side of the block; Figure 3 shows an open view of the block, exposing the internal computer and its optical fiber.) When blocks are in a series, each block communicates both its own letter and those of preceding blocks to the following block; the final block sends the entire word to a speech synthesizer in a desktop machine.

There are still other types of materials that can be used for sensing or communication. *Thermistors* are temperature sensors that work by altering their electrical resistance in response to changes in temperature; they are typically composed of metal oxide semiconductors [5]. Numerous *chemical sensors* have likewise been developed in recent years for a variety of specific purposes (such as detecting pollutants); some of these sensors employ biomaterials such as enzymes to detect specific substrates [5].

Miscellaneous materials. There are, of course, still many other interesting, affordable materials likely to play an increasingly prominent role in children's lives; the catalogs and Web sites of science hobbyist enterprises offer fascinating examples. These materials include novel types of plastics and other polymers; semiconductor-based solar power cells; demonstration kits for high-temperature superconductors; and so forth.

New Materials and Children's Activities

Emerging materials could transform classroom apparatus. One could incorporate coatings of piezoelectric sensors into (say) an anatomical model, so that a child could, for example, ask for the name of a particular muscle or bone by touching its representation in a physical model. A wave tank could be designed to employ electrorheological fluids to produce highly complex or beautiful patterns of controllable fluid flow; a mathematical model of a surface might be created of material that changes shape over time to display a sequence of parameterized surface constructions; dioramas or displays might change appearance with ambient temperature or humidity.

But perhaps it could be even more compelling to integrate new materials within the sorts of homespun activities that have always captivated children. One might imagine incorporating electroluminescence into the string games that children play, so that a handheld string figure lights up in gorgeous colors; trading cards might be made of programmable paper so that each card can include a child-designed graphical effect; constructions currently made in paper (such as polyhedral models and pop-ups) might eventually incorporate programmable paper elements to produce spectacular dynamic displays in children's creations.

Children might create mosaic constructions on sensor-equipped substrates, so that by pressing a personally coded sequence of stones in the mosaic, the construction responds in some interesting way. More generally, sensor-equipped surfaces could be customized by their child users so that individual patterns of touch are used to play music, open (or close) locks, record diary entries, and so forth. Puzzles and games are especially fertile ground for this sort of brainstorming. One might imagine topological puzzles whose pieces change shape over time, or jigsaw puzzles whose pieces change color in response to light or sound, or board game pieces that alter depending on how they are moved.

Construction kits could be composed of pieces that communicate via optical fibers, or that conduct or manipulate patterns of light, or that change color or shape.

The landscape of new materials is thus likely to create a pervasive change in children's artifacts and activities comparable in scope and creativity to that effected by computers over the previous generation. In a sense, children have always played and worked with interesting new materials, wherever those materials become available: paper dolls, glass beads, synthetic rubber balls, and plastic construction pieces have all represented technological advances at somepoint. What is unique about the present historical moment is the way in which the range, variety, and expressive power of new materials is poised to explode within the next generation or two. **C**

REFERENCES

1. Amato, I. *Stuff.* Basic Books, New York, NY, 1997.
2. Ball, P. *Made to Measure.* Princeton University Press, Princeton, NJ, 1997.
3. Eisenberg, M. et al. Computationally enhanced construction kits for children: Prototype and principles. In *Proceedings of the International Conference on the Learning Sciences.* (Seattle, WA, 2002), 79–85.
4. Forester, T. (Ed.) *The Materials Revolution.* MIT Press, Cambridge, MA, 1988.
5. Fraden, J. *Handbook of Modern Sensors* (2nd ed.) Springer-Verlag, New York, NY, 2004.
6. Mann, C. Electronic paper turns the page. *Technology Review* (Mar. 2001).
7. Resnick, M., Berg, R., and Eisenberg, M. Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *J. Learning Sciences 9,* 1 (2000), 7–30.
8. Resnick, M. et al. Programmable bricks: Toys to think with. *IBM Systems J. 35,* 3 (1996), 443–452.
9. Worden, K., Bullough, W., and Haywood, J. *Smart Technologies.* World Scientific, Singapore.
10. Wrensch, T., and Eisenberg, M. The programmable hinge: Toward computationally enhanced crafts. In *Proceedings of UIST98.* (San Francisco, 1998), 89–96.

MICHAEL EISENBERG (duck@cs.colorado.edu) is an associate professor in the Department of Computer Science and Institute of Cognitive Science, University of Colorado, Boulder.