3. See, for example, Y. Y. Cui, J. H. Li, Y. Dai, B. X. Liu, *J. Phys. Chem. B* **115**, 4703 (2011).

Jianbo Liu
(jbliu@tsinghua.edu.cn)
Tsinghua University
Beijing

■ **Schroers replies:** In the section of my article that Jianbo Liu cites, I did not attempt to report correlations with glass-forming ability but simply to state how GFA is defined—namely, by the critical cooling rate, which also establishes a critical casting thickness.

In their work, the Tsinghua University researchers report a correlation with GFA and try to understand and predict why glasses form. Their work is based on an idea by Takeshi Egami and Yoshio Waseda.[1] The Tsinghua group essentially confirms the well-established Hume-Rothery rules—in particular, that for a specific size difference between two metallic atoms, only a limited range of compositions will form solid solutions.

I agree with Liu that destabilizing solid solutions is a requirement for glass formation, but it is at most a minimum one. However, predicting and quantifying GFA through identifying compositional limits of solid solutions is insufficient. Beyond those solution limits, mixtures often form intermetallic phases, homogeneous crystalline phases that compete with the glass in terms of stability. Moreover, intermetallics can be difficult to consider in molecular dynamics simulations that have been used by the Tsinghua group, depending on the simulations' assumptions. In summary, the Tsinghua group's finding is a requirement for glass formation; however, it is insufficient to predict glass-forming ability in a quantitative manner and is certainly not suited to act as a predictor for glass formation.

Reference

1. T. Egami, Y. Waseda, *J. Non-Cryst. Solids* **64**, 113 (1984).

Jan Schroers
(jan.schroers@yale.edu)
Yale University
New Haven, Connecticut

Black-box electronics and passive learning

Ludwik Kowalski raises some interesting points on the nontransparent technological devices that pervade our lives (PHYSICS TODAY, October 2013, page 8). I have an additional concern about those devices. I agree with Kowalski that they fail to promote curiosity. But suppose one of my electronic devices behaves in a way I don't expect. If I do somehow become curious about its behavior—Was it a network glitch? Design whim? Virus?—what I might learn has nothing to do with science or causality. I'm more likely to learn about human nature, corporate look and feel, or perhaps that what I observed was just a random event I cannot duplicate. What I learn will lead me away from science—from even thinking that science could be relevant for understanding my world.

On the engineering side, if I want to fix or improve my device, I can't; the hardware is typically sealed. Software presents a similar situation; writing for devices requires advanced skills from the outset and possibly a license agreement. My curiosity is far from encouraged. The lesson to me is, "Sorry, technology is beyond your grasp."

I think most modern devices not only fail to promote curiosity, they actively discourage it. I find it ironic that our wealth of technology, distributed widely in the population, may end up contributing to an antiscience mindset. That could bode ill for public debate on, say, climate change.

Bennett Battaile
(glass@spatialreasoning.com)
Portland, Oregon

■ **The lack of transparency** of our new electronic gadgets, Ludwik Kowalski wrote, is an advantage in efficiency, but it also carries potential harm. While I agree, I suggest that the harm could largely be avoided by novel teaching methods and new ways of writing high school textbooks.

What can we do to raise our technological gadgets above the level of black boxes—or black holes that swallow any student involvement? To appropriately connect modern technological tools to the important principles and laws of nature, we need to teach science, technology, engineering, and mathematics (STEM) as a whole, based on unifying principles. That approach should not only remedy some of the problems that Kowalski mentions but also help us to resolve the lingering problems of STEM education altogether. In fact, if I were asked to formulate the educational problems of STEM in one sentence, I would say, "It's the textbooks."

I was confronted with the problems of STEM education in 2007, when I was serving on the National Science Board.