

Educating Physicists for Industry: The Rest of the Story

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As more and more of their students move into careers outside traditional research, physics educators have been grappling with how best to provide the necessary background, skills, and experiences to promote lifelong career success. The qualities needed to succeed in industry are generally agreed on. They include persistence, technical breadth, flexibility, and strong problem-solving skills. The abilities to communicate effectively, meet deadlines, and work in teams are also indispensable.

My own experiences support these prerequisites, and I applaud the many innovations that have been proposed or implemented in physics departments to promote them. I'm particularly sympathetic to the idea that the traditional physics PhD program takes too long to finish and is too narrow in scope to prepare students effectively for careers in industry. And I'm glad to see that professional master's degree programs in physics are being developed and that many entrepreneurial physics students are being encouraged to receive formal business training.

Such efforts are clearly on the right track. Nevertheless, I've found that many discussions about university-industry interactions miss the forest for the trees. The forest in this case is the fundamentally different perspective required for success in industry as opposed to academia. The prevailing perspective in academia is often caricatured by the metaphor that "basic research is like shooting an arrow into the air and, where it lands, painting a target." Historically, university physics programs have done an outstanding job of teaching physicists to shoot, but not necessarily to aim.

Industry, on the other hand, is replete with preexisting targets: a

company's business plan, product performance specifications, project cost and timing goals, and so on. Few companies today can afford to invest in significant amounts of high-risk, unfocused, exploratory research with the goal of capitalizing on any breakthrough wherever and whenever one occurs. Instead, what companies need most from their technical workforce is the ability to direct arrows onto targets.

'Alternative' careers

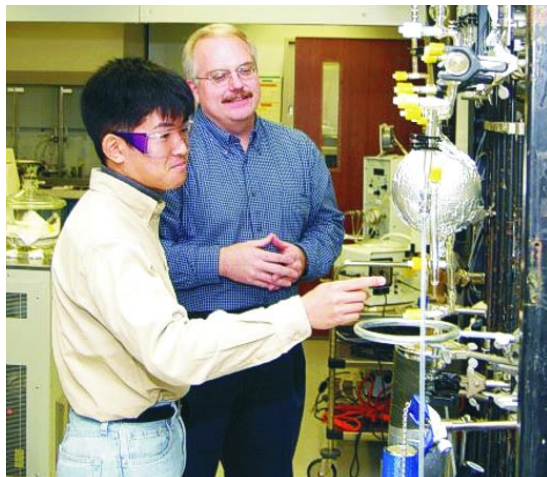
Appreciating this difference in perspectives is essential to educating physicists for industry. I've always been amused—and disturbed—by the academic physics community's widespread

wonder that many physics students question the objectivity of the career advice they receive from their professors. And it's no wonder that many industrial and political leaders question the ability of physicists to assess the relative value of different activities in a business and societal context.

The expectations placed on physicists in industry are clearly different from those on academic physicists. No matter how big the company they work for, no matter what their area of responsibility—R&D, finance, computer services, quality assurance, management—industrial physicists are much more likely to be focusing their efforts and creative skills to support known needs and existing commercialization plans than to be generating new ideas and targets out of the blue.

The importance of following through explains why the particular qualities listed in my opening paragraph are critical to success in industry. Directing arrows toward targets generally requires much greater breadth, persistence, and teamwork than shooting a new arrow in whatever direction one chooses. Even the development of a largely physics-based technology will almost certainly require some level of understanding of the associated materials science, chemistry, and engineering—not to mention customer usage requirements, market potential, manufacturability, and financial challenges. Strong two-way communication with highly diverse contacts—most of whom are likely to be nonphysicists with different values, knowledge, work styles, and agendas—is essential. Problems of all kinds are sure to arise and need to be overcome; most bear little resemblance to the types of problems one encounters in a physics problem set.

Does working in industry sound daunting? It is. But students and educators shouldn't be discouraged. A physicist's solid grounding in fundamental concepts, facility with quantitative reasoning, and ability to abstract and generalize provide a



STUDENT COLLABORATIONS with industry provide a win-win situation. Here Satoshi Nishida, a physical chemistry graduate student from the University of Nagoya in Japan, describes the atmospheric research he is conducting at the Ford Research Laboratory to Ford physicist John Ginder.

use of the term "alternative" career as nearly synonymous with "nonacademic" career. I had the same reaction recently when I heard this backhanded compliment to an industrial physicist who had significantly advanced the state of the art of several commercial medical products: "He is sadly not a professor in a university, but he should have been."

With attitudes like that, it's no

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strong foundation for rapidly assimilating new information, responding to shifting priorities, and identifying and maintaining a steady focus on the most critical issues in a complex, multidisciplinary environment.

Although most physicists begin their careers in narrow areas and typically aspire to shoot new arrows (that is, generate breakthrough ideas), those physicists who fully understand the importance of the entire trajectory—from scientific advance to successful commercialization—usually thrive in industry. There is still plenty of room for invention and good science in industry, but the more aligned those are with the overriding targets, the more value they generally return to a company.

Successful industrial innovation also entails combining arrows that were initially launched in many different directions or detecting the most significant ones early and directing them to a company's own needs—or both. Physicists tend to be very good at such tasks and at recognizing the importance of, and the diverse possibilities for, innovation in any activity within a company. And as many well-known examples attest—such as the Manhattan Project or the development of radar—physicists are indeed capable of meeting highly focused and challenging targets and of enjoying the intellectual stimulation, camaraderie, and excitement that result from working in a team to pursue a common goal.

Constructive improvements

All this is good news for physics educators. The types of changes required to improve the preparation of students for industrial employment need not amount to a major perturbation. The last thing anyone wants is to modify courses and programs so radically that they no longer instill the traditional strengths of physicists. Many constructive improvements based on the preceding insights can be easily implemented.

For example, physics students could be introduced to industrial physicists and to students, faculty, and professionals in other fields. Educators could put more emphasis on written and oral communication. And more opportunities could be provided for students to work in multidisciplinary teams toward specific goals. But to be effective, any modification must be embraced without self-defeating behaviors such as steering the best students away from any program or activity that appears “too industrial.”

I contend that all these measures

will benefit even those students who remain in academia and will help to move the entire physics community more rapidly into the 21st century. But for more ambitious educators, I have additional suggestions.

A widespread belief exists that the greatest scientific and societal challenges ahead revolve around the subject of complexity: assembling materials atom by atom; understanding how genomes give rise to living organisms and how neural networks produce consciousness; assessing and coping with global economic, terrorist, and environmental threats; and, of course, reconciling the emergence of higher-level

Further Reading

- ▶ J. Harte, “Toward a Synthesis of the Newtonian and Darwinian Worldviews,” *PHYSICS TODAY*, October, 2002, p. 29.
- ▶ Special Issue: Careers for Physicists, *PHYSICS TODAY*, April, 2001.
- ▶ J. F. Waymouth, “Physics for Profit and Fun,” *PHYSICS TODAY*, February 2001, page 38.
- ▶ R. A. Pielke Jr, R. Byerly Jr, “Beyond Basic and Applied,” *PHYSICS TODAY*, February, 1998, p. 42.
- ▶ E. Sickafus, “What Makes an Employable Physicist?,” *The Industrial Physicist*, June, 1996, p. 22.
- ▶ J. A. Armstrong, “Rethinking the Science and Engineering PhD.: What Is It For?,” *APS News Online*, April 1996, <http://www.aps.org/apsnews/articles/11438.html>.

laws and phenomena with the most fundamental theory of everything.

In meeting these challenges, physicists are in the vanguard. Unfortunately, the traditional physics curriculum tends to promote a primarily linear, reductionist, and equilibrium worldview. It doesn't expose students sufficiently to nonlinear, holistic, and nonequilibrium concepts. The reductionist worldview is certainly not wrong. On the contrary, it has dominated Western society since the time of Isaac Newton and has contributed to most scientific, technological, and industrial progress to date. However, I believe that worldview holds too much sway over traditionally trained physicists and impedes their ability to appreciate the needs of a complex industrial environment.

As an example, consider how much confusion persists in the physics community around the “linear” distinction between basic and applied research. By contrast, other sciences, especially biomedicine, seem to accept

more readily the inherent multifaceted nature of research and see little conflict between the quest for fundamental understanding and the consideration of its use. The real world of business and technology development is rarely simple and not always rational. Physicists would benefit by recognizing early on that many important phenomena and human activities lie beyond the prevailing worldview they encounter in course work.

One way to ensure more balance in the classroom would be to introduce more complex systems concepts into traditional courses. At least, one should avoid consistent oversimplification. For example, courses in condensed matter physics often give short shrift to the defects, microstructure, and transformations that dominate most practical considerations of materials. Another suggestion is to present more examples of the real history of how advances in physics have, or have not, had an impact on commercial products.

Technology, markets, and companies evolve. They rarely follow a predictable linear trajectory. Although most physicists believe in Darwinian evolution, relatively few of them have thought seriously about how biological analogies apply in such issues as technology transfer, career development, and interactions within and between organizations.

The business world has rapidly embraced the subject of complexity but needs a great deal of guidance in understanding its practical implications. Teaching physics students about complex systems would not only provide a competitive advantage in this area to those headed for industry, but might help the entire physics community deal more effectively with such complex issues as research funding and prioritization, public policy, and university-industry-government interactions.

Here's the bottom line (always important in industry!): One of the most important things physics educators can do to ensure the broad marketability of their students is to convey objectively the value of different perspectives and the benefits of aligning one's priorities with the demands of whatever problem or career one pursues.

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