: I think that using a variety of questioning strategies strengthens all students. Students need to hear the way other students think and understand the processes. When a variety of ways are discussed, all students reap the benefits.

Notably, these messages are devoid of specific references to the video case. Rather, the teachers respond with general statements reflecting their already held beliefs about the value of "questioning strategies" whose nature is not spelled out. The video cases play only a marginal or superfluous role in the exchanges. Further, we could not identify instances in which the teachers had changed or enriched their views.

In order to deepen the discussions and the rich potential of the video cases for teacher professional development, we realized the need to "ground" the discussions in the particulars of the video case and the actual experiences of the teachers in their classrooms. This shift of facilitator strategies was apparent during the fall 2002 course.

Facilitator: What statements did you hear in the introduction that caused you to begin reflecting on the traditional method of teaching division? Did anything Mary Beth or Nancy said "ring a bell" with you?

Teacher: When they presented the arrays for division facts and then discussed using manipulatives, I realized that I had really reinforced the notion that mastering the algorithm for division was the be-all and end-all of division, rather than to help my students to develop a solid numerical understanding of what it means to divide and how to fluently describe division with language.

Teacher: Now I am starting to utilize the ideas presented with arrays – manipulatives and writing of problems. I am teaching multiplication now and will have the kids write their stories tomorrow.

Here, the facilitator requests commentaries on particular utterances included in the video case. Teachers respond to examples in the video case with reference to the practices in their own classroom, regarding their own teaching.

The Seeing Math project has learned that sustaining rich, grounded discussions – grounded in the video case as well as in actual ongoing stories from the participants' classrooms – is the facilitator's major role. This role needs to be made explicit and actively supported. @

Alvaro Galvis (agalvis@concord.org) is Senior Researcher at the Concord Consortium.

Ricardo Nemirovsky (ricardo_nemirovsky @terc.edu) is Senior Scientist at TERC.

Seeing Math's Vision

Video cases should:

- Be analyzed, not imitated
- Initiate shared inquiry about the object of study, rather than transmit a given teaching model
- Be authored by a professional group of producers and educators
- Adhere to a production standard, while allowing flexibility for the uniqueness of each case
- Exhibit a clearly defined pedagogy, as chosen by the creator of the video case

Teacher Professional Development using video case studies should have the following characteristics:

- Facilitator moderates from the side, not from the center – in either face-to-face or Web dialogue
- Discussions are driven by both professional and personal interests and needs
- Discussions are focused around both local and shared, "supralocal" issues
- Participants are both intrinsically and extrinsically motivated and rewarded
- Discussions are grounded in video and classroom experience – not merely in participants' ideas and opinions
- Video case study and classroom practices are integrated

CC Resource Center Offers Free Software and Curriculum

By Robert Tinker

We have developed exciting software, curricula, and tools that are available to you – for free! We hope you will use these materials, distribute them, critique them, and tell us about your experiences.

You do not need to be a member of the Concord Consortium to get these materials, but we encourage you to join at our Web site. Joining is free and easy, and you will not be added to any of our mailing lists unless you so request. We just like to know who is using our software. As a member, you'll also have access to a community discussion area for sharing stories of your successes or for troubleshooting technical glitches.

To access these materials, go to our Web site and click on the CC Resource Center. You'll find additional information and detailed instructions for downloading software and other tools. There are several kinds of material from which to pick and choose, according to your subject area or research interest. Whatever interests bring you here, we hope you'll find something you can use.

Genetics Modeling Activities. The BioLogica software consists of 13 stand-alone activities that enable students to learn classical genetics through guided exploration. There are also assessments and an open-ended version.

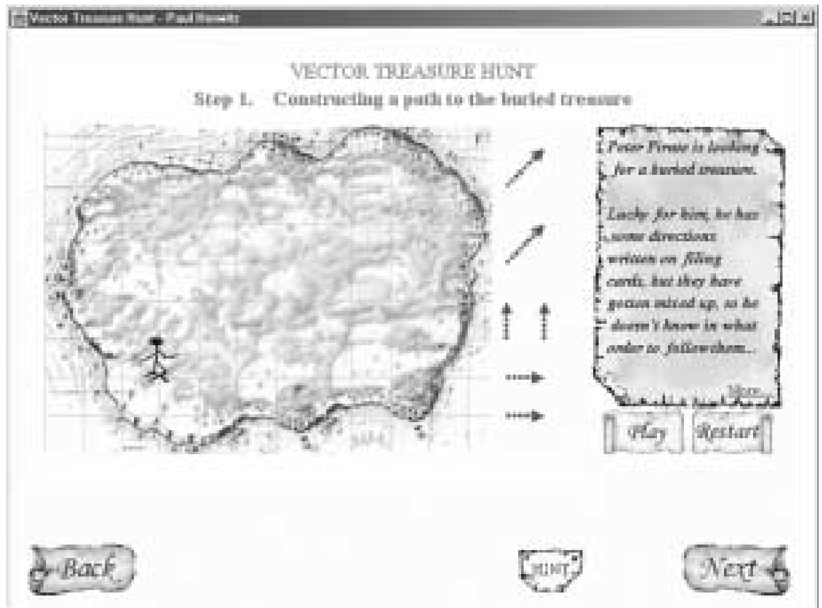
Molecular Modeling Activities. There are 14 activities and associated curricula that use molecular dynamics models to allow students to explore the ways atoms and molecules determine the basic properties of matter. Activities cover diffusion, phase change, compression, heat transfer, the gas laws, dissolving, and osmosis.

Dynamics Modeling Activities. Five activities focus on vectors and elastic collisions, topics addressed in middle school physical science and physics.

The Concord Modeling Workbench. This large collection of activities uses molecular dynamics along with an authoring environment that allows you to make your own student activities. The content is similar to the modeling activities listed above, but also includes chemical reactions and protein conformation. (See also "Experimenting with Atoms and Molecules" on page 10.)

Sustainable Future Applications. Three applications and curriculum units help learners think about the future. For example, the simple "What If? Builder" allows students to create and share branching stories that have alternative endings. Also available are the "Ecological Footprint Calculator" and the "Community Planner."

Video Case Studies. We currently have a video case study of the use of a pan balance for developing a sense of equivalence. This case study features professional video segments linked to student work, class notes, standards, and commentary. This can be used as a stimulus for discussions and reflection on elementary or middle school mathematics teaching practice. (Due to the nature of these materials, we will need to verify your educator status before you can view this case study.)



With this dynamics modeling activity, students learn vector addition while helping the pirate find the treasure.

VideoPaper Builder 2 (VPB2). This application simplifies the creation of classroom video case studies. The resulting case studies can be used to stimulate reflection on teaching strategies. (For additional information on VPB2, see "Reflecting on Monday's Lesson Using VideoPaper Builder 2" on page 6.)

This list will expand, so please return to the CC Resource Center regularly for new software. Additional materials – including NetLogo activities, molecular biology models, and a system dynamics package – are under development. Members can request email notification when additions or updates are available.

All our software is open source, which means there will never be a charge for it and others are welcome to improve on it. As a result, many people will be able to support the software into the future.

Please use these materials and share them with your colleagues. They are all based on solid instructional theory and most have been tested in classrooms. The materials share an educational vision that uses student exploration of models and tools to revolutionize learning. Help us realize this dream. @

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

Experimenting with Atoms and Molecules

Molecular Dynamics lays the foundation for science reform

By Robert Tinker

Atoms and their properties determine our world. The way atoms and molecules bounce, stick, stretch, bend, combine, fall apart, and interact determines what you feel, touch and see, how every living thing grows and dies, and why we use certain materials in our environment. Most of the important modern technologies – molecular biology, chemistry, nanotechnology, electronics, cryogenics, lasers, and composites – can be understood only by considering atoms and their interactions. The common thread of atomic-scale interactions could integrate the sciences and technology around a few core ideas that run through the entire curriculum.

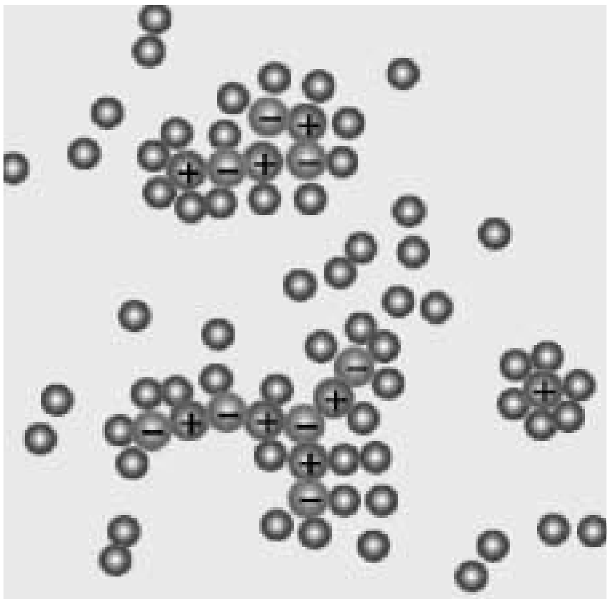


Figure 1. An ionic crystal dissolving in water. The ions are labeled with plus and minus signs. All the ions are surrounded by uncharged water molecules represented here by unlabeled balls. When this model is run, the ions tend to clump, but if there is sufficient water, they become completely surrounded with water "snowballs," one of which can be seen on the right.

One of the reasons that the connections between macroscopic and microscopic properties are not well addressed in the typical curriculum is that the order of subjects is wrong. The basic ideas of atomic-scale energy conservation, temperature, heat, pressure, electrostatic forces, and electrons belong in physics. But physics is usually taught after chemistry and biology, which need to build on these ideas. Worse, physics courses usually fail to apply mechanics and electrostatics to atoms and molecules. Physics or physical science at the ninth grade should address atoms and molecules to support subsequent chemistry and biology courses, but they rarely do.

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Enter computers. Now it is a simple matter to model lots of atoms that collide according to Newton's Second Law applied to the kinds of forces that actually exist between atoms. This is called a molecular dynamics (MD) model. Students can understand the forces that apply to each atom in such a model and experiment with ensembles of lots of them. The gas laws are an experimental result of such a system. Students can even observe non-ideal behavior in a very dense gas of attracting atoms or molecules.

This is an example of the many macroscopic properties that "emerge" from simple laws governing the microscopic world. It is not at all obvious that the gas laws will emerge from classical mechanics applied to interacting atoms, but a molecular dynamics model can convincingly demonstrate that this is so.

Molecular dynamic models can help students discover:

Energy conservation. Put any number of atoms in a "box" and start them each off at any velocity. The total energy of the system will stay constant.

Temperature. Each atom in a mix of atoms in a box – whether small, large or part of a molecule – will have the same average kinetic energy, defined as temperature.

Thermal conduction. Put a hot gas of fast atoms in contact with a cold gas of slow atoms. The hot gas will cool and the cold one will warm until the two are the same temperature.

Entropy. Start a model with atoms arranged in some distinct pattern; the atoms always end up looking essentially the same, bouncing around at random.

Phase change. At high temperatures, a collection of atoms resembles a gas. Remove energy and it will condense into a disordered, dense swarm – a liquid. Continue removing heat and the atoms become ordered – a solid.

These examples are only the beginning. The ideal and non-ideal gas laws, vapor pressure, diffusion, dissolving (see Figure 1), osmosis, filtering (see Figure 2), breaking, and many other basic phenomena can be understood by exploring MD models.

Molecular dynamics provides another way to understand relationships such as the gas laws. "Laws" such as these are no longer seen as the mysterious result of an abstract mathematical derivation, but can now be understood in the light of something new: simple, quick computer experiments. Because these experiments are more accessible to young learners, it should be possible to use them to make new connections between subjects and to give students a far better understanding of large segments of science. New three-dimensional, interactive models make it possible to visualize cause and effect, turning abstract, theoretical ideas into concrete phenomena.

Indeed, our initial classroom experiences indicate that middle and high school students can learn through experimentation with molecular dynamics models; they can understand atomic-scale models, relate them to macroscopic phenomena, and transfer their learning to new situations. Encouraged by our initial findings, we are in the process of extending our models to encompass new content: chemical reactions and protein conformation.

The molecular dynamics work at the Concord Consortium is laying the foundation for major reform in introductory science teaching that focuses on atoms, molecules, their interactions, and how these determine macroscopic properties. We encourage you to use and modify the software and curriculum materials. Please see "CC Resource Center Offers Free Software and Curriculum" on page 9 for additional information. @

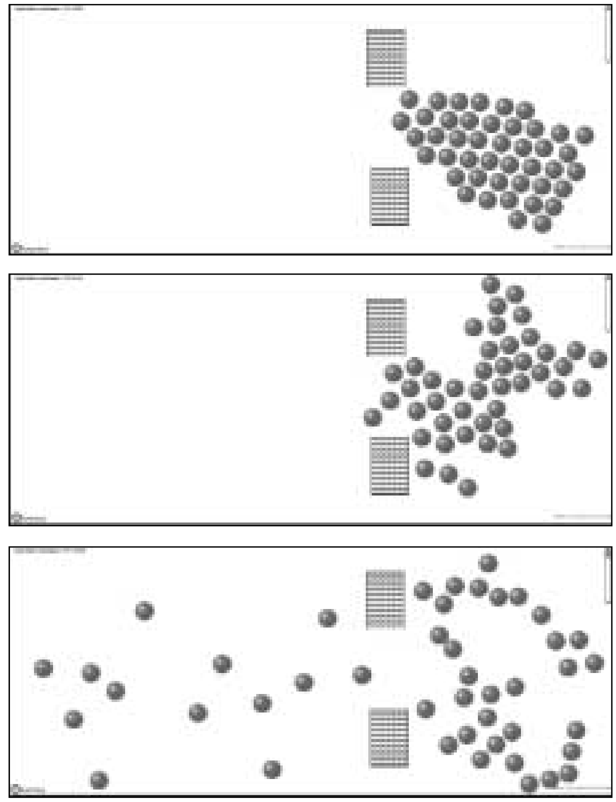

Figure 2. A solid, liquid, and gas encounter a sieve. Here a sieve or filter is modeled by two barriers shown as brick rectangles. When the model is run at a low temperature (top), the balls form a rigid crystal that is trapped on the right side of the sieve. When the temperature rises (middle), a liquid forms, but it still cannot squeeze through, because the atoms attract one another. This illustrates surface tension. Further heating (bottom) creates a gas that can get through. (To appreciate fully these images requires seeing the models evolve dynamically and interacting with them.)

MODELING ACROSS THE CURRICULUM

The Concord Consortium invites interested high schools to join *Modeling Across the Curriculum* (http://mac.concord.org) as contributing schools. This NSF-funded project is a three-year longitudinal study of the effects of modeling technology on science learning. Implementations in three Massachusetts high schools began in 2002-2003 and ten additional U.S. schools were selected to participate in 2003-2004. We are observing students closely in order to measure cumulative gains in science content areas. Our main concerns are to determine whether computer-based modeling helps students learn to use mental models as explanatory devices, and if so, whether student modeling ability is transferable between content areas.

Contributing schools will be provided with two-week replacement curriculum units in Physics, Chemistry, and Biology that include embedded assessments and teacher manuals.

Subject	Replacement Units
Physical Science	Kinematics, Newtonian Mechanics
Chemistry	Gas Laws, States of Matter
Biology	Genetics, Population Dynamics

Benefits to teachers include access to information in the project database. Student work is recorded and organized, allowing teachers to see how students approach and find solutions to problem-solving activities. By logging answers in each activity, we generate individualized reports for each student with information such as:

- Answers to multiple-choice questions
- Relevant student actions as they run models and manipulate variables to solve problems
- Numbers of trials needed to arrive at target outcomes successfully
- Readouts of hypotheses and conclusions
- Activity scores

Further data analysis provides teachers the ability to compare answers to each question across the class, giving an overview of class needs and strengths.

For more information contact:
Paul Horwitz, Principal Investigator – paul@concord.org, 978.371.5856
Joanna Lu, Project Director – joanna@concord.org, 978.371.1339

Inside @concord for Spring 2003

Realizing the educational promise of technology

Concord Consortium News

The Virtual High School – Seven years ago, the Concord Consortium, along with Hudson Public Schools, created the Virtual High School®. Although there have been many imitators, the Virtual High School remains the innovative leader, offering the highest quality courses for the least costs using a cooperative model. A book that chronicles its development and quality has been published recently by the project evaluation team: Zucker, A., et al. (2003). Teaching Generation V: The Virtual High School and the Future of Virtual Secondary Education. New York: Teachers College Press. The VHS is now a separate non-profit dedicated entirely to providing excellent online secondary courses. This is an outstanding example of how grant-supported R&D can be converted into a permanent service post-funding. The Concord Consortium is proud that VHS is now standing on its own and has been for two years. http://www.goVHS.org

Online Learning Services – Concord Consortium offers online courses based on our two books: Facilitating Online Learning: Effective Strategies for Moderators and Essential Elements: Prepare, Design, and Teach Your Online Course. http://www.concord.org/courses

The Concord Consortium

10 Concord Crossing, Suite 300
Concord, MA 01742

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