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REALIZING THE EDUCATIONAL PROMISE OF TECHNOLOGY

How Important is the Online Facilitator?

Seeing Math offers Moderator-Lite Scalable Professional Development

BY GEORGE COLLISON

The architecture of Concord Consortium's *Seeing Math Secondary* curriculum expands the limits of existing course design and delivery. Seeing Math tightly integrates five powerful tools, all delivered online: 1) video of student problem solving, 2) video of a national math education expert providing commentary on content and pedagogy, 3) an applet (Java-based software that runs over the Web) that permits students and teachers to explore math concepts in a radically new way, 4) a "Diving In" math challenge, and 5) a moderated threaded discussion area. Based on this powerful course design, the role of the facilitator changes in important ways.

The metaphor guiding course construction was the experience of a visitor to the exhibit rooms of the *Exploratorium* museum. The Seeing Math experience, like an Exploratorium exhibit, is conceptually and intellectually engaging. The design shifts the online museum guide from instructor or potential content provider to that of a moderator who monitors each participant's progress through the exhibit, encourages participation, troubleshoots technical difficulties, and, through private feedback, provides guidance on topics that may need more attention.

Structure of the Seeing Math courses

Seeing Math Secondary courses are offered through PBS TeacherLine to a national audience or to PBS member stations. Each course is comprised of five week-long segments. The first week introduces the course and the platform. After a community-building activity, participants engage in problem solving

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Inside

Free CD! with interactive software included!

Where Are the Educational Innovations?

BY ROBERT TINKER

Education cannot thrive without innovation, but effective innovations do not just happen. They need to be based on solid ideas, they need to be developed by a talented team with diverse skills, and they need to be widely disseminated.

This issue of *@Concord* is dedicated to exploring how innovative materials are developed and disseminated. We document several different decade-long paths from research to practice (see "How Do Innovations Travel from the Lab to the Classroom?" on page 14). The lesson is that the development of powerful ideas is a good investment and that no one dissemination strategy is best.

The balance of this newsletter provides a detailed review of an important innovation created by our Seeing Math project. This is a cutting-edge approach to teacher professional development based on online courses featuring video case studies and interactive software. The courses are a unique blend of resources carefully crafted into powerful learning experiences. They are now available nationwide.

> Nationally, there are **too few innovations** such as the ones reported here.

Our greatest concern is that the pipeline of educational innovations in math and science is drying up. Nationally, there are too few innovations such as the ones reported here. Funding cuts are causing us, and others like us, to dismantle our teams and reduce our capacity for innovation. The priority has shifted to having teachers and university faculty innovate locally. Of course, these efforts seldom have the resources needed for a major impact. Instead, education funding is being dissipated on a broad portfolio of programs that are well meaning, but unfocused. The focus should be on visionary innovations and national dissemination of the best of these.

Imagine that the U.S. had decentralized NASA the way it has decentralized education. The entire NASA budget would be block-granted to the states, which are required to distribute $1M per year to each of 17,000 local rocket clubs. The primary responsibility of NASA headquarters would be to require continuous improvement as part of a "no club left behind" (NCLB) initiative.

The result would be 17,000 tiny rocket clubs, tremendous duplication of effort and no innovation. The clubs would probably manage some areas satisfactorily, but there would be virtually no space program. Expensive innovations that require the best minds and resources in the nation would be missing. There would be no moon landing, no GPS, no Hubble, no satellite imagery, no Cassini-Huygens mission—no significant innovations. The U.S. space effort would lag behind Singapore, Bulgaria, and many other countries.

This is the situation in science and math education. Our radically decentralized system is duplicative and inefficient. When pushed by standards and possible sanctions, it may be able to do some things adequately, such as basic literacy and numeracy, but it fails in science and math education because these areas are complex, ever changing, and difficult to teach. Local and state agencies cannot fund large-ticket items, such as a new curriculum, and they cannot innovate. We are far behind many countries with more centralized educational systems.

Educational technology has a huge potential for innovations that could remake math and science education. Using technology, traditional content can be taught better, more deeply, and sooner. Technology can be used to assess students as they learn and keep teachers informed in real time about student progress and difficulties. More importantly, technology can support new approaches to learning. However, funding for technology-enhanced educational innovations has almost completely evaporated. Less than 1% of federal education funding goes into exploring educational applications of the computational and communications capacity of modern computers or handhelds.

It seems obvious that both NASA and education need centralized R&D for just those items that states and districts cannot undertake: big-ticket innovations. This is not happening. Math and science education in the U.S. is severely under-investing in significant innovation and is failing to take advantage of our lead in technology. As a country that relies heavily on innovation and technology, the U.S. seems averse to educational innovations that could have a national impact. This aversion is undermining our future.

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

Are Online Courses Effective for Professional Development?

Lessons from a Decade of Experimentation

BY ROBERT TINKER

Online courses have generated a lot of controversy. Some say they are going to revolutionize education and render current arrangements obsolete. Others claim they are a fad that will soon vanish. A decade of experimenting with online professional development has given us important insights into this debate.

Ten years ago we identified the potential of online courses for teacher professional development. We developed a year-long course for teachers on inquiry-based learning in secondary math and science, called INTEC. The design of that course became the "*Concord e-Learning Model*" for online courses: high-quality, inquiry-based activities that all participants undertake and then discuss online using asynchronous, moderated groups led by a trained facilitator.

INTEC had a profound impact on teachers as evidenced by responses like these:

"I have been changed as a teacher, and that change has been for the better."

"The kids liked it a lot. They responded more so with those [INTEC materials] than many other things, because they 'empowered' them. It gave credit to their own thinking."

We also learned two complementary lessons from the INTEC experience:

The Concord e-Learning Model really works. Online asynchronous discussions about shared experiences can result in profound, lasting learning when a reflective community is cultivated by both course design and the moderator.

The moderator role is critical. The best approach is to train moderators in an online course that models the same design. This experience led to our influential book *Facilitating Online Learning: Effective Strategies for Moderators* and to our online "metacourses."

We also started in 1996 the *Virtual High School*, a pioneer in online courses for secondary students. The key innovation of VHS was a course for teachers on how to create and facilitate online courses, called the Teachers Learning Conference (TLC). This intensive online professional development course was similar to INTEC. TLC was also 120-plus hours and based on the Concord e-Learning Model, though the motivation was much higher, because a school could not enroll their students until one or more of their teachers completed the online course.

The course is difficult, but rewarding as the following quotes testify:

"The TLC training course has given me a shot of adrenaline at a time when I had begun to look ahead favorably toward retirement."

"Legislators often lament the quality of teachers. If they could only contact any of the TLC participants! They are student oriented, creative, and enthusiastic."

Five years ago we felt that the technology available to teachers was finally able to support the integration of video case studies into online courses (see "Lights, Camera, Action" on page 7). This was the birth of the *Seeing Math* project that is extensively reported in this issue.

> The case studies stimulate **deep conversations** about how teachers respond to **student thinking.**

In that project, we built courses around a more manageable five-week time frame, and also included interactive software (see "Interaction and Interactivity" on page 8). These video and software technologies don't change the basic Concord e-Learning Model, but they do augment it in important ways. The case studies stimulate deep conversations about how teachers respond to student thinking. Investigations based on the software give teachers a way to "brush up" on their content knowledge by looking at familiar content from a new perspective. The software is free and can be used in classrooms, so the new insights can be applied immediately to teaching. In addition, many of the video case studies document how teachers use the software in their classes.

This decade of experimentation has convinced us that online teacher professional development can be effective. Well-designed online courses with rich content have great educational potential, but careful design and well-trained facilitators are required.

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

LINKS *Online Courses*

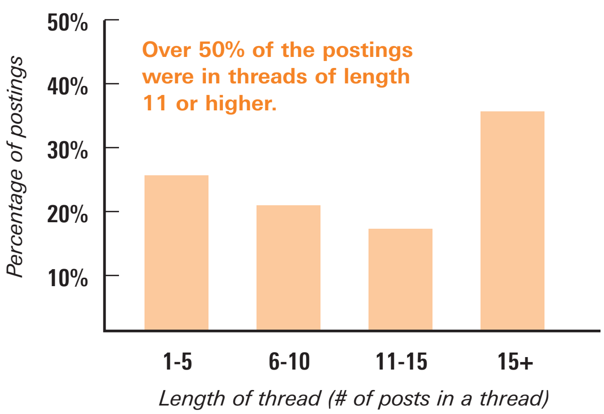
- **Virtual High School**
  http://www.goVHS.org
- **Seeing Math**
  http://seeingmath.concord.org
- **Concord e-Learning Model**
  http://www.concord.org/courses/cc_e-learning_model.html

Facilitator—*continued from page 1*

through a *Diving In* activity, which features significant mathematical content embedded in an interesting problem. An applet displays unique representations of the problem and new ways to think about solutions. Participants can share their solution paths with each other in an online threaded discussion area that supports text as well as pictures and snapshots from the applet. In week three participants view two or more short videos of students tackling the same problem. The students' impasses and false starts often mirror the participants' own struggles. In weeks three and four, a math specialist comments on the students' efforts and highlights important content issues, potential unresolved areas of confusion, and links to current research. In the threaded dialogue, participants integrate multiple solution paths and complexities revealed by the students and the expert commentary, and discuss insights from the linked multiple representations displayed by the applet. As a summative experience, participants design or adapt course activities for their own curriculum.

> The Seeing Math architecture offers **alternative, scalable sources** by expanding on key ideas, conceptual conflicts, ambiguities, and unresolved issues within the text surround, video commentary, Diving In activity, and student video.

Histogram of postings by thread length



"Here's what I valued most about this course: The excellent classmates! I gained so much from seeing other perspectives on our given tasks and issues! I really loved the interplay of our postings and responses, and the fact that all of us had all the time we needed to read each other's views, mull over our own views, and respond in our own time frame. In a regular class, if you don't have your thoughts all formulated at the right time in the discussion, you can't just rewind the tape and ask the question or add the ideas later! It was great, too, for the shyer of us to have the anonymity of a posting, rather than a face-to-face interaction, and the knowledge that even the most vociferous critics couldn't sneer in our faces, so we could all share our insecurities, questions, and even occasional criticisms with increasing comfort."

The role of the moderator in Seeing Math Secondary

The Seeing Math course design follows the Concord e-Learning Model, which describes nine key characteristics of quality online courses. The role of the moderator in our model diverges signif-

Try a Seeing Math Secondary course

Below are selected highlights of the Transformations of Quadratic Functions course. Visit *http://seeingmath.concord.org* to register for free access to a complete Seeing Math course.

1. The Quadratic Transformer

Access the Quadratic Transformer at
http://seeingmath.concord.org/sms_interactives.html

Take some time to familiarize yourself with the applet. Use the Warm Up activity, if you like. Make a few parabolas using the "New" tab; apply the slider to locate points on the parabola; and use the arrows within the "Polynomial Form" to change coefficients.

2. Diving In

The *Diving In* problem poses three challenges regarding the impact of coefficients on shape and position of a parabola. Try challenges A, B, and C with the Quadratic Transformer or a graphing calculator: *http://seeingmath.concord.org/Interactive_docs/QT_Activity.pdf*

3. Student Thinking

Observe students working on Challenge B. (Note: Windows users may find the .wmv format more accessible. Mac users may access the .mov format more readily.)
http://seeingmath.concord.org/nctm/qt/StillatDiffPoints220.mov
http://seeingmath.concord.org/nctm/qt/StillatDiffPoints220.wmv

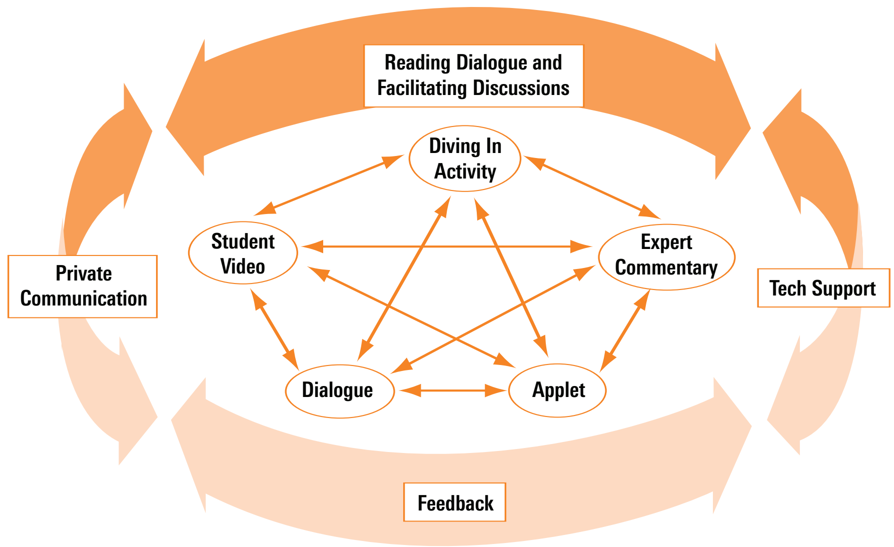
4. Expert Commentary

Dr. Daniel Chazan, University of Maryland, offers insights on students' efforts at moving the parabola web. He explains some of the advantages of a complex representation such as the Quadratic Transformer in eliciting student expectations and understanding of the different symbolic forms.

Listen to Dr. Chazan comment on student thinking as they work on Challenge B.

http://seeingmath.concord.org/nctm/qt/MakingMeaning220.mov
http://seeingmath.concord.org/nctm/qt/MakingMeaning220.wmv

Structure of the Seeing Math design



The moderator's critical functions—providing feedback, reading dialogue and facilitating discussions, offering technical support, and communicating privately with course participants—effectively surround the five key elements of a Seeing Math course.

icantly from that detailed by Feger and Zibit in *The Role of Facilitation in Online Professional Development: Engendering Co-construction of Knowledge.* Feger and Zibit build on previous researchers and detail three areas of "teaching presence" or focus for the online moderator: 1) instructional design and organization, 2) facilitating discourse, and 3) direct instruction. The "co-construction" moderators they describe employ a facilitator-mediated discussion design that includes supporting lesson study processes, supplying teacher resources and context, and coaching and addressing cross-grade issues. This model falls short of the goals and achievements of the Seeing Math design in notable ways. The co-construction model proceeds dependent on significant levels of moderator analysis, input, and intervention that potentially hinders independent thought and development.

The Seeing Math design recognizes that high-quality expertise is needed to foster deep engagement in the content. The Seeing Math architecture offers alternative, scalable sources for this important course element by expanding on key ideas, conceptual conflicts, ambiguities, and unresolved issues within the text surround, video commentary, *Diving In* activity, and student video. The expert commentator in the videos takes on many of the characteristics of a co-participant in the group, and also serves to assist the moderator by focusing the discussions. Access to this valuable window on content depth shifts the moderator out of the center of discourse with the participants. The applets, using linked multiple representations, also provide a powerful way for teachers to approach old ideas in new ways. The Seeing Math discussion boards abound with teachers' discoveries within this media-rich environment.

Dialogue analysis

For approximately half the participants, Seeing Math was their first online course. Statistical analysis of the dialogue in three Seeing Math course sections offered in the spring of 2005 revealed an unusual moderator profile. The participant to moderator response ratios were quite high, ranging from 19:1 to over 100:1. A single, targeted comment by the moderator often generated considerable discussion among participants. The software platform required that the moderator place the initial post in each thread. This post was scripted by the course authors and provided in the facilitator's guide. It highlighted the main themes for discussion and the important conceptual tensions evident in the student and expert commentary. In a study of three courses, 1,529 posts were made by a total of 53 participants. The moderators posted 39 scripted messages and 18 unscripted messages for an average participant to moderator postings ratio of 27:1. By comparative word count, moderators occupied only between 1% and 2% of the public discussion areas. Over 50% of the postings occurred in threads containing 11 or more posts, and the average word count of a participant entry was 108, indicating considerable participant activity in the online discussions.

Moderator-lite is not moderator-easy

Seeing Math moderators exert considerable formative influence on the course outside the discussion area as well. They spend significant time resolving technical issues, such as diffi-

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Teachscape and PBS TeacherLine Offer Seeing Math Courses

BY CYNTHIA MCINTYRE

A series of online and blended courses developed by the Concord Consortium for elementary and secondary math teachers is available from our partners, Teachscape and PBS TeacherLine.

Seeing Math courses are based on video case studies, using videos of real teachers in real classrooms or after-school settings. The focus of each video is teacher-to-student and student-to-student interactions, including teachers' questioning strategies that elicit student thinking and help make that thinking explicit. Additional video commentaries from math specialists highlight areas of student misconceptions and insights. Activities using interactive software provide course participants with a math challenge, so they explore the same content as students in the videos. Participants are asked to observe carefully their own processes as they work towards a mathematical solution; they share their processes in discussions with colleagues, and are thus exposed to a wider framework for understanding different problem-solving approaches, including those used by their own students.

PBS TeacherLine

http://teacherline.pbs.org
1-800-572-6386

- Proportional Reasoning
- Linear Functions
- Transformations of Linear Functions
- Linear Equations
- Systems of Linear Equations
- Quadratic Functions
- Transformations of Quadratic Functions
- Quadratic Equations
- Data Analysis

Seeing Math Elementary

"As I reflected on (struggled with) my own solutions to the broken calculator, I was aware of my own levels of thought and realized the value of such a learning activity in my classroom. The notion that there are many viable strategies that cause deeper thoughts about the math takes math instruction away from rote algorithms and toward critical thinking and application."

Seeing Math Elementary uses blended communities of practice (with both face-to-face meetings and online activities and discussions) to reflect on video case studies. The courses aim for depth rather than breadth in skill and content areas; they concentrate on concepts from the NCTM standards that are typically difficult to teach or to learn, including fractions, division with remainders, and using data to make predictions. Two courses look at pedagogy, including formative assessment and questioning strategies. An overview course considers foundations of effective math teaching. Teachscape customizes its program for schools and districts to ensure success.

Seeing Math Secondary

"I have heard over and over that a reflective teacher is an effective teacher. Well, this course demanded deep reflections and got it. Many times I had to dig deep to come up with my responses to the assignments—deep mentally and physically into the night! But I think the reward is worth it: I am coming out with a bag full of great teaching ideas scraped together from great teachers and specialists, online interactive tools, tons of ready-to-go activities, and a deepened understanding of algebra!"

Seeing Math Secondary online courses comprise the core units of a first-year algebra curriculum, covering linear and quadratic functions and equations, plus data analysis and proportional reasoning. Courses employ powerful tools, including videos of students and a national expert in math education, a content-rich math activity and interactive software for solving math challenges, plus threaded discussions guided by trained facilitators. PBS TeacherLine, which received funding from a Ready to Teach grant from the U.S. Department of Education, offers Seeing Math Secondary courses.

Teachscape

http://www.teachscape.com 1-877-98TEACH (988-3224)

- Foundations of Effective Mathematics Teaching
- Effective Questioning in the Mathematics Classroom
- Formative Assessment in the Mathematics Classroom
- Number & Operations: Division with Remainders
- Number & Operations: The Magnitude of Fractions
- Number & Operations: Broken Calculator
- Geometry: 2D and 3D Figures
- Geometry: Calculating Area of a Triangle
- Data Analysis and Probability: Using Data to Make Predictions
- Data Analysis and Probability: Measures of Center
- Pre-Algebra: Pan Balance Equations
- Pre-Algebra: Patterns and Functions

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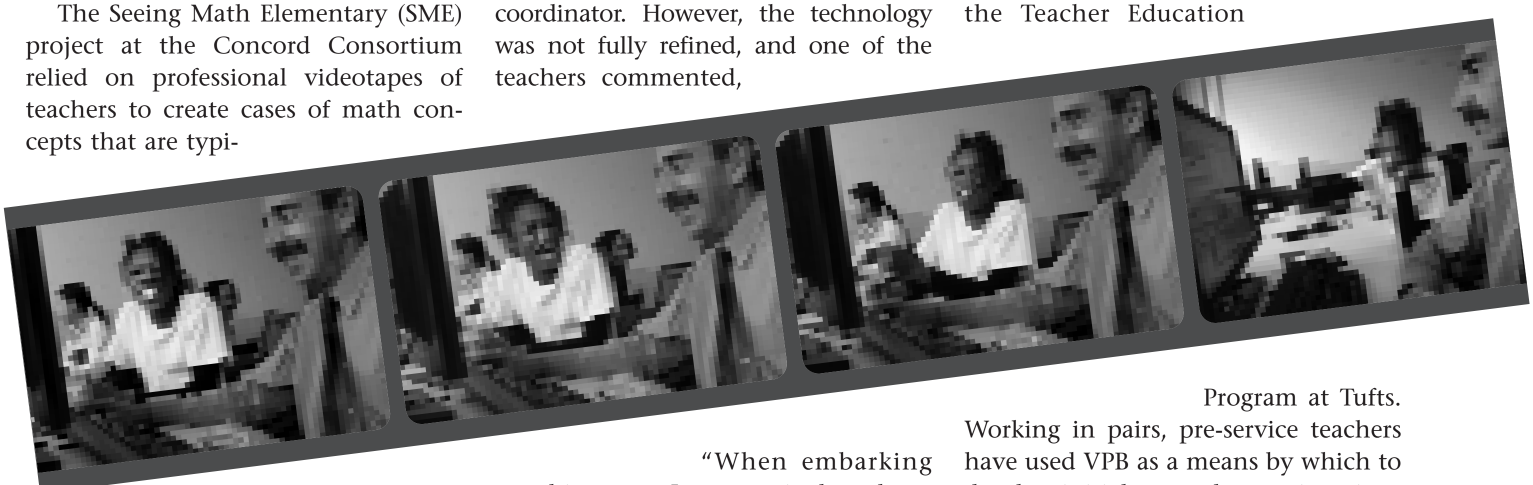
Lights, Camera, Action: Videotaping Teachers for Professional Development

BY ALVARO GALVIS

A professional crew comes into your math classroom to videotape. Stage fright dissipates as you work from your lesson plan and forget about the camera. What later appears on tape intrigues you so much that you enlist your colleagues in discussing your teaching strategies and the questions and misconceptions students displayed. As a group, you get so excited about the video episodes and the value of a learning community built around classroom dialogue that you create your own video case study, videotaping yourself and your students, scanning student work to digital format, and coming up with questions for reflection.



Sound like your typical elementary classroom? Perhaps not. But many teachers—from the elementary to the pre-service level—are doing just this.

The Seeing Math Elementary (SME) project at the Concord Consortium relied on professional videotapes of teachers to create cases of math concepts that are typically difficult to teach or to learn. Twelve cases were developed as five-week blended courses, offered with both face-to-face meetings and online discussions.

SME soon learned that teachers wanted not only to watch other teachers on tape, they also wanted to develop their own videos. The project created technology, VideoPaper Builder, to support communities of practice that reflect on their teaching and build their own cases in digital and interactive format.

The idea was piloted in Hudson, MA, where SME participants and their math coordinator shared classroom episodes. Teachers were videotaped; they screened the videos to select episodes for a case study focused on calculating the area of obtuse triangles. Teachers reviewed relevant literature, transcribed the dialogue in the selected episodes, and wrote a draft paper. But it was the Concord Consortium's research group that transformed these separate pieces into a VideoPaper. The technology to support VideoPaper production was still unsophisticated.

A second generation of the software was prepared and the same group from Hudson was invited to create a new VideoPaper. "Building the VideoPaper allowed us to highlight the importance of giving students time to share their mathematical thinking," said the math coordinator. However, the technology was not fully refined, and one of the teachers commented, "When embarking on this paper I was excited to learn about the technology and to be involved with it more. As I moved through the paper I felt overwhelmed with the technology. The programs worked and had good directions. I knew that there was support available, but even with all of that, there was just more technology than I could keep up with."

The SME project revised VideoPaper Builder, preserving the features that allowed users to synchronize video, text and images, while increasing the application's power to create adjustable user interfaces, to handle different types of video and graphic formats, to write and edit basic HTML pages, to add captions to video segments, and to create a printable version of the hypertext with the corresponding index and references.

VideoPaper Builder 3 (VPB3) was released in October 2005. VPB3 is easy-to-use software for creating multimedia case studies. It's free and open source, and runs on MacOSX or Windows operating systems, with interfaces in English and Spanish. It can be viewed with any Java-enabled browser. The software can be downloaded from http://vpb.concord.org or from the enclosed CD.

Future educators are already benefiting from this tool. Daniel Cogan-Drew of Tufts University tells us, "VideoPapers have become an integral part of the pre-service teacher portfolio in the Teacher Education Program at Tufts. Working in pairs, pre-service teachers have used VPB as a means by which to develop initial research questions into their emerging classroom practice. VPB has allowed us to reflect upon and share our classroom teaching."

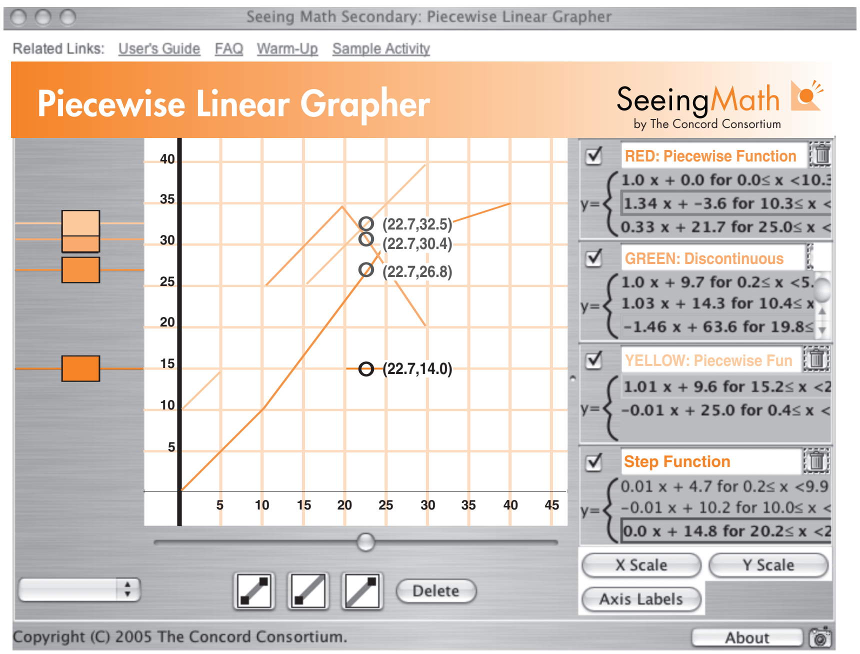
Is your classroom camera-ready? Your own video episodes can make powerful fodder for local professional development.

Alvaro Galvis *(alvaro@concord.org) is Research Director of the Seeing Math project.*

Interaction and Interactivity

BY GEORGE COLLISON

In 1999 Dr. Judah Schwartz challenged mathematics educators: “Can technology help us make the mathematics curriculum intellectually stimulating and socially responsible?” Schwartz envisioned a major paradigm shift in the teaching and learning of mathematics in which web-based technology would add representational power and thus new dimensions to visualizing, as well as capacity to communicate mathematically with others. The *Seeing Math* project, in support of that vision of stimulating and socially



The Piecewise Linear Grapher displaying piecewise, discontinuous, and step functions.

responsible teaching, has developed eight web-based interactive software tools for middle and high school mathematics. The Seeing Math software design represents functions, data sets, and proportional relationships in a way that is not possible on current handheld devices, like the graphing calculator. Through web communication, *Seeing Math interactives* enable users to share with others images of their mathematical products as part of an online discussion board.

Researchers have identified two qualities of applets (small interactive software that runs on the Web) that make them effective cognitive tools to support growth of understanding: interaction and interactivity. Interaction characterizes the “conversation” between the tool and the learner. Seeing Math interactives support the learner/applet conversation in many unique and highly effective ways. In some, users move a slide bar below the x-axis to draw the graph. The design emphasizes the function as the link between the independent and dependent variables. Users can shift readily from one algebraic form of a function to another equivalent form by clicking a tab. The graph of a function and its symbolic representation are dynamically linked, so changes in one affect changes in the other in real time. For instance, vertical or horizontal shifts (transformations) change symbolic representations. The Quadratic Transformer enables users to experiment directly with $f(x)$ notation. Questions like “How is $a(f(x))$ different from $f(ax)$ or from $f(x-a)$?” become the focus of individual and group inquiry. Immediate feedback through linked representations draws users deeper into exploration of mathematical content.

Interactivity refers to the feel, form, properties, and quality of the interaction with the tool. Seeing Math applets permit online sharing of screen shots, which supports online dialogue. Because they explicitly and dynamically link graphical representation and symbolic and numerical forms, the tools abound with “what if” possibilities to explore mathematics. For example, the Piecewise Linear Grapher permits students to define linear relationships that are not functions. If a user has created a graph with multiple y values for some values of x, a warning box indicates the double y-value assignment for that region, but does not suggest how to fix the problem. The animation of the function simply disappears for the region of the domain for which the function is improperly defined. The design turns an annoyance (the disappearing animation) into a learning opportunity. The student asks herself, “What changes in the domain will fix the problem?”

The eight Seeing Math algebra interactives support an approach to algebra using the function concept as a central theme. Traditional approaches offer sets of exercises detailing proper manipulation of symbols

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Schwartz, J.L. (1999). **“Can technology help us make the mathematics curriculum intellectually stimulating and socially responsible?”** *International Journal of Computers for Mathematical Learning,* 4: 99-119.

and equation solving. Teachers and students miss many opportunities to make connections to real-world, understandable mathematics. The function concept unifies later study in algebra and the study of change in calculus; introducing functions earlier aids students' understanding of mathematics significantly.

> **This course helped me** learn something about myself. When I approach math, I have a tendency NOT to 'take the risk.' I am afraid I might make a mistake. When I began this course, I was afraid to say certain things because I thought others might think I was nuts. I soon learned that some of the misconceptions, thoughts and ideas I had were just like those of my fellow colleagues. So, how does that reflect in my classroom? I might think I am letting the kids 'explore' math, but what can I do to encourage it more? I have given this a lot of thought and hope to use what I have learned in this course to encourage 'math talk' and the 'inner learner' in all my students. The concept that yields real gold is the 'function' and how it relates to the linear equation.

Seeing Math interactives

The interactives, plus warm-up exercises, User Guides, FAQ's, and activities are available on the CD included with this newsletter, as well as at the Seeing Math website. Try them out yourself and with your students. (Note: you need Java 1.3.1 or higher to run them.)

Piecewise Linear Grapher

A huge variety of problems, from discrete rate problems like taxi fares, cell phone plans, or purchase of building materials are fundamentally linear, but employ variable rates depending on quantity. The study of piecewise functions can forge important real-world links for beginning algebra students. Piecewise functions also provide a concrete, readily understandable entrance to key ideas like range and domain. Open the Piecewise Linear Grapher, and do the warm-up exercise to get familiar with the layout of the interactive. Next, try the sample activity, which explores a cell phone problem. After completing these, you may wish to try something more challenging. Not all real-world problems have unique solutions. Use your knowledge of slopes of line segments to solve the following challenges.

A hotel with four elevators

A shopping mall has four elevators. They all move at different speeds, but each moves at a constant speed, whether up or down. Elevator One starts on Floor 1, and Elevator Two starts on Floor 10.

All four elevators start moving at the same time. After 4 minutes, two of the elevators are on Floor 6. After 6 minutes, three of the elevators are on Floor 4. (None of the elevators change direction.)

At what floors did Elevators Three and Four start? Which elevators are on the same floor after 4 minutes? After 6 minutes?

Consider the approaches you used to solve the problems (graphic, symbolic, or something else altogether). Did you feel the need to use a symbolic approach? Did you use a combination of approaches? Which felt more natural, and which was more helpful?

Design and solve your own 2 or 3 elevator problem with the elevator(s) stopping at some floors for specific lengths of time.

LINKS *Interaction and Interactivity*

- **Seeing Math** *http://seeingmath.concord.org*
- **Seeing Math interactives** *http://seeingmath.concord.org/sms_interactives.html*

System Solver

The System Solver permits representation and manipulation of systems of linear equations in rational form. It is not an artificial intelligence support for solving that suggests the next steps in the process. The System Solver directly links the graphs of intermediate steps and associated numerical tabulations with the solution process and with the solution set. The software clarifies how legitimate manipulations can result in perplexing equations like $7=2$ or $-6=-6$. Try the warm-up and sample activities, then create your own systems of equations and solve them.

Conclusion

The Piecewise Linear Grapher and the System Solver demonstrate how excellent software design can support the conversation of the learner with the content through fluidly linked representations, and with other learners through sharing on the Web. The interactives also show how web-based devices can be effective cognitive tools that open up opportunities to develop understanding in mathematics for all students, not only those adept with symbols. With such tools, the teaching and learning of mathematics can be an intellectually stimulating and socially responsible activity for all.

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Seeing Math Research: Promising Gains

BY ALVARO GALVIS

What *teacher gains* in math content and pedagogy can be attributed to teacher participation in the Seeing Math professional development courses developed by the Concord Consortium? What *student gains* in math performance can be attributed to the participation of their teachers in the Seeing Math project? Such questions were the basis of the research in the final year and a half of the Seeing Math project, in response to the U.S. Department of Education's interest in quantitative results.

Seeing Math Elementary (SME) includes twelve interactive video cases in four NCTM strands for grades 3-6. Three six-week blended (online and onsite) courses in the Number and Operations strand were selected by participating school districts. Math coordinators were trained to facilitate video case-based discussions and to build local communities that reflect on their own practices.

Seeing Math Secondary (SMS) includes nine five-week online courses focused on improving teachers' understanding of key algebra topics at the secondary level. Interactive tools or applets afford teachers and students multiple approaches for solving math problems and making explicit their algebraic thinking. Classroom video episodes and expert video commentaries invite teachers to discuss content and pedagogical issues, and to listen to student thinking. For research purposes a 13-week family of three units on linear algebra (functions, transformations, and equations) was selected.

A quasi-experimental design created by the Concord Consortium in collaboration with external evaluators Edcentric and Hezel Associates was approved by the Department of Education. It allowed for cross-sectional comparisons (across cohorts within a given year), as well as longitudinal comparisons (within cohorts across consecutive years). The research was implemented in the spring of 2004 and during the 2004-2005 academic year.

The Concord Consortium developed open-ended measures aligned with content and pedagogy being taught in Seeing Math courses. These teacher assessments were field tested and adjusted before they were administered. Teachers took tests before and after participation in a Seeing Math course; the tests were scored with specially designed rubrics.

NWEA, which specializes in the measurement of student math knowledge, created student tests for both SME and SMS courses. Multiple-choice questions measured math knowledge within the NCTM standards that were directly related to the particular Seeing Math courses taken by participating teachers. These tests were based on Item Response Theory (IRT) and yielded three scores: overall, target, and non-target. (Target items relate to content that treatment teachers were exposed to, while non-target relate to content in the same NCTM strand, though not studied by treatment teachers.)

Cohort 1 teachers participated in Seeing Math courses during spring 2004; they were encouraged to apply course ideas when teaching their students that semester and the following school year. Cohort 2 and Cohort 3 teachers participated in Seeing Math courses during the 2004-05 school year and were asked to apply this knowledge in their classroom. Pre- and post-tests for content knowledge were administered to participating teachers and their students.

Seeing Math Elementary findings and discussion

Studies about the effect and impact of the SME course materials on elementary math teachers and their students at three participating school districts indicate that:

Treatment teachers performed significantly better in Pedagogy as well as in the Modeling/Formulating, Transforming/Manipulating, Inferring/Drawing Conclusions, and Communicating Content areas than did the control teachers.

Student findings were difficult to interpret. In one school district, there were no significant student gains for either year of the study, and no differences between treatment and control groups. In a second district, treatment students made significant gains over the second year of the study, and had significantly higher gains than did the control students. In the third district, treatment students had significant gains in both years in some test scores; however, both mean scores and gains for the control students exceeded those for the treatment students for all scores.

The study tested for statistical differences related to student grade level, ethnic group, gender, teacher gain scores, and teacher experience teaching math. There were no significant differences in gain scores by grade level within any school district, nor between any ethnic group gain scores; males had higher gains than females, though differences were not significant; very low correlation values indicate no relation between student gains and teacher gains or teacher's math teaching experience.

The above findings confirm that Seeing Math programs can improve teacher pedagogy and content knowledge. Edcentric also found that the courses met or exceeded participant expectations, and that the major elements of the courses—video cases, expert commentary, hands-on math activities with interactives, face-to-face meetings, and discussions—were considered important by the majority of the respondents. Qualitative evaluations also noted anecdotal evidence of teacher change and student change. Some teacher comments illustrate this: "I encourage my students to discuss their strategies more. I am aware of my own questioning and try to echo students, pose questions to clarify misunderstandings, and highlight different strategies." "I think the students who have more difficulty with math changed most. When I give the students a word problem and tell them to draw it out and use a method that works, they feel they have a choice and they start to solve it in a way that makes sense to them."

Seeing Math Secondary findings and discussion

Studies on the impact of SMS course materials on secondary education algebra teachers and their students indicate that:

Overall differences on teacher assessment (content and pedagogy) favored the treatment group; significant advantages were found only for the pedagogy subscale.

Less mathematically educated teachers tended to learn more in Linear Functions.

In the year after taking the Seeing Math course, teachers continued to learn in some content and pedagogy areas. (This may be biased by attrition in the sample.)

The treatment on teachers had no effect on student learning in target areas, but had a positive effect in non-target areas: students of treatment teachers declined less over a year than students of comparison teachers.

A pattern in all cohorts shows decline in non-target areas of linear algebra knowledge over a school year; however, this finding is difficult to interpret.

Students of teachers with a mathematics degree gained less in target areas than students of teachers without a degree. In non-target areas, students of treatment teachers declined less when their teachers had a mathematics degree, and declined more when their teachers did not.

Quantitative findings concerning teacher gains are coherent with the qualitative evaluation that found that Seeing Math can be an effective program for experienced middle and high school math teachers in helping them explore algebra instruction for their students. All SMS course completers (41 out of 57 teachers) found online discussions to be valuable in helping with instructional strategies for teaching algebra and with clarifying course content. Ninety-eight percent said they were using or planning to use strategies and activities from the course in their classes.

Student findings are difficult to explain. It is not clear why, independent of treatment, students of teachers with a math degree gained less in target areas than students of teachers without a degree. It is also unclear why, independent of cohort, students, including those of treatment teachers, declined in non-target areas over a school year.

Future research

From these studies we know that teachers made gains in pedagogy, but we also need to know whether they incorporated this learning into their practice, and if so, how? Do the findings imply that more or deeper content knowledge is less relevant than finding ways to translate existing understanding to students in meaningful ways, or understanding how students think and solve problems? A finer-grained look at some of these areas may be more informative than broadly assessing if teachers and their students learned as a result of taking a course, and may allow for more focused development of new materials. While the results are promising, more research is warranted to exploit the best methods for developing and implementing online professional development for math teachers.

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REFERENCES *SM Research*

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Building an Online Community after the Hurricanes

BY CYNTHIA MCINTYRE

"If Katrina did not blow me away, this class sure did." **(Michelle Brower)**

"As a teacher and administrator, I have been interested in integrating technology into both instruction and administration. I feel like the sky is the limit and hope one day, every child in the New Orleans Public Schools will be given a laptop, and read their assignments and books online. And when the next big one comes and we are scattered across the country, we can still work online and switch to a virtual campus. It is a vision that I think can become a reality." **(Russell Owen Plasczyk)**

The vision of a virtual classroom *is* a reality for many Louisiana students. Following hurricanes Katrina and Rita in the fall of 2005, the Concord Consortium offered three sections of Designing and Teaching Online Courses, a six-week online professional development course customized to train teachers to deliver courses for the Louisiana Virtual School, to 75 prospective LVS teachers. The Louisiana Department of Education and the Louisiana School for Math, Science, and the Arts, which administer the virtual school for over 2,600 students from across the state, knew it would see an increased need for online courses for students displaced by the hurricanes. With more online students, it would need additional qualified online teachers.

Designing and Teaching Online Courses covers the pedagogy and methodology of teaching on the Internet, with collaboration and community building at the core. Course assignments require posting to the online discussion board at least three times each week with substantive posts that build on the posts of peers and contribute to the overall dialogue. Participants cannot sit back and passively absorb lectures; they must participate in knowledge construction. They must be learners, and act as teachers to their peers. A trained facilitator also intervenes in discussions to move them deeper, and provides individualized formative feedback.

Participants in the three course sections came from all over the state of Louisiana, including areas that were hit by one or both hurricanes (the "twin sisters" or "the one-two punch of Mother Nature," as participants dubbed them). Schools and homes were devastated, but Louisiana teachers wanted to learn new ways to reach and teach their students.

Collaboration

"Out of all of my online classes, this one has been the most rewarding and I have enjoyed this one the most, have had the most fun, and have learned more through the interaction and collaboration with all of you." **(Heather McDaniel)**

"Out of all of my online classes, this one has been **the most rewarding** and I have enjoyed this one the most, have had the most fun, and have learned more through the **interaction and collaboration** with all of you."

–HEATHER MCDANIEL

Participants take part in a three-week group activity, designed to get them to make decisions together, give feedback to one another, and produce a joint project (e.g., a web page, PowerPoint presentation, or Word document) of shared resources. Collaboration is not easy; online collaboration presents a new set of challenges. For instance, decisions take longer as folks work at their own pace (within the confines of a "scheduled asynchronous" model, with weekly deadlines). Facial cues and verbal intonations are also absent, so participants must be careful to share their thoughts accurately through text alone. As with families and the workforce, collaboration in education is key. Opportunities must be presented; mutual trust must be fostered.

Shared experiences

One of the hallmarks of the Concord e-Learning Model is the use of purposeful virtual spaces: each discussion forum has a particular focus. Some are designed for working together on a collaborative project; others are created for sharing thoughts and insights sparked by an assigned reading. Three general-purpose discussion areas are available throughout the course, including Questions on Technical Issues, Questions on Assignments, and the Virtual Café. In addition to focused community-building activities in the opening weeks (in one activity, participants post introductions from the eyes of their pets), the Virtual Café provides a forum for social dialogue that is an essential ingredient to building a learning community. People share experiences and ideas here; they get to know one another on a personal level.

"Dealing with not one but two hurricanes was very difficult, but I feel like my life is finally getting back on track. I believe working with my students and actually having a job to go back to has helped to get my mind off the

devastation that is all around me. My students and this class have really helped me through one of the most difficult and traumatic times in my life!" **(Sheree Caminita)**

The outpouring of support for those who were affected by the hurricanes was evident. For instance, due to the disrupted postal service following the hurricanes, at least one participant did not receive the package of three required course texts. Another participant mailed her set of books to him (the readings were also available as PDF documents within the course).

Providing support and encouragement

"For a time in my life that I have needed encouragement, you all, my dear friends, have supplied it." **(Margarita Farrell)**

"It was great to be able to help lifting up the spirit of some of our classmates through this class, with words of support and prayers." **(Paula Landry)**

Participants shared both their stories and their support. It became clear that a virtual hand can hold just as tightly as a human hand.

Healing

"I really feel that taking this class will help us heal those wounds we have suffered and help us to move on. Taking this class is like moving on from the past and into the future. We know that it can only get better from this point forward! We are happy and grateful to be here." **(Sheree Caminita)**

The timing of the six-week course was, perhaps, "just what the doctor ordered" for many teachers in Louisiana, following on the heels of the hurricanes. It provided stability in cyberspace when the world around them was less stable. The scheduled, asynchronous course meant that participants needed to post throughout the week and stay current with their assignments. Some participants posted daily; many posted late at night. Because the course was available round-the-clock, participants could log in whenever they wanted (or whenever they had a reliable Internet connection) for a moment of what one described as ***"a place of hope and serenity."*** **(Russell Owen Plasczyk)**

One graduation speech summed up the experience for many:

"We sure had a lot of other things on our minds, because of our late Louisiana natural catastrophes. We had roofs to fix, houses to level, money to find, help to find, friends to help, etc. Nonetheless, throughout all this madness, a glimpse of hope was there, one little class lost somewhere in cyberspace, but always open (24/7), and always full of people who did not have to be there, but who were there because they chose to… Not only were they there, but also they were there for each other. Many of them lost a lot in the last three months; nevertheless, they still managed to give a lot to each other." **(Stephen Lizin)**

Thanks to a generous grant from the BellSouth Foundation, the Louisiana Virtual School will continue to expand the number of seats offered to Louisiana students wherever they are post-Katrina and Rita. Their online teachers will be ready to support them in their education, and provide them with a new meaning of community in the wake of the hurricanes: a community built in the virtual world.

Cynthia McIntyre *(cynthia@concord.org), Director of Communications & Online Learning, had the privilege of facilitating Designing and Teaching Online Courses for Louisiana teachers in the fall of 2005.*

Facilitator—*continued from page 5*

culty installing video players or the proper version of Java to use with the applets. They also give weekly feedback to participants in their private discussion areas. Moderator feedback includes highlighting participants' contributions that received significant attention from other participants and suggesting where more effort to communicate or articulate ideas could benefit others in the course. Moderators received seven weeks of training based on the ideas in *The Online Teaching Guide* and *Facilitating Online Learning*, which familiarized moderators with "voice" and "tone" and a set of critical thinking strategies. Technical training was also included.

Implications for future video cases for professional development: Getting to scale

Judah Schwartz, Ph.D., has offered a vision of mathematics education and professional development on the Web. He has looked beyond ordinary tinkering to the effective use of well-designed cognitive tools, which engage the user in dynamic visualization, concrete manipulation of abstract mathematical objects, and discourse that is stimulating. Schwartz's vision is realized in the five elements of Seeing Math professional development. Supported by a media-rich context and interactions with significant mathematical ideas, Seeing Math participants work together to generate new ideas, build new connections, and extend their understanding of both math content and pedagogy. The ability to learn from each other greatly increases the likelihood that large-scale implementation of professional development in secondary mathematics is feasible.

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LINKS *Facilitator*

- **Seeing Math**
  http://seeingmath.concord.org
- **Exploratorium**
  http://www.exploratorium.edu
- **Concord e-Learning Model**
  http://www.concord.org/courses/cc_e-learning_model.html

How Do Innovations Travel from the Lab to the Classroom?

BY ROBERT TINKER

Technologies don't just happen; there is a fascinating and revealing history behind most popular technologies. Did you know that the *mouse* was invented with Air Force funding in 1963 at the nonprofit SRI by Doug Engelbart? Then a Xerox lab integrated it with software windows for the laser printer they invented. In 1979 Xerox shared the window concept with Apple, which Steve Jobs incorporated into the Macintosh in 1983. After resisting the mouse, Bill Gates incorporated the idea in Windows in 1985. It finally took off in 1990. Widespread use of the mouse required almost three decades!

Educational innovations also have histories that often start with government funding and wend their ways into classrooms through various channels. Let's look at several that have made it into many classrooms, and consider the general themes that can guide future dissemination efforts.

Logo

In the late 1960's Wally Feurzeig at Bolt, Baranek and Newman developed a programming language for children called Logo that ran on time-shared computers. Seymour Papert at MIT seized on this idea and obtained NSF funding to develop a microcomputer version that first ran on the TI-99 and, later, the Apple II. A compelling speaker and writer, Seymour popularized the idea of using Logo programming to teach math and thinking skills. Beginning in the 1970's the project developed and extended the language, created student activities, supported school implementations, and studied their impact. This early work had a huge effect worldwide.

At that time, the NSF had a cumbersome commercialization procedure that required MIT to solicit publishers and split any royalty with the NSF. Eventually, two companies agreed to publish Logo, but in the year that it took to negotiate the agreement, Seymour formed *LCSI* and made a new version that circumvented the copyright on the grant-supported material. LCSI still markets Logo. An NSF grant in the 1980's funded Logo-in-a-brick, which was commercialized as *Lego Mindstorms*. The MIT team continues to improve Logo, now supporting two multi-agent versions that are free, one of which is open source. Funding comes from a variety of sources, including additional NSF grants and the Media Lab. While interest in Logo as a programming language has waned in the U.S., it is still viable and widely used internationally. Mindstorms continues to reach kids worldwide, and the new Logos are likely to continue in this tradition.

Microcomputer-Based Labs

In the late 1970's my team at TERC applied to education the idea of collecting and displaying real-time data using microcomputers, a technique we called Microcomputer-Based Labs, or MBL. A Department of Education grant in 1983 allowed us to apply this to the Voyage of the Mimi project and an NSF grant in 1984 supported further development. At that time, we attached a Polaroid ultrasonic sensor to the Apple to create the first motion sensor, an original probe that is now a cornerstone of physics instruction. The project developed the software, hardware, and student activities, and studied student learning with this approach.

The NSF still required licensing commercial exploitation of materials, so HRM Software became the publisher. We also made $10 kits, which we advertised through our free newsletter. Other companies picked up the idea, in several cases through the kits. IBM funded a major improvement in hardware and software and TI adapted them to calculators, changing MBL to CBL. This strand of R&D is responsible for probe use, which is widespread in secondary and college science teaching. Five vendors now serve this market and offer over 40 kinds of sensors.

Kidnet

In the early 1980's my group at TERC developed Kidnet, learning activities based on kids collecting data and networking to share their results with other students. The NSF funded this under a program that required dollar-for-dollar matching from a publisher. We selected the National Geographic Society, not your average publisher, but one deeply committed to our project. Our collaboration was successful and led to the NGS *Kids Network* that reached a quarter-million students after a huge effort resulted in award-winning software, tested curricula, and impressive learning results.

Web technology overtook the product in the 1990's and the NGS was unable to fund its reinvention as a web-based product. Subsequent grants to TERC have accomplished this, and the material is now available, though not widely used. In parallel, Kidnet led to other independent projects. Al Gore was inspired by Kidnet to write about it in *Earth in the Balance,* which led to the GLOBE project. Currently, dozens of other free projects are based on the Kidnet success.

LINKS *Innovations*

- **The Mouse/Windows history**
  http://arstechnica.com/articles/paedia/gui.ars
- **LCSI**
  http://www.microworlds.com
- **Lego Mindstorms**
  http://mindstorms.lego.com
- **Kids Network**
  http://www.enviscinetwork.com
- **Virtual High School**
  http://www.goVHS.org
- **Open source educational applications**
  http://www.concord.org/publications/newsletter/2005-spring/opensource.html
- **Open source code at CC**
  http://source.concord.org

examples started with government funding of an R&D group and achieved their greatest distribution after a decade or more by others. Logo, MBL, and Kidnet tried the standard method of licensing materials to a publisher, but all eventually failed and none generated significant income for the developer. Mindstorms stands as a unique example of a grant-supported innovation breaking into a mass market.

Another clear message is that the original innovation needs to be more than simply a good idea. To take off, extensive and continuing development is needed of the technology and of educational applications. Research on student learning with the innovation is required, as well as close cooperation with experienced teachers.

With software, the complexity of the required code is a major factor in determining the route to dissemination. Of these examples, only Logo and Kidnet involved extensive software. Two of the commercial Logo efforts failed and the third barely survived. The NGS did not have the capacity to maintain Kidnet software and additional grant funding was required to make the transition to the Web. The MBL software is relatively simpler, but vendors are challenged to produce the needed code and we are currently helping them all with grant funding.

This history has convinced us that the best way to disseminate educational innovations that incorporate sophisticated software is to encourage mimicry by giving away the technology and making it easy to author related student materials. We hope to duplicate for educational applications the phenomenal worldwide spread of the open source GNU/Linux operating system. All the software now being developed at the Concord Consortium is free and open source. These include a wide range of models, probeware, and graphing tools, along with hundreds of student activities based on these.

This history has convinced us that the best way to **disseminate educational innovations** is to encourage mimicry by **giving away the technology** and making it easy to author related student materials.

The Virtual High School

The Concord Consortium conceived the *Virtual High School* (VHS) in early 1996 and initiated it later that year in collaboration with the Hudson Public Schools of Massachusetts with funding from the U.S. Department of Education. It is unique, because it is a cooperative through which schools share over 200 online courses. VHS offers rigorous online courses to teachers where they learn how to create and offer successful online courses. Most schools offer virtual courses in proportion to the number of participating students.

After five years of federal funding, the project was proven and ready to be licensed. We set up a separate nonprofit, jumpstarted by a major grant from the Noyce Foundation. VHS, Inc. has expanded and generates its primary income from fees and services.

The VHS idea of offering online high school courses has been widely copied, but without the cooperative economic model. There are now hundreds of thousands of secondary students enrolled in other virtual school projects, many of which were inspired by VHS.

Seeding future dissemination

These examples illustrate the time it takes for technology-enhanced educational practice to become widespread and the range of paths taken. All these

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NEWS at Concord Consortium

CC's Open Source Contributions

Schools have a wide range of devices—from desktops to handhelds. To have the broadest impact, educational software should run on all of them. In addition to creating and using open source software, Concord Consortium staff have contributed improvements to existing open source projects in order to achieve the goal of ubiquitous software.

Nearly all Concord Consortium's interactive activities are written with Java. Some activities work with sensors, so we need ways of communicating with those sensors from Java. Many sensors use serial ports for this communication. Dima Markman contributed to the RXTX project, so Java applications could use serial ports on OS X.

Our interactive Java components use a graphical framework called Swing, but Swing-based Java components are currently not as portable as they could be. Scott Cytacki is contributing to the SwingWT project, so our models can be used more widely.

For instance, Palm handhelds can run Java applications, but Swing is not supported. SwingWT allows Swing applications to run on the Palm. Java applications can run on the newer Windows operating systems, including Pocket PC handhelds, without separately installing Java. This mode of running Java applications relies on SwingWT to display Swing-based components. Finally, SwingWT allows for the integration of Swing-based components into Eclipse, which provides a rich authoring environment.

Getting our software into the hands of teachers and students requires a huge group effort; we're proud to be part of the open source community.

Performance Assessment Project

In May, we will start on an exciting three-year project to demonstrate the feasibility and cost-effectiveness of computer-assisted performance assessment for evaluating student knowledge and ability in advanced technological education. With the support of the Advanced Technological Education Program of the National Science Foundation, we will develop, field-test, validate, and disseminate automated analyses of students' understanding of key topics in introductory electronics, based on their performance on relevant tasks. The analyses will be used as formative assessments for the teacher, as well as feedback to the students themselves. We expect that this project will lay the groundwork for large-scale implementation of this style of assessment in technical high schools and two-year colleges around the country.

Performance assessments, which go beyond the memorization and snap responses required by multiple-choice questions and closely resemble the challenges offered by the workplace, are widely recognized as the preferred way to assess students' understanding and skills, particularly in technical areas. They offer students problems with ambiguous questions, multiple steps to a solution, and often more than one satisfactory (and no optimal) outcome. Implementation of performance assessment has been limited because it is expensive, labor-intensive, and subjective. We will combine software and probeware in a computer-based approach that can offer the same advantages as typical performance-based assessments at a fraction of the cost, while also providing a more objective outcome.

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