over perceived enemies or rivals. Remember that the money, although originating with the taxpayers, is ultimately doled out at the discretion of politicians.

With this in mind, we may answer a question that Mehta did not actually ask: When, exactly, did science cease to be a vocation? The answer is World War II, which spurred the notion that science could not only win a war but maintain a permanent technological, and hence economic, advantage. That sort of thinking created the factory mentality in which well-rounded intellects, as Mehta notes, are now actively deselected. The job market presently favors those who stay in the same academic discipline, finish their studies in record time, and thus bring the least perspective—and maturity—to the job. Generalists are not wanted; familiarity with the programming code of the day is now more important than being able to think outside the box.

Mehta also notes the "stifling of merit by politics," the small-scale corruption of winks, nods, and handshakes that no one wants to acknowledge. Ultimately, she concludes that physics "became a business with very small stakes." But in that she is dead wrong. Physics, as a largely tax-funded and multibillion-dollar enterprise, became a business with truly enormous stakes: the very supremacy of the old colonial nations. And therein lies the problem.

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Mehta replies: I thank both authors for their thoughtful responses and appreciate the interdisciplinary span of their ideas.

Ramesh Gopalan's point, about people taking the underlying physics of everyday gizmos for granted, is well made. The "marketplace of ideas" to which he refers puts technology on a far higher pedestal than the basic physics behind it. In my opinion, the way to fight that attitude is not by speed (physicists will never overtake engineers in that regard!), but by innovation. Physics needs to come back to its status as an art and a philosophy, where space is made for originality of thought, rather than sticking to the assembly-line mentalities I've alluded to in my article.

Lance Nizami's letter spells out possible reasons for these assembly-line mentalities—although I'm not convinced that international political competitiveness is the only cause of such academic philistinism, or, indeed, that physics across the globe could lay claim to being a big-stakes business, as it might be in relatively developed countries. However, his letter certainly provides an interesting perspective.

Finally, I plead guilty to being understated, both for reasons of personal preference, and because it leaves space for interesting discussions such as these by Gopalan and Nizami.

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Fine points on *Productive Learning*

When I read Diane Grayson's review of *Productive Learning: Science, Art, and Einstein's Relativity in Educational Reform* (Physics Today, September 2007, page 72), I saw it was flawed and chose to ignore it. However, discussions with colleagues convinced me that it should not remain uncontested and presumed accurate.

Grayson suggests that the first four chapters of *Productive Learning* were written by my coauthor Seymour Sarason, and summarizes them as dealing primarily with "educational matters at pre-college levels." That is wrong. The book states that Sarason drafted the second chapter and that the theme of the initial chapters is how teachers learn to teach *after* they finish college.

It is not true that Sarason and I "make no reference to more than 30 years of systematic research in physics education." We reference Arnold Arons, Lillian McDermott, and Kenneth Wilson. In addition, we refer to several resources that contextualize the criticism of the educational system; those include a book by Diane Ravitch, an issue of *Daedalus*, and several books by Sarason. The objections appear to stem from superficial reading and lack of familiarity with the depth of issues that hamper educational reform.

Our text states that so far, all systemic reforms have failed. My diagnosis of the review's superficiality is reinforced by its citation of a website that supposedly exemplifies a successful systemic reform. The site contains a dead link and a one-page promotion with a few sentences quoted in the review about the Discovery program in Ohio.

I visited Discovery in the mid-1990s. My positive experience there is reported in the last chapter of *Productive Learning*, though without naming the program. I was so impressed that I engaged in translating McDermott's modules into Polish and designing and attempting to implement a program of instruction by inquiry in Warsaw.

The most recently published longitudinal study that I could find about Discovery[1] describes its pioneering role in Ohio. The study concludes that "Further explorations of the data . . . would help to provide further evidence about the link between inquiry-based instructional practice and student achievement and help to tease out the effects of different intensities of training." This is far from saying that a successful systemic reform has been accomplished.

As part of that study, nearly 1500 trained teachers were surveyed by mail over a four-year period before 1997; they were asked about their attitudes toward using the inquiry-based classroom methods they had been taught. Although the study suggests that students of teachers trained in Discovery fared better than students of a control group, it also says that over time the number of mail survey responses from the trained teachers dropped by half. The study did not find why, and the margin of error in interpreting various numbers found in the study is unknown. Carl Wieman has stressed the need for extreme caution in measuring results of teaching and warns university faculties that they can easily create for themselves illusions about what students actually learn.[2] I have not found any research results on Discovery more recent than 2000.

The reviewer complains that *Productive Learning* does not refer to the 1999 National Research Council report *How People Learn: Brain, Mind, Experience, and School*. Instead we chose to underscore two studies of successful school programs by David Bensman[3] and Eliot Levine[4] that are probably more useful to the intended audience.

Although the review decries parts of the book on psychology of learning and reform, it speaks highly about the part on Einstein's energy–mass formula. That reflects a general problem of physicists and physics educators: They have not yet come to terms with the context of the interpersonal relationship between teacher and student and its role in science education. The lack of understanding of that context goes a long way toward explaining why science education reform has not been successful: One teaches students, not the subject matter.

Lastly, the review avoids entirely the book's central message concerning the relevance of science, art, and Einstein's relativity to educational reform. Therefore, this review is a disservice to the field; it steers educators away from a positive resource.

References

1. J. A. Supovitz, D. P. Mayer, J. B. Kahle, *Educ. Policy* **14**, 331 (2000).
2. C. Wieman, *APS News* **16**(10), 8 (2007).
3. D. Bensman, *Central Park East and Its Graduates: "Learning by Heart,"* Teachers College Press, New York (2000).
4. E. Levine, *One Kid at a Time: Big Lessons from a Small School*, Teachers College Press, New York (2002).

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Grayson replies: I shall address Stanisław Głazek's points one by one. The authorship of each chapter is not explicitly stated, but I include teacher learning as part of "educational matters at pre-college levels." Although the authors mention works by three highly regarded physics educators, results of the vast body of physics education research do not seem to have played a role in framing their arguments or moderating their criticisms. Yet physics education research has provided a wealth of useful insights for addressing issues the authors refer to, including the different frames of reference of students and teachers and aspects of physics learning environments that lead to productive learning. Reinders Duit compiled the most comprehensive list of such references.[1] ComPADRE (http://www.compadre.org), a collaboration of several physics and astronomy professional associations, maintains a website of physics teaching and education research resources.

NSF has supported a number of systemic reform initiatives over the past two decades, of which Discovery was one. As an example of the outcomes, NSF reports,

> During the 1994–95 school year, the first year that NSF funded the urban systemic program, Chicago's school system saw significantly more of its students score above the national norm in mathematics on a commonly used assessment called the Iowa Tests of Basic Skills. What's more, Chicago students' performance in mathematics has increased in 61 out of 62 high schools, suggesting that improvement is occurring across the board.[2]

My reference to *How People Learn: Brain, Mind, Experience, and School* was not because it describes successful school programs (it does not), but because it comprises a synthesis and overview of research into the process of learning, which the authors conclude "has gone unexamined."

Głazek states that I decried "parts of the book on psychology of learning and reform." That is not true. Nor would I deny the central role of the relationship between student and teacher in student learning. My criticisms were of the writing style—I found the sections on the psychology of learning and educational reform to be overly wordy and poorly integrated into the sections on Albert Einstein and his science. If the central point of the book is to come across more clearly, the services of a good editor are needed.

References

1. Bibliography, Students' and Teachers' Conceptions and Science Education, http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html.
2. National Science Foundation, "Education: Lessons About Learning," http://www.nsf.gov/about/history/nsf0050/education/moresynergistic.htm.

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Fleshing out the search for WIMPs

Bertram Schwarzschild's story "A Bubble Chamber Brings New Capabilities to the Search for WIMPs" (PHYSICS TODAY, April 2008, page 22) is undoubtedly interesting, and the application of bubble chamber technology to searches for weakly interacting massive particles (WIMPs) by the COUPP collaboration is certainly newsworthy. However, the only "new capability" brought to bear is the spatial concentration of the active detector mass: For several years the SIMPLE[1] and PICASSO[2] research teams have used superheated liquid microdrops suspended in a gel matrix, in concentrations of 1% to 3%. The background insensitivity capabilities of these superheated suspensions are the same as a bubble chamber's, since the underlying physics is the same. The continuous-sensitivity difficulty is why the droplet suspensions were developed in the first place; the devices are continuously sensitive for up to 100 days in the case of SIMPLE, and longer with repressurization as in PICASSO.

Achieving large active mass has simply required space and engineering of the instrumentation. The COUPP team,