TECHNOLOGY REVIEWS

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Section Co-Editors

Projecting Science and Mathematics

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New technologies have made computer projectors affordable for most classrooms. Good quality projectors with 1,200 lumens can now be purchased for $1,200 or less. Unfortunately, before most schools budgets could even accommodate them, projectors had already earned a bad reputation with many educators – due primarily to the text-heavy PowerPoint slides flashed endlessly before us at professional meetings and in college lecture halls. In many cases, educators have been convinced that projectors are no more than glorified overhead projectors, only more prone to glitches and more time consuming to prepare for.

Computer projectors have the potential to be much more useful educational tools than overhead projectors could ever be. At the very least, they can be used to address some of the common dilemmas faced by teachers who want to integrate technology. With the combination of a computer, a projector, and good pedagogy, however, teachers can bring to the classroom all the potential of appropriate technologies to enhance science and mathematics learning.

Facilitating Technology Integration

The following are some ways projectors can facilitate technology integration in the classroom:

Classroom Computer Access. In a classroom with only one or two computers, a projector can bring technology access to every student. As noted by one local teacher, a projector converts a single computer from merely a planning tool to a teaching tool. Anything a teacher or student can do individually on a computer can now be shared with the whole class.

Computer Lab. When teachers do have access to the computer lab or to a traveling classroom set of laptops, projectors can provide focus to the class. A teacher in our county whose students all had wireless handheld computers commented that having a projector in her room was crucial: "Having 17 kids on 17 computers creates a need for crowd control – it's hard to know where and when all 17 are focusing. The projector adds a focal point to the class." Following the direct instruction model, a teacher can project the computer screen in order to demonstrate the types of activities in which students will engage with the software, then walk through how to use the software step by step before allowing students to work on their own.

Learning New Software. Often, teachers do not want to sacrifice instructional time to teach students how to use complex new software applications. After all, in most cases science or mathematics concepts are the target of instruction, not the technology. In these cases, teachers may use class time more efficiently by projecting a computer application and working through the concept with the whole class. Science teachers have been doing lab demonstrations this way for a long time, especially when lab activities are too dangerous or too expensive for every student to do "hands on."

Expensive Software Site Licenses. And speaking of expensive…good software that may cost $50 for a single copy can cost hundreds of dollars for a site license for the entire classroom or computer lab. A projector allows teachers to take good advantage of the single copy.

We like projectors for all of these reasons, but we are most excited about uses of computer/projector combinations that take instruction beyond the ordinary. Effective uses of these technologies have the potential to support standards-based instruction by heightening student engagement, providing visualization of complex science and mathematics concepts, and increasing opportunities for inquiry – especially in classrooms where low student-to-computer ratios are not possible.

Conceptualization and Student Engagement

Still images. The Web, CD-ROMS, and digital cameras provide teachers wider access to a variety of photographs that can be used to capture students' attention, initiate a discussion, and provide a real-world context for analysis.

For example, after some initial instruction on the Doppler Effect, a science teacher might challenge students with the cloudburst pictured in Figure 1. The teacher might ask students to use what they know about sound waves and compression to explain the conditions or factors that would cause the cloud to be produced by the jet. (For opposing explanations of this effect, see http://sonicbooms.org/images/F18Condensation.html and http://www.eng.vt.edu/fluids/msc/gallery/conden/pg_sing.htm.)

Figure 1. *Condensation cloud (from http://www.chinfo.navy.mil/navpalib/images/hornetsb.jpg. U.S. Navy photo by Ensign John Gay. [990707-N-6483G-001] July 7, 1999)*

In the mathematics classroom, students can use digital images to explore mathematics concepts. For example, Figure 2 shows a digital image a student created to illustrate a vanishing point in projective geometry. The student took a digital picture, imported the picture into the Geometer's Sketchpad, and constructed lines to locate the vanishing point.

Multidimensional images. One-dimensional illustrations are useful in many cases, but can be limited in their ability to help students understand multidimensional objects or processes. A number of Web sites and other digital resources provide images in three dimensional (and sometimes movable) form that teachers can display with a projector.

In science classes, students typically have difficulty connecting macroscopic, submicroscopic, and symbolic representations of substances. Chime representations of molecular structures allow students to rotate, zoom, and view different model systems for chemical elements and compounds and can help students build more useful three-dimensional atomic mental models (Figure 3). You can view a number of Chime molecule representations (after downloading the free Chime plug-in) at the following Web sites:

- http://www.wellesley.edu/Chemistry/Flick/molecules/newlist.html
- http://www.geo.ucalgary.ca/~tmenard/crystal/crystal.html
- http://www.biologie.uni-hamburg.de/b-online/ibc99/biochemistry/Molecules.html

Linear programming is a topic taught in intermediate and advanced algebra classes. Typically, students are just shown a standard algorithm for solving linear programming tasks. This two dimensional algorithm relies on a "corner point theorem," which is presented without any conceptual underpinning. Figure 4 shows a Flash movie teachers can use to illustrate visually the

Figure 3. *Chime images of cubane, straight-on view (left) and rotated view (right), from http://www.wellesley.edu/Chemistry/Flick/molecules/newlist.html*

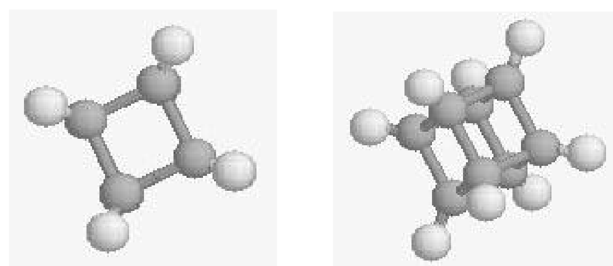


Figure 2. *Photo placed in Geometer's Sketchpad for analysis.*

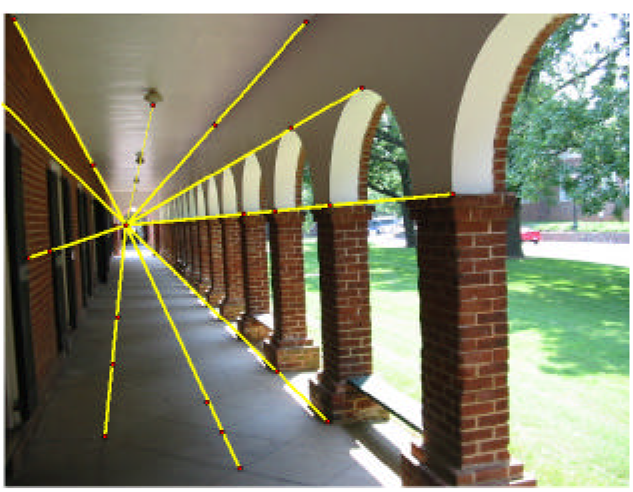
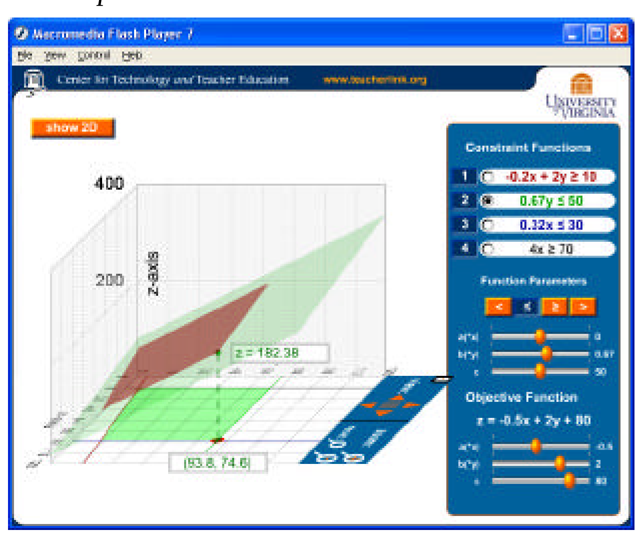


Figure 4. *Three dimensional illustration of the corner point theorem.*



three dimensional rationale behind the corner point theorem. (This Flash application can be downloaded free from http://www.teacherlink.org/content/math/interactive/flash/home.html)

Animations and video. The Web abounds with animations, simulations, and video clips of natural processes that are difficult to portray with still images. On the Ithaca City School District's Web Zone (http://ithacasciencezone.com/chemzone/lessons/03bonding/dogbonds.htm) you can view animations that provide humorous analogies for four types of atomic bonding (Figure 5). The goal of these animations is to make chemical bonding (which you cannot see) more understandable by comparing them to more familiar interactions (dogs fighting over bones).

The ExploreLearning Web site (www.explorelearning.com) provides simulations to help students understand a number of natural phenomena, such as high and low tides (Figure 6).

Trigonometry students can use their graphing calculators with teachers' projection systems to demonstrate their simulations of projectile motion situations. Figure 7 shows a graphing calculator simulation of three similar projectiles launched at angles of $\pi/6$, $\pi/4$, and $\pi/3$ radians. To create such simulations students need to derive equations for the horizontal and vertical motion of each projectile and attend carefully to units.

Students can ask their classmates to predict which projectile will go the highest, which will travel the furthest horizontally, and which will take the longest time to hit the ground, and explain their predictions. The simulation can be used to then calculate these times and distances.

Students can use the simulation to determine relationships between a projectile's launch angle, maximum height achieved, distance traveled, and time to hit the ground. This task can be followed up by similar contextual tasks involving projectile motion, such as in rocket flight or sports.

Inquiry and Analysis

Interactive simulations and spreadsheets allow students do more that just watch something happen. Even in a one-computer classroom, teachers can engage students in active learning by projecting the computer simulation and asking students to suggest changes in parameters and apply their understanding by making predictions. With this type of software, students can ask "what if" questions and then immediately view the results.

Starry Night, described in a previous Technology Review column (Volume 103, pp. 397-401), is a powerful simulation program for helping students understand astronomy concepts, from phases of the moon to apparent motion of stars. Because the software has so

Figure 5. *Screenshots from the dog bone bonding analogies at http://ithacasciencezone.com/chemzone/lessons/03bonding/dogbonds.htm. Copyright 2004 by Science Joy Wagon (used with permission).*

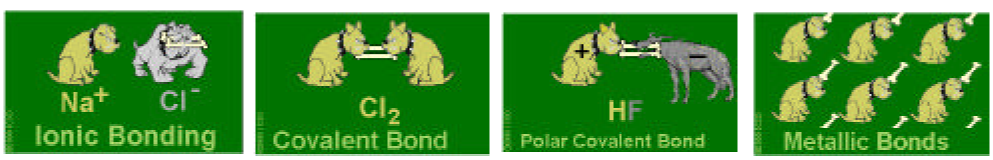


Figure 6. *Screenshot from ExploreLearning's tides gizmo.*

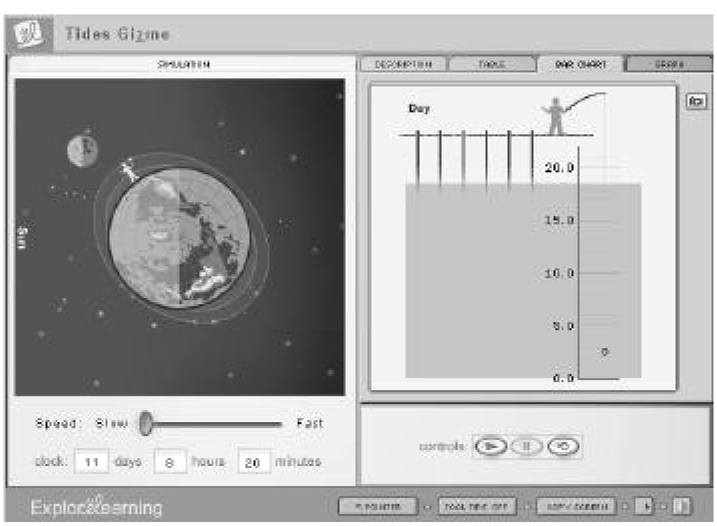
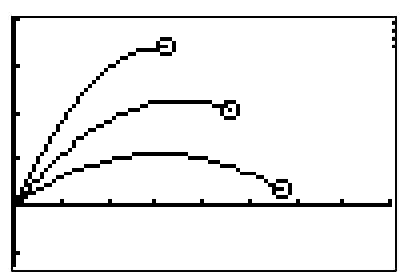


Figure 7. *Screenshot from a graphing calculator screen showing a simulation of projectile motion.*



many features and possible parameter settings, sometimes it works better for the teacher to be in control of the software, while facilitating inquiry in a whole class setting and asking questions like,

- What is a constellation?
- Do all constellations rise and set?
- Are the circumpolar constellations the same everywhere on Earth? (see Figure 8)

In geometry classes students can use projected simulations to analyze generated fractals, such as the Sierpinski Triangle. A Sierpinski triangle can be constructed in the following way: (a) start with an equilateral triangle and a randomly chosen point inside, on, or outside the triangle, (b) randomly choose a vertex of the triangle and place a new point half way between the initial point and the randomly chosen vertex, (c) randomly choose a vertex of the triangle and place a third point half way between the second point and the randomly chosen vertex, and (d) continuing this recursive process. Generation of a "good" triangle will necessitate the plotting of several thousand points. Clearly, this is impractical to do by hand, so we developed our Sierpinski Polygon program in MicroWorlds to carry out this process. Figure 9 shows Sierpinski's triangle constructed with 7,525 points.

Students, individually or in groups, can analyze this triangle and comment on their observations. They can be asked to predict and explore various "What if" questions (e.g., What if we started with a hexagon? What if we used a ratio of one third instead of one half? What if we used ratios greater than 1?). Figure 10 shows a triangle constructed with a ratio of 1.5.

To use this interactive simulation, firstdownload the MicroWorlds webplayer from http://www.microworlds.com/webplayer/index.html (select the download for your operating system, then select "Web Player for MW 2 and Pro Projects"). Access the simulation at http://www.teacherlink.org/content/math/interactive/ and select "Sierpinski Polygon."

Conclusion

Over the past decade millions of dollars have been spent to place computers in classrooms. This effort has been so successful that today better than 95% of classrooms have at least one computer. Yet several studies have shown that these computers are being relegated to administrative tasks rather than being used instructionally – primarily because a single computer cannot accommodate 25 or so students at one time. Newly affordable computer projectors can provide the bridge from the one computer to the whole classroom.

The ideas we have provided in this column merely scratch the surface. A creative teacher can use a projector to tap much of the technology's potential, providing learning opportunities consistent with the reform documents in both science and mathematics education.

See our next column for a list of projector buying tips for teachers.

Figure 8. *Screenshot of constellations from Starry Night virtual planetarium software.*

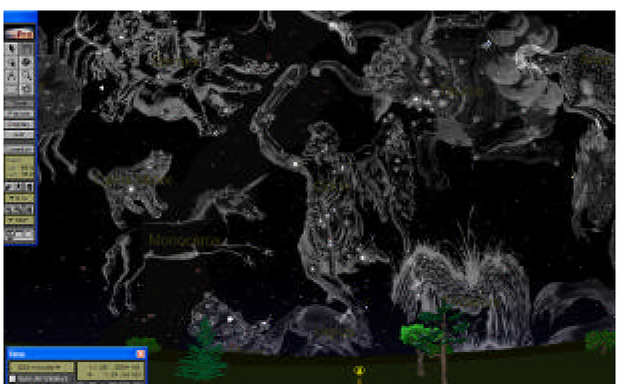


Figure 9. *Sierpinski's triangle.*

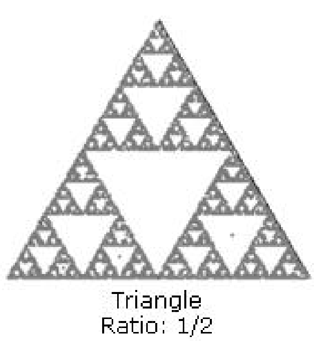
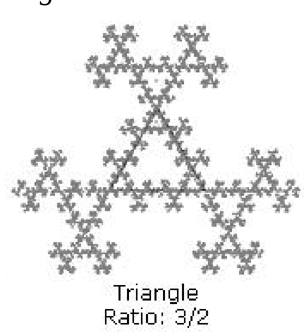


Figure 10. *Sierpinski Triangle with r = 1.5*



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