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Probing the Unseen World

Advanced Probe Captures Subtle Changes in Temperature

Students measure changes in water temperature with an ultra-fast response temperature probe connected to an iPaq handheld computer.

By Stephen Bannasch

When students use both sensor- and model-based computer visualizations, will they gain a deeper understanding of the difficult concepts of heat and temperature? Can we extend that learning experience to the investigation of conductivity and thermal gradients in different materials? Can we go even further to include the concepts of radiation and convection, the subtleties of which are far more difficult to grasp? These are some of the questions driving our research with middle school students as we work with them to conduct hands-on experiments in temperature and heat flow.

Through our many years of work on models and probeware, we have encouraged students to use these tools for understanding the world around them. Now we are excited about a new development that will help them understand natural phenomena on a much deeper level.

For the Data and Models project, we have created an ultra-fast response temperature probe (Figure 1, page 4). This new generation of highly sensitive probeware enables students to easily conduct investigations into heat and temperature phenomena that we only imagined possible before now.

Thermal Conductivity...from our skin's perspective

The first heat and temperature sensor most of us use is our skin. When we make a snowball in the winter or walk over hot beach sand in the summer, our brain uses information relayed by nerve cells under our skin to decide whether something is "too hot," "too cold," or "just

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Perspective

Jump-starting a Revolution in Learning

By Robert Tinker

We are on the verge of an educational revolution, one enabled by computers and networking. The revolution, however, may stall before it starts due to the lack of innovation. Effective educational technologies require careful development and long-term support and funding; it is not clear where these funds will come from.

Current research is showing how technology-rich materials could revolutionize education. The mechanisms are in place to disseminate such materials. Yet there is insufficient funding to create the materials in the first place. Applied research and materials development is desperately needed if we are to fully realize the educational potential of technology. Innovative, technology-rich materials could trigger sweeping improvements in teaching and learning in all grades and subject areas.

> Education is a national security issue because education is fundamental to the economy and to the quality of life.

Education is a national security issue because education is fundamental to the economy and to the quality of life. Compared to the cost of traditional aspects of national security – the military, intelligence agencies, and the new homeland defense initiative – the funds required are trivial.

To generate technologies that could improve K-14 education broadly, an investment is needed at the level of $100M per year over five to eight years. While this is a huge sum, it is far less than the total funding from federal and private sources for educational technology, currently between $1 billion and $2 billion per year.

Funding is needed to support roughly 50 innovative projects at $2 million per year. Each project would address national needs in a particular subject and grade range from elementary through beginning college. The funding would cover software development, the creation of activities that could be disseminated widely online, initial research, materials evaluation and revisions, and related teacher professional development strategies.

Again and again, scientists, business leaders, government panels, and educators have called for this level of funding. For example:

Scientists. The Federation of American Scientists recently released a report that quantifies the low level of support for these materials internationally. This report states:

"Given that the private sector is principally interested in identifying relatively immediate, profit-making ventures, government investment in education research is extremely important, necessary and justified if educational systems are to maximize the use of technology."

Business leaders. Last year, the CEO Forum published a report urging policy-makers to expand support for educational technology investments. Their recommendation for research and development is:

"The federal government should increase its investment in dedicated education technology research and development to at least $100 million. This is similar to the education technology proposal made by President Bush during the fall campaign. Research and development should be used to determine the most effective technology methods to improve student achievement, and support the development of assessment tools that measure 21st century skills."

Government. In 1997, a report by the President's Council of Advisors on Science and Technology (PCAST) warned that the promise of educational technology would "remain unfulfilled in the absence of a significant increase in the level of funding."

Educators. Last year Harvard's Prof. Chris Dede provided detailed

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The Concord Consortium

The result could be explosive. In a few years, a broad range of research-based, classroom-tested materials that make good use of technology could be available online free or at low cost.

testimony on the appropriate role of government in technology-enhanced education. He said that "ten percent of federal and states' total investments in learning technologies should be directed to educational research and dissemination, with emphases on sophisticated curriculum development."

Because the required effort would need to be funded with public funds, the software and materials should be made available to schools free or at a nominal cost. The Linux/Gnu open source effort provides a precedent for the collaborative creation and dissemination of free software that is both complex and reliable. The open source community has created Linux, the best, most stable operating system, and also a broad range of general applications.

Why not harness that same spirit of cooperation for the field of education? In the Winter '02 issue of *@concord*, I detailed our launch of the Open Source Library for Educational Tools (OSLET). This is an online library of free software, seeded with several powerful applications we have developed here at the Concord Consortium. We expect OSLET to grow as we add more tools to the library. We are hoping that others in the research community will contribute as well.

The projects we envision would have much greater impact by developing interchangeable software and using the same platform for network-based learning activities and online materials. The platform could use templates to incorporate good instructional design that would enforce across projects the inclusion in all modules of clear objectives, links to standards, scaffolding, and a balanced approach to student assessment. The Web-based Inquiry Science Environment (WISE), developed by Professor Marcia Linn at UC Berkeley, is an example of the kind of platform that could become a standard.

Using a template-based platform like WISE would allow schools, developers, and publishers to modify the activities and modules, adapting them to different educational environments. Teacher professional development should be designed around the module modification process so that teachers learn the content and pedagogy while tailoring the materials to their students' needs and interests. The resulting new versions could be shared online.

The US currently has an unbalanced national strategy for educational reform. We are focused heavily on dissemination while providing inadequate resources to create innovative materials to be disseminated. The cure is to continue supporting dissemination, while significantly increasing our commitment to supplying new, technology-rich materials – materials that are proven effective through research and that offer the potential for vastly improving education.

The result could be explosive. In a few years, a broad range of research-based, classroom-tested materials that make good use of technology could be available online free or at low cost. The existing dissemination channels could prepare teachers and schools to use these materials effectively. We would soon see significant, measurable gains in student learning. The advances would be impressive in mathematics and science, where current research has demonstrated such gains in small studies. Comparable research in other disciplines is lacking, but similar gains are likely. All that is missing is a relatively modest investment from government and private funders to fill in a gap in the current educational reform strategy.

This is an investment that will have an impact on all students at all grade levels. It will revolutionize education. We cannot afford to miss this opportunity. @

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Concord Consortium

ARTICLE LINKS & NOTES

Federation of American Scientists – International Review of R & D Priorities and Funding, January 2002 report
http://www.fas.org/learn/intl_rev/index.html

CEO Forum – Education Technology Must Be Included in Comprehensive Education Legislation, March 2001 Policy Paper
http://www.ceoforum.org/reports.cfm?CID=4&RID=5

President's Committee of Advisors on Science and Technology (PCAST) – Panel on Educational Technology, Report to the President on the Use of Technology to Strengthen K-12 Education in the United States, March 1997 http://www.ostp.gov/PCAST/k-12ed.html

Chris Dede – testimony http://www.house.gov/science/research/may10/dede.htm

Web-based Inquiry Science Environment (WISE) – http://wise.berkeley.edu

Open Source Library for Educational Tools (OSLET) – article by Robert Tinker, *@concord*, Winter 2002
http://www.concord.org/newsletter/2002winter/oslet.html

OSLET – http://oslet.concord.org

Ultra-fast Response Temperature Probe Allows Deeper Exploration of Heat and Temperature

→ PAGE 1

right." These qualitative judgments are based on the temperature of the nerve cells and how quickly that temperature is changing.

When you quickly let go of the handle of a pot that is too hot to hold, your brain has interpreted the quick rise in temperature sensed by the nerve cells under the skin as an alarm. In effect, your fingers sense the rate of heat flow into them. A much greater alarm is elicited by an object that raises your skin temperature to 50 degrees in one second than by an object that does the same in 30 seconds.

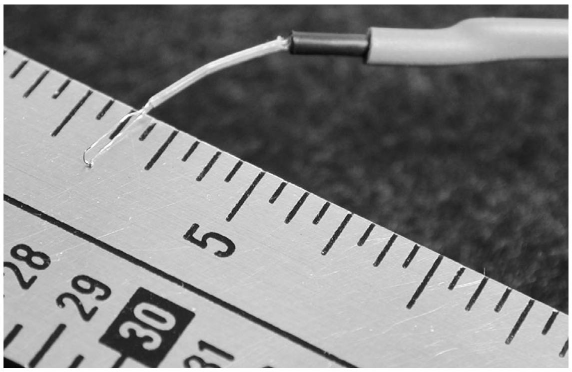
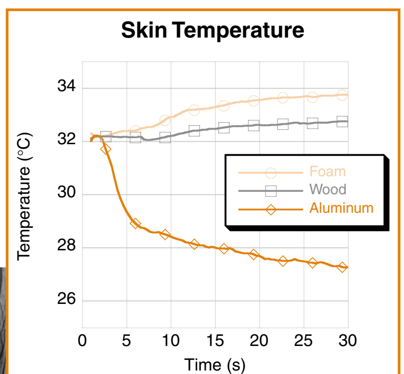


Figure 1. In order to support continuing investigation into heat and temperature, we developed an ultra-fast response temperature probe. The sensing element is the very tiny bulb in the wire that is touching the ruler.

A classic heat and temperature misconception many students have is that metal is colder than wood. For example, take three similar small blocks of aluminum, wood, and rigid foam. Even though they are the same temperature, the aluminum block will feel cool to the touch while the foam block feels warm.

Figure 2. Below: A student measures the surface temperature of a finger as it is placed in contact with rigid foam, wood, and aluminum blocks – all at room temperature (24°C).

Right: The graph shows the changes in surface temperature.



The graph in Figure 2 shows the surface temperature of a finger (32°C) as it is placed in contact with rigid foam, wood, and aluminum blocks at room temperature (24°C). While touching the foam and wood blocks, skin temperature has reached a warmer equilibrium. However, when touching the aluminum block, skin temperature quickly dropped three degrees and was still cooling after 30 seconds. Heat from the finger was able to flow more quickly throughout the aluminum block because of aluminum's greater thermal conductivity when compared to wood or foam.

The ultra-fast response temperature sensor allows rapid investigations that help students tease apart the concepts of thermal conductivity and heat capacity in different materials. While the blocks are the same temperature, the graph in Figure 2 clearly shows skin temperature getting colder when touching the aluminum block. Yet, from our finger's point of view, the aluminum block is clearly colder because, after the initial warming of the aluminum surface, the heat from our finger continued to flow quickly into the aluminum block.

In order to help students develop more robust mental models, we combined sensor- and model-based visualizations in the software the students used. Students created simple virtual thermodynamic systems on the iPaq handheld computers using blocks of different thermal conductivities along with heaters and coolers. The model shows the temperature gradient within the blocks. You can use the Heat Flow applet on our Web site to experiment with a similar modeling tool. See *Monday's Lesson* on pages 6 and 7 for an introduction to that tool.

Radiant Lollipops and Thermal Radiation

We also encourage students to investigate the thermal effects of radiation on the objects around them. The surface of the probe's sensing tip reflects both visible and near-IR radiation. The temperature rise when we hold the probe within six inches of a 100 watt incandescent lamp is less than 0.1°C. The radiant energy from the lamp does not warm the probe as you might expect, because the radiation is reflected rather than absorbed.

Figure 3. Students hold the black surface of the radiant lollipop near an incandescent lamp to measure heat rise due to absorbed radiation.

In order to experiment with the thermal effects of radiant energy, we devised a simple instrument we call the "radiant lollipop" (Figure 3). It is, in effect, a broadband radiometer.

The small piece of rigid foam insulation is covered on one side by regular weight aluminum foil with the shiny side up. The other side is covered by aluminum foil painted flat black with high-temperature stove paint. The sensing tip of the probe is carefully slid behind the aluminum foil. Students find that it is quite difficult to raise the temperature of the shiny side of the lollipop. However, the black side is exquisitely sensitive to incoming radiation.

The equilibrium temperature reached by the black side is affected by two phenomena. These are conductivity with the surrounding air and the balance of emitted and absorbed radiant energy. When the black foil is at the same temperature as nearby emitting surfaces (such as the walls in a room), the radiant energy emitted by the black foil is closely balanced by the energy absorbed. This causes no net

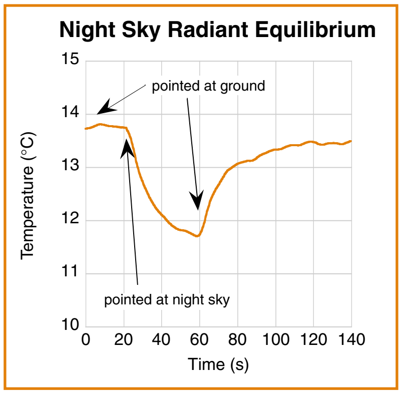


Figure 4. The temperature of the radiant lollipop drops two degrees in 40 seconds when pointed at the sky on a clear night.

change in the temperature of the foil. However, if the black foil is pointed at the sun, a bright lamp, or even a warm hand, the absorbed incoming radiation exceeds the radiation that is emitted. This causes the temperature of the foil to rise until the heat lost (through conduction to the air) balances the additional energy absorbed from radiation.

The radiant lollipop can also be used to indicate the lack of radiant energy. During a clear night the radiant energy coming from the night sky is very small. By taking the radiometer outside and first pointing it at the ground and then at the sky, it indicates that the sky is cooler than the ground (Figure 4).

Hot Hands and Thermal Convection

The ultra-fast response probe can also be used for measuring the small, and often ephemeral, temperature differences associated with convective flow. Convective heat transfer is the movement of a gas or liquid propelled by buoyancy. This buoyancy is associated with density changes caused by temperature differences. The graph in Figure 5 shows the air temperature directly above a copper tube that is held firmly in the student's hand. Within seconds of grasping the copper tube, her hand warmed the tube and the air inside. This lighter air then flowed up the tube and was detected by the probe.

With this probe students can measure the thickness of a film of air falling down a cold window, the extent of a plume of hot air leaving a television, or even the effect of pouring cold air from a chilled bowl into another bowl.

Pressure, Volume, and Temperature

We can also plot the increase in air temperature caused by increasing pressure. We placed the sensor in a sealed plastic soda bottle and squeezed it hard, reducing its volume and increasing the pressure. The graph in Figure 6 shows the air temperature rising 14°C. As soon as the pressure was removed, the temperature dropped back close to room temperature. In this experiment temperature variation is caused by changes in density, while in convection the density varies due to changes in temperature.

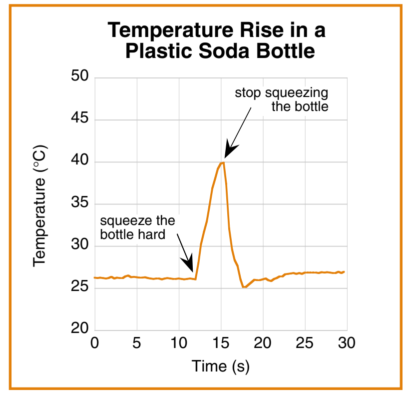


Figure 6. Air temperature inside a sealed plastic bottle rises when the pressure is increased by squeezing the bottle.

The simple experiments described in this article are either impossible or impractical with the temperature probes currently used in schools. A probe that responds this quickly will allow the kind of deep explorations that help students understand heat and temperature as indicators of physical and chemical processes. Research has shown that students who use data from probes to analyze experimental results gain a deeper understanding of science concepts. We must supply them with the most appropriate probes for the tasks.

For more details of these and other interesting experiments, including information on how we made this probe, as well as our research with middle school students, visit the Data & Models project Web site. @

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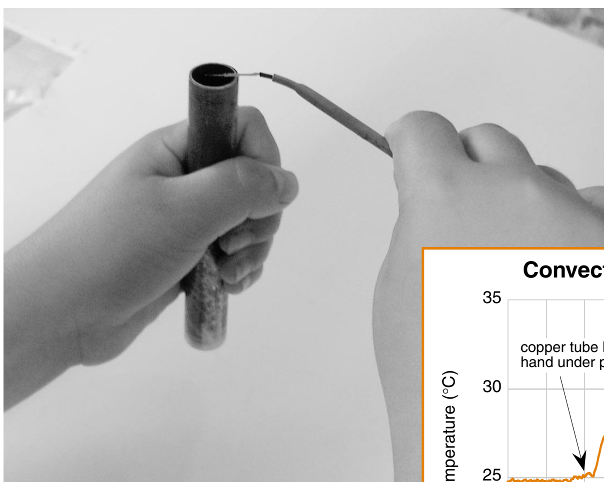

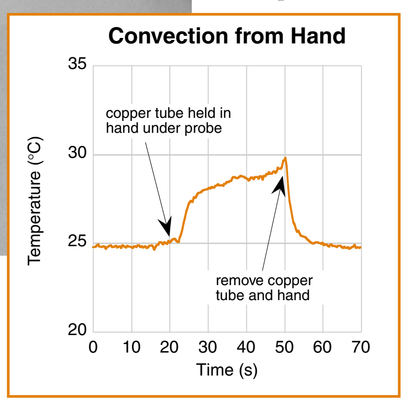

Figure 5. Above: A student holds the probe over the mouth of the copper tube while her hand warms the tube.

Right: the graph shows the temperature changes recorded.

ARTICLE LINKS & NOTES

Data & Models — http://www.concord.org/data-models/

To learn about the interface hardware and the open source software (CCProbe) that allows probe visualization on PalmOS, PocketPC, MacOS, Windows, and Linux — http://www.concord.org/ccprobeware/

In the Spring 2001 issue of @concord, we described our thermal conductivity block system for investigating heat flow — http://www.concord.org/newsletter/2001spring/evidence.html

To read about our research in the middle school classroom, see Barbara Buckley's article, "Investigating Heat Flow at the Hot & Cold Club: Looking Closely at Students' Mental Models" — http://www.concord.org/data-models/hot-cold-club.html

This research is supported by National Science Foundation grant #REC99-73179.

Monday'

Modeling Heat a

Why does metal feel cold while Styrofoam feels hot?

Can a winter coat keep you cool in the summer?

Does wrapping a cold drink in metal foil keep it cold?

When you drop an 8-ounce ice cube into a quart of 100°C water, what is the resulting temperature?

Can heat turn a corner?

Why is wood better than metal for cooking hotdogs over a campfire?

By Bob Tinker

Students (and most adults, too) find questions like these difficult. A Concord Consortium project, Data & Models, is exploring whether one kind of mathematical model can help students understand these concepts, for example, the conduction of heat through different materials. (Read about the tools we are developing to help students understand temperature in the cover story of this issue.)

Early in the project, I made a simple AgentSheets model to help prototype our software. Since this model is easy to share over the Web, we invite you to try it out with your students. In your Web browser, go to:

http://www.concord.org/applets/heat-flow

For this *Monday's Lesson* we have developed some investigations into heat and temperature that you can use with the AgentSheets model. Because of space limitations we can't provide all of the investigations here. You can find the complete set of activities and more detailed instructions on the Web site.

When you start the simulation, you will see a blank worksheet with seven square blocks across the top, as in the screen shown here (right). These are the "agents" for this model (see the key at far right on page 7). The tools for manipulating the agents are arranged vertically along the left side of the worksheet.

You can put any number of agents in the worksheet and move them around with the tools while the model is running. Once you become familiar with the agents in the worksheet, try running some trial simulations to get used to the model. For example, you could try putting a fast (good) conductor next to a hot agent and then moving it away. Put the good conductor next to a cold agent and move it away. Note the change in color. Repeat with a slow (poor) conductor and an insulator.

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Now make a horizontal row of nine good conductors and place a graph under each. Put a hot agent at one end and a cold one at the other. In a short time, you will see that the conductors form a color gradient between the hot agent and the cold agent. The steps will be 10°C apart. Predict what will happen if you move the hot agent away from the end of the row. What would happen if you were to substitute a poor conductor for one of the nine good conductors? What if you substituted an insulator for one of the good conductors?

Now investigate the following question:

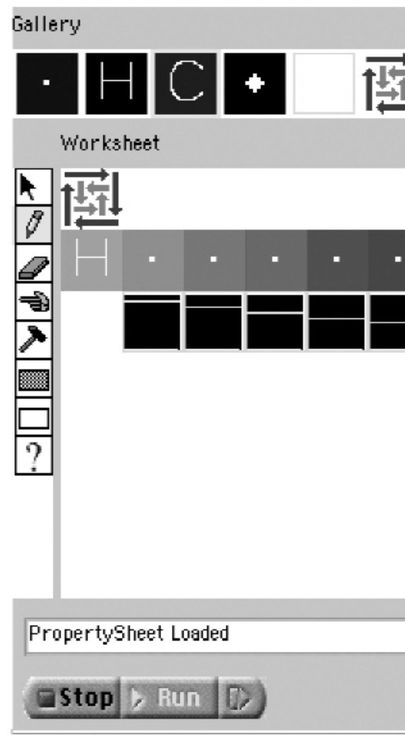
What happens when you mix things with different temperatures?

First, make a row of nine good conductors with "H" on one end and "C" on the other. Use this to estimate temperatures. The computer simulation shows varying mixes of red and blue for each 10°C step from 0°C to 100°C. As the simulation runs, the temperature of each agent will be graphed in the block beneath it.

Set one good conductor agent at 100°C by touching it to an "H" agent and then removing it. Make a second good conductor agent 0°C by touching it to a "C" agent. "Mix" these two blocks by placing them next to each other. From the resulting color, estimate their final temperature.

Predict what will happen before trying each of the following experiments:

- Mix four hot blocks with one cold one. Use only fast conductors.
- Mix four cold blocks with one hot one. Use only fast conductors.
- Repeat all these experiments with slow conductors and insulators.
- Mix one hot fast conductor with one cold slow conductor.

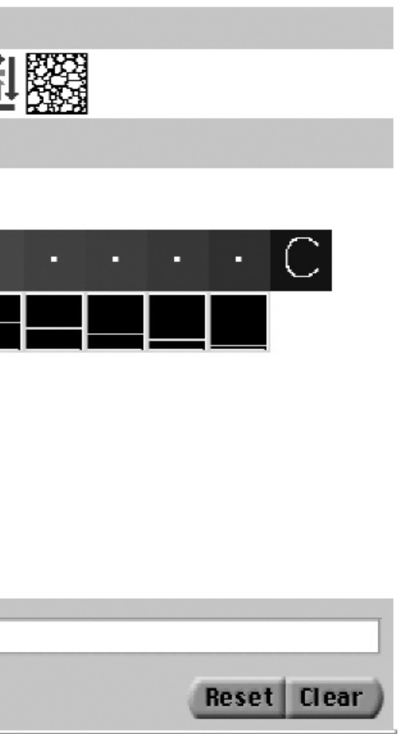


A row of nine good conductors makes co other. When you run the simulation, the bl change in ten-degree steps. (We were not illustration provided here.) A graph agent During the simulation, the temperature of

’s Lesson
nd Temperature

The Science of Heat and Temperature

The difficulty in understanding these simulations is that the flow of heat is hidden from view. Nevertheless, heat flow plays a critical role in the changes that are taking place. The only way any of the agents changes temperature is when heat flows in or out. The model calculates how much heat energy flows in and out of each agent. Heat always flows from a hot agent to a cold one. The amount of heat that flows depends on the difference in temperature and the thermal resistance of each block. The good conductors have little resistance to the flow of heat, while the insulator has high resistance. In this model, the thermal resistances of the three conductors are in the ratio of 1 to 10 to 500.



ntact with “H” on one end and “C” on the locks change color to represent temperature able to reproduce the actual colors in the is placed directly beneath each conductor. each block is automatically graphed.

The degree of temperature change of a block caused by a certain amount of heat inflow depends on its heat capacity. Something with a high heat capacity is hard to heat up; it takes a lot of heat to increase its temperature. The agents in the model have heat capacities of 10 (for the fast conductor) to 2 (for the slow conductor) to 1 (for the insulator). This explains why it takes five “slow” blocks to balance the warming or cooling effect of one “fast” agent. Both the heat capacity and thermal resistance determine the thermal properties of any object.

Educational Significance

These simple investigations should help students get a “feel” for heat flow and conduction. You could test this by asking students the questions at the beginning of this article before and after they explore these investigations. We would be most interested in any insights you gain about your students’ learning of these ideas.

How hard is it for students to understand all these “hidden” properties: heat flow, thermal resistance, and heat capacity? If these ideas are too abstract for beginning students, does exploring the model provide an alternative? Can they gain sufficient intuition from models like this to answer the questions that begin this article? Will insights from these models help students understand the more abstract ideas? As they say, further research is needed, but it seems likely that experiences of this type could be the foundation for deeper learning.

A deeper question concerns the value of models like this one that do not try to provide mechanistic explanations. An alternative kind of model would show what is happening at the atomic scale. In such a model, heat flow could be visualized as the transfer of random motion from areas where there is a lot of motion to areas with less. But we’ll save that for another Monday. @

Key to “Agents”

The simulator has seven “agents” you can use. These are represented by one of the seven square blocks along the top of the screen at left:

- Fast (good) conductor. (Like aluminum, this conducts heat well.)
- Hot. (Always at 100°C)
- Cold. (Always at 0°C)
- Slow (poor) conductor. (Like wood, this conducts heat slowly.)
- Graph. (It looks like a blank square, but when you put it in the worksheet and run a simulation, it graphs the temperature over time of any agent touching its top.)
- Arrows. (One is needed in the worksheet in order to run the simulation.)
- Insulator. (This conducts heat poorly, like Styrofoam.)

ARTICLE LINKS & NOTES

Data & Models — http://www.concord.org/data-models/

AgentSheets — www.agentsheets.com

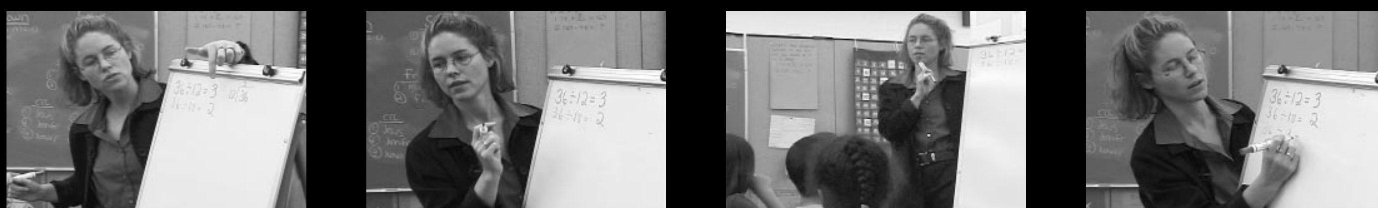
The Data & Models project is funded by National Science Foundation grant #REC99-73179.

Seeing Math

Interactive Video Case Studies Help Teachers Reflect on Their Practice

By Alvaro Galvis, Janet Hadingham, and Ray Rose

Nancy Ward has taught for 19 years and is all too familiar with the problems of delivering effective professional development to busy teachers. She speaks of the difficulty of finding one or two hours in an already-packed schedule for a training workshop, and the lack of follow-up that renders such experiences unproductive. “We call it the ‘spray and pray’ method. We bring in a trainer who gives out lots of information and when it’s over we pray it takes hold. Without follow-up, teachers go back to doing the same things they did before. It’s not effective in promoting change.”



A picture is worth a thousand words
Combining video with the case study method creates a highly useful tool for teacher professional development. It can show an entire classroom environment and how a teacher responds to typical student issues. Video conveys experiences too complex to fully describe in text alone. A case study can present problems and issues that evoke intense discussions, greatly enriching the learning experience. The stills shown here are from *Number and Operations: Division with Remainders*, featuring Mary Beth O’Connor, a 4th grade teacher at the Gerena School in Springfield, Massachusetts.

Nancy is leading her colleagues in an innovative experiment in teacher professional development: the Seeing Math Telecommunications Project. Her school district, the Rapid City Area Schools in South Dakota, is one of four districts across the nation that began piloting the project during the 2001-2002 school year.

> “I can watch the videos over and over again and I learn something new... each time.”
>
> Participant in Pilot Study

Seeing Math is a pioneering effort to study the effectiveness of teacher professional development using online video case studies for elementary and middle school teachers. To develop the case studies, the Concord Consortium partnered with TeachScape, an educational service that delivers teacher professional development over the Internet. During the project’s first two years, five courses were completed, with another four currently in development. Each focuses on a concept from the NCTM standards that is typically difficult to teach or learn, such as fractions, division with remainders, calculating the area of a triangle, or using data to make predictions.

Each case study is built around a set of short video segments documenting an experienced teacher working with students in the classroom. For seminar participants, the videos provide a kind of “fly on the wall” perspective on another teacher’s work, allowing them to watch how the teacher responds as difficult situations arise.

Although the teachers selected for the case studies tend to be reformers, the videos are not intended as exemplary models for course participants to emulate. They present no hidden agenda or specific conclusion. Rather, the video cases are open to a variety of interpretations. The main intent is to foster a reflective attitude among the course participants, one that will inspire them to think deeply about their own teaching and perhaps even enhance their understanding of the mathematics they teach.

A key innovation of this project is the interactive design of the video case studies. Because the case studies are online, teachers can progress through the materials at their own pace. Each individual learner can stop, replay, and jump ahead in the video, or branch to a wide range of related materials such as lesson plans, typical student work, relevant standards and assessments. The experience is further enhanced when participants discuss the case and share their own experiences with other teachers and facilitators. These can take place online, in face-to-face sessions, or both, depending on the strategy chosen by the school district.

The case discussions are moderated by local facilitators, each trained through a special netcourse developed by the Concord Consortium. The facilitator helps to keep the discussion focused and promotes a sense of community. However, breaking the ice is sometimes a challenge. As the Seeing Math facilitator for her school district, Nancy Ward has worked hard to get her teachers to talk together online and not everyone participates as fully as she would like. “Joining an online discussion is like going to the refrigerator. If you find something good, you come back again.” She has found that weekly face-to-face meetings help draw people

"Someone put some thought into this."

Participant in Implementers Netcourse

into the discussion, which "then spills over into the online discussion."

In addition to the video segments of the classroom lesson, each case study contains interviews with the teacher, expert commentary on the subject matter, a copy of the teacher's lesson plan, samples of student work, and relevant information about the community. There are also links to NCTM 2000 standards, self-assessment tools and other resources. All these materials are delivered over the Internet but are also available on CD-ROM. A content expert at TeachScape provides online support whenever necessary.

The project is being piloted with a total of thirteen teachers in four demographically diverse school districts across the nation. Besides Nancy's school district in South Dakota, other test sites are District of Columbia Public Schools, Hudson Public Schools in Massachusetts, and Windham Central Supervisory Union in Vermont.

According to one teacher involved in the study: "My methods have definitely been affected by participating, if for no other reason than by the time I have spent reflecting on what I am doing. I also feel for at least this short period of time I have stepped back into a thoughtful practice rather than an auto pilot practice. I have recognized what comes naturally to me and what I need to work on incorporating in a more conscious manner." @

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ARTICLE LINKS & NOTES

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

TeachScape — http://www.teachscape.com

NCTM — National Council of Teachers of Mathematics standards — http://www.nctm.org/standards/

HighWired — http://www.highwired.org

EdTech Exchange — http://www.concord.org/cc-group/etx.html

Pre-Algebra: Pan Balance Equations — http://www.highwired.org

The project is funded by grant #R286A000006 from the U.S. Department of Education.

Free Access to Seeing Math Materials through EdTech Exchange

By Ray Rose

The Concord Consortium believes that innovative learning materials should be made available to the widest possible audience, especially underserved communities. For this reason, we want to make the Seeing Math course materials available free-of-charge to schools that can't afford to purchase the complete courses through TeachScape.

Trimmed-down versions of the Seeing Math case studies will be available through our non-profit subsidiary EdTech Exchange (ETX). ETX recently acquired HighWired, an Internet-based company that provides free Web communications tools to schools and teachers. Thousands of schools throughout the U.S. and abroad already rely on HighWired's Web hosting tools for their Web sites and online newspapers. Now they will have access to professional development resources including the Seeing Math courses.

The Seeing Math course materials provided through HighWired are the same as those available through TeachScape. The main difference is that the HighWired version doesn't offer access to TeachScape's online community with its focused discussions moderated by a facilitator. Using the self-contained materials available on HighWired, schools can design their own course, tailoring it to suit the needs of their teachers.

Pre-Algebra: Pan Balance Equations is the first case study available on HighWired. It is based on the NCTM Algebra standard for grades 3-5, and is built around a series of video segments showing a teacher conducting a lesson on pan balance equations. The case study contains introductory materials, video segments showing six classroom teaching examples, teacher reflection, specialist commentary, lesson plans, examples of student work, and references. There is also a course guide for participants and facilitators. @

Education for a Sustainable Future (ESF)

Technology-based Curriculum Encourages Global Thinking

By Janet Hadingham

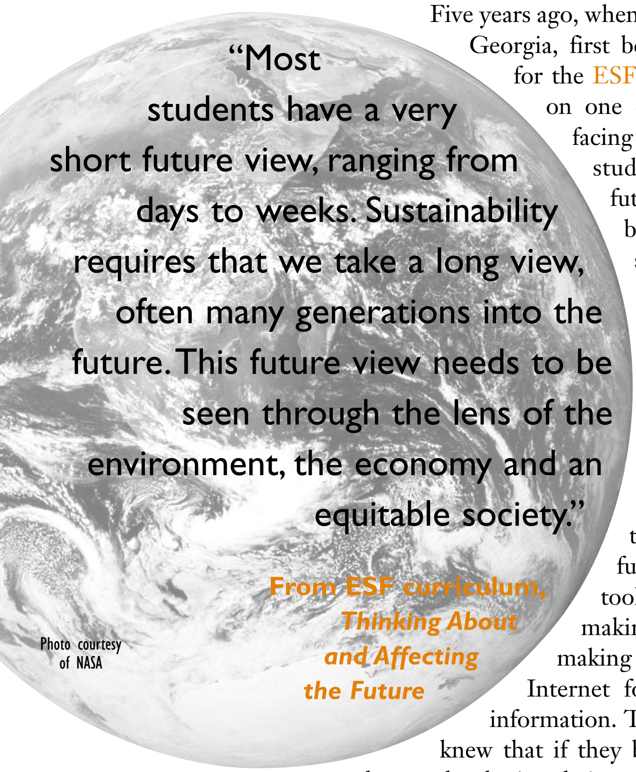


Photo courtesy of NASA

"Most students have a very short future view, ranging from days to weeks. Sustainability requires that we take a long view, often many generations into the future. This future view needs to be seen through the lens of the environment, the economy and an equitable society."

From ESF curriculum, Thinking About and Affecting the Future

Five years ago, when teachers in Cobb County, Georgia, first began developing curricula for the ESF project, they were taking on one of the biggest challenges facing educators today – getting students to understand the future consequences of their behavior. Sustainability studies require thinking about the needs of future generations as well as our own. Even most adults have trouble with that.

Fortunately, the new field of sustainability science has grown up alongside the technology tools that can help us envision future scenarios: modeling tools for seeing trends and making predictions; decision-making tools for role-playing; the Internet for gathering and sharing information. The Cobb County teachers knew that if they built a curriculum around these technologies, their students would become more actively engaged in learning the concepts of sustainability.

ESF became an ambitious five-year effort to develop and field test a wide range of materials. The teachers created more than 60 curriculum units with activities for all grade levels and subject areas. For example, first graders collect trash, sort it and graph their results; seventh graders develop a survey of citizens' perception of local air quality; high school students model global population growth.

Evaluation results from 400 classrooms throughout Georgia and nationwide have shown a dramatic improvement in technology skills and an improved classroom environment. One teacher documented 100% attendance among her "at risk" students on the days designated for ESF. Another teacher reported that the project gave her a reason to stay in the teaching profession.

Sue Brown, ESF co-director, worked closely with the teachers as the project took shape and grew. "Sustainability creates a context for learning, a connection between the classroom and the real world," comments Brown. "The students are learning the core curriculum objectives, yet they are engaged in these projects because they are student centered."

Among the tools used are special software developed for the project by the Concord Consortium: Ecological Footprint Calculator, What-If Builder, and Community Planner. All are available to the public on the ESF Web site, along with the curriculum units and resources for professional development.

The ESF project demonstrates the Concord Consortium's commitment to expanding the curriculum with technology to address important topics. @

Building Bridges for Sustainability Education

A Global Network for Change

Janet Hadingham is Managing Editor of *@concord*

The global importance of ESF became clear when the teachers were invited to share their work with educators in Eastern and Central Europe. Earlier this year, Sue Brown and Randall Crump, a language arts teacher from Harrison High School, joined a CSF team on a visit to Hungary, Slovakia, and the Czech Republic.

"The issues that these teachers in Cobb County, Georgia, are facing are very similar to those faced by teachers in different parts of the world," says Keith Wheeler, CSF Director. "Although the cultural context is different, the concerns are the same."

The project, Building Bridges for Sustainability Education, grew out of a long-time collaboration between CSF principals and educators and environmentalists in Eastern and Central Europe.

In January 2002 the Building Bridges team began traveling to Central Europe to meet with a group that included educators and representatives from government ministries, non-governmental organizations (NGOs), and the UN development program. The purpose of the meetings was to compare notes on each country's efforts toward sustainability education and to identify exemplary programs. Ultimately, this network will extend worldwide. @

ARTICLE LINKS & NOTES

Education for a Sustainable Future (ESF) – http://csf.concord.org/esf

Center for a Sustainable Future (CSF) – http://csf.concord.org

Cobb County School District's ESF Web site – http://www.cobb.k12.ga.us/%7EGrants/

Ecological Footprint Calculator, What-If Builder, and Community Planner – http://csf.concord.org/esf/Software.cfm

ESF Curriculum units – http://csf.concord.org/esf/CurrViewByTopic.cfm

ESF is funded through a U.S. Department of Education grant (#R303A70182) awarded to the Concord Consortium's Center for a Sustainable Future (CSF) in partnership with the Cobb County School District, the Marietta City Schools, and the Fulton County Schools.

Building Bridges for Sustainability Education is supported by a grant from the Trust for Mutual Understanding.

Accelerating Educational Research

By Bob Tinker

Much of the research in education is undertaken by individuals, often junior researchers under the direction of senior faculty at universities. However, this solo approach is an inappropriate model for research on educational technologies, which often involve complex projects requiring a range of skills.

Yet society is increasingly demanding technology-rich materials that can be applied to large numbers of diverse students. This requires larger scale research, operating at a higher level of sophistication, than individual researchers can achieve.

The Center for Innovative Learning Technologies (CILT) brought together leading researchers at SRI International, Berkeley, Vanderbilt, Stanford, and the Concord Consortium. During its 5-year lifetime, CILT stimulated collaboration within the educational technology research community through conferences, workshops, online resources, direct grants, and a post-doctoral program.

CILT demonstrated convincingly the importance of collaboration in educational technology research. Through its auspices researchers who were previously unaware of each others' interests have made advances that would have been unattainable had they worked separately.

Even more benefit could be realized at a permanent national facility for collaborative research in educational technology. We have dubbed this the "Educational Accelerator," analogous to shared facilities in science such as the Fermilab particle accelerator. Scientific labs like these are critical to advancing science because they enable researchers to collaborate on large-scale projects. Individual researchers can make important contributions without needing to create all the equipment, master all the sub-specialties, or administer the huge resources required.

An Educational Accelerator could provide exactly the same functions by combining in one place all the expertise needed in the following areas:

Software

Much of the innovation in educational technology requires new software with increased capacity and function. Projects need programmers who are familiar with education and cutting edge software development, and who can quickly generate new applications.

Materials

Testing with students often requires that new technologies be integrated with good materials using exemplary instructional strategies. This requires experts in instructional design, software design, and media integration who can generate the best possible materials. Most projects require the engagement of teachers, which demands expertise in professional development, often at a distance.

Schools and Students

Technology-rich materials can be tested with individual students, small numbers of classrooms, or entire schools. Schools need to be actively engaged in the research design, and committed to using the results. Recruiting, supporting, and retaining the schools and students, as well as providing the technology, is a major task facing all researchers.

Back-end Services

Most projects require servers to deliver the materials, collect student results and provide appropriate access to the materials for students, teachers, and researchers. These services need to be highly reliable and secure.

Research Expertise

Many researchers will need assistance in research design, the selection of sophisticated analysis tools, and help in data mining. Embedded assessment and other technology-based evaluation techniques are becoming a vital component of modern research in educational technology.

CILT demonstrated convincingly the importance of collaboration in educational technology research. Through its auspices researchers who were previously unaware of each others' interests have made advances that would have been unattainable had they worked separately.

Through an Educational Accelerator facility, technologies and experts in all these areas would be available to qualified researchers. The actual research undertaken would be determined by the individual researchers within bounds set by the community of users. This natural evolution of the CILT experience could contribute the innovations and knowledge necessary to help schools realize the educational potential of technology. @

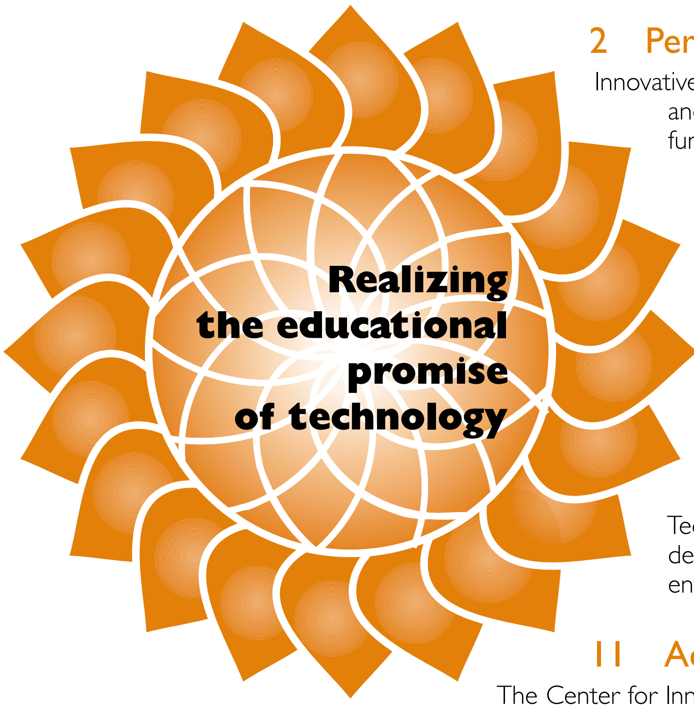
Robert Tinker (bob@concord.org) is President of the Concord Consortium

ARTICLE LINKS & NOTES

Center for Innovative Learning Technologies (CILT) – http://www.cilt.org

CILT is supported by National Science Foundation grant #EIA-0124012.

Inside @concord for Fall 2002



News from our Web Site

Essential Elements: Prepare, Design, and Teach Your Online Course – by Bonnie Elbaum, Cynthia McIntyre, and Alese Smith. This new book from the Concord Consortium describes the process of putting your course online. The authors, who have helped to develop hundreds of online courses, show how to create a high-quality learning environment for your students. **http://www.concord.org/publications/books.html**

Making Thinking Visible – Making Thinking Visible is a research project involving students from California and Massachusetts who collaborated online in their study of plate tectonics. Visit our new Web site for this project to see the curriculum and dynamic models that were used. **http://mtv.concord.org/**

Usight – Visit the new Web site for a close look at ubiquitous technologies such as handheld computers and their use in education. **http://usight.concord.org/**

The Ten Commandments of Technology Implementation – Carolyn Staudt explains how to integrate handheld computers effectively into schools. **http://usight.concord.org/new/tcti.html**

Investigating Heat Flow at the Hot & Cold Club – Concord Consortium researchers take a close look at middle school students' mental models as they work with sensors and model-based visualization tools. **http://www.concord.org/data-models/hot-cold-club.html**

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