Students in the sciences need to learn entrepreneurial skills

Douglas Arion's article about entrepreneurship education for physicists (PHYSICS TODAY, August, 2013, page 42) is exactly on point: All working physicists today need entrepreneurial skills, especially if they hope to do anything new. However, offering special degrees to a few is not enough; rather, the basic practices of finance, marketing, negotiation, and bureaucratic survival should be taught to all science majors. We spend much of our lives and most of our creative energies working on those challenges, not physics. Even Arion's "stage–gate" model of innovation (see the article's figure 2) has "gates" manned by gatekeepers and toll takers. Getting past them is as essential to success as excellence in any of the R&D stages.

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■ **The career path** into management for physicists and engineers, as Douglas Arion wrote in his August 2013 article, has been proposed many times, as if it would lead to some kind of promised land. More often than not, it would lead instead to unhappiness for a person who values science above all and relishes participating in it.

Typically, physicists, and many engineers too, are drawn to their disciplines by the idea of an exciting life of scientific discovery rather than by the money. Therefore, it is not unusual for researchers to see a promotion into management as a step downward.

I was particularly disappointed in Arion's long list of administrative duties. Granted, such duties cannot be ignored, but my experience suggests that administration should be minimized. Early on as an independent principal investigator, I discerned that over-administration at best leads to excessive expense and at worst stifles progress.

Much has to do with motivations. My own R&D service and consulting company, Innovative Mechanics, is not an entrepreneurial company as served up in Arion's article. Instead, I established it to have a way to do frontier research without being encumbered by management from above. I suggest that entrepreneurially inclined people start out in a business major and take significant technological courses in math, physics, biology, and so on at the sophomore or higher level. It sure beats making reluctant entrepreneurs of people who could become good scientists.

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■ **Arion replies:** My thanks to Marc Levenson and Andres Peekna for taking interest in entrepreneurship education for physics. Permit me to restate a major theme in my article: Entrepreneurship education is not about startups, but rather about giving science students the skills, knowledge, and attitudes to be successful in their careers, whatever those might be.

Levenson's comment about the need to provide those skills to all students is spot-on, and we in the entrepreneurship education community hope that this vision indeed comes to be. The upcoming American Physical Society conference "Reinventing the Physicist: Innovation and Entrepreneurship Education for the 21st Century" in June 2014 is a step in that direction (see http://www.aps.org/programs/education/conferences/innovation.cfm). My article highlighted a few of the approaches that institutions are using to provide entrepreneurial skills training to physics students. Special degrees are only one option; the article also lists some of the other means by which the content can be brought to students. Methods of implementation are available to suit the particular circumstances, environment, student demographics, and desired outcomes of each institution and department.

Peekna apparently missed the main point of the article. Entrepreneurship education is not at all about channeling people into management, creating startups, or separating management careers and technical careers. It is about helping science students be successful in any position they may obtain, whether in academia, industry, or government. "Administrative duties," as he puts them, are unavoidable, and entrepreneurship education will make them easier to handle while also preparing students to deal with and excel in the real world. A business major with a sampling of science courses will not prepare students well for a technical career; a science major with entrepreneurship content will. Having entrepreneurial skills and being a scientist are not mutually exclusive but mutually supportive.

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Letters and commentary are encouraged and should be sent by email to ptletters@aip.org (using your surname as the Subject line), or by standard mail to Letters, PHYSICS TODAY, American Center for Physics, One Physics Ellipse, College Park, MD 20740-3842. Please include your name, work affiliation, mailing address, email address, and daytime phone number on your letter and attachments. You can also contact us online at http://contact.physicstoday.org. We reserve the right to edit submissions.

Role of black carbon in the Arctic's new normal

In "The Arctic shifts to a new normal" (PHYSICS TODAY, October 2013, page 35), Martin Jeffries, James Overland, and Don Perovich state, without citing a reference, that "the warming might be further enhanced by the rise in atmospheric concentrations of carbon aerosols. . . . Black carbon deposition might be reducing the albedo and thus accelerating the melting of sea ice and of snow and ice on land."

Actually, the atmospheric concentrations of black carbon have been declining, as shown at all three of the atmospheric observatories making continuous measurements on the coast of the Arctic Ocean: Alert, Canada; Barrow, Alaska; and Ny Ålesund, Svalbard, Norway.[1] Alert has the longest record; the wintertime peaks there for 2006–8 were one-third of their average for 1989–91. The decline of Arctic black carbon has been attributed to the dissolution of the Soviet Union, which resulted in the closing of emission sources in Russia and Eastern Europe and depopulation of the Russian Arctic.[2] Correspondingly, the black carbon content of Arctic snow is now no higher than it was 30 years ago.[3] The dramatic loss of Arctic sea ice must therefore be attributed to other causes.

References

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■ **Jeffries, Overland, and Perovich reply:** We thank Stephen Warren for pointing out that Arctic atmospheric black carbon concentrations have been decreasing. Nevertheless, black carbon remains a short-lived climate forcer that affects the radiation balance in the Arctic. As such, it is one of several potential contributors to Arctic amplification of global warming that is manifested, for example, in the dramatic reduction of sea-ice extent in the summer. Each of those contributors to Arctic amplification was described in our article. Nowhere in the article did we propose black carbon as the sole cause of sea-ice loss, as Warren's final sentence seems to imply.

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Early sightings of comets near the Sun

The article "Comets as solar probes" by Karel Schrijver, Carey Lisse, and Cooper Downs (Physics Today, October 2013, page 27) was very enjoyable and informative. Readers might be interested in some additional examples of comets that have been observed close to the Sun.[1] Obviously, in historical times these comets were only seen during total solar eclipses. The earliest comet observed traveling near the Sun was around 94 BC, "the comet that once was seen near the sun when the latter was eclipsed"; the record appears in *Naturales quaestiones* (7.20.4) by Seneca and in other classical sources.[2]

Several comets have been spotted near the Sun in the past two centuries. One example, observed during the eclipse on 17 May 1882, was the first comet photographed during a total solar eclipse.[3] Another interesting case demonstrates the difficulties of interpreting astrophysical observations: A modern analysis showed that the coronal comet of 16 April 1893, reported by John Martin Schaeberle from Mina Bronces, Chile,[4] was actually a disconnected mass ejection.[5]

References

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Weighing in on the cost of research papers

The story entitled "A nuclear bomb worth more than its weight in gold?" (Physics Today, December 2013, page 26) caused me to consider other specific cost comparisons (dollars per gram) that could be made.

For example, one could ask a typical science or engineering department to calculate the specific cost of its published refereed papers by dividing the department's total annual budget (in dollars) by the mass (in grams) of the published refereed papers for the same year. (No cheating! Use only standard-weight journal paper.) Ignoring for the moment that a department's publications might be entirely in electronic form—weightless soft copy, in which case the specific cost would be infinite—I believe that the specific costs of published technical papers would greatly exceed the cost of gold, currently about $46 a gram.

I actually did a similar measurement some years ago for an organization I headed. In that case, the specific cost of refereed papers turned out to be midway between that of small diamonds (relatively cheap at about $30 000 per gram) and high-quality large diamonds (about $1 million per gram). In comparison, lunar rocks returned by the Apollo program in the 1970s cost about $80 000 per gram in 1975 dollars.

Thus, relatively speaking, gold and nuclear weapons are quite cheap.

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Corrections

April 2014, page 26—The input of the National Ignition Facility laser is not 1.8 mJ, but 1.8 MJ.

March 2014, page 46—In the figure caption, the facility being dedicated was the Submillimeter Array, and the year was 2003. ■