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STEM EDUCATION

To build a scientist

Thought leaders across the globe answer one question: what is the biggest missing piece in how we educate scientists? Responses ranged from the practical to the philosophical.

PAUL NURSE
Expand across specialities

Director of the Francis Crick Institute, London

PhD programmes often lead to an increasing narrowness and specialization, which results in graduate students who are not sufficiently exposed to wider aspects of their subject and of related subjects. Looking outside the immediate interests of a thesis project can lead to real creative advances.

One way to expand thinking is to ensure that students have access to a series of inspirational speakers who will cover a wide range of scientific topics, with at least some who are more removed from their PhD focus. At the Francis Crick Institute, we will cover a wide range of biomedicine with truly inspirational speakers, but also look at other areas of science, such as high-energy physics, dark matter and aspects of biology, such as evolution and ecology, that are more distant from biomedicine.

Another suggestion is for what I call 'master classes', after the model of players of musical instruments. In science master classes, a group of graduate students would be exposed to a true expert, an excellent practitioner who would talk about doing science. I don't mean discussing the details of experiments, but discussing the broader questions: how do you do a satisfactory experiment, how do you do rigorous work, what is the nature of knowledge and so on.

The final suggestion is to broaden expectations. When students are three-quarters of the way through their graduate degree, they should be intensively mentored and urged to discuss their future careers. If they want to consider other careers, we need to build in a period of time — a few weeks — which they can use for short internships. We need to be honest, and acknowledge that not all of our students and postdocs will have a long-term career in basic research, but their education is still meaningful because they attain skill sets that they can take elsewhere — to enterprises that will profit from having scientists. We need to establish ▶

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▶ a culture among advisers and investigators in which students who leave the academic pipeline are not considered 'failures'. They are making sensible choices and are to be cherished because they are taking science to other areas that will benefit from having them.

ATSUSHI SUNAMI
Broaden expertise across institutions

Professor at the National Graduate Institute for Policy Studies, Tokyo

As a nation, Japan needs more expertise in emerging fields such as brain science, cell engineering, data science and cybersecurity, but universities are still stuck in conventional scientific disciplines. We are asking universities to create programmes to represent these growing fields. Educational institutions need to cooperate to form a network of such programmes as they face the decline of Japan's university-age population and severe limitations on their resources.

Another urgent problem is how to encourage young scientists and engineers to go out and work with the best in the field and to gain the global connections that have become an essential aspect of science. Under changes to Japan's university system that have taken place over the past decade, many new positions are supported by competitive outside funding. This means that young scientists are hired on a fixed-term contract, which creates an insecure employment situation. Every 3–5 years, they look for another 3–5-year job. If we ask them why they do not go abroad to gain international experience, they say that they cannot risk losing the opportunity to secure another project in Japan. To resolve this, we are working to create international connections within our universities that will allow researchers to move to another country and back home again.

We also have to force change and diversity in the career track. In Japan's private sector, it is still rare for companies to hire PhD students and postdocs after they complete their training. In the past, it was almost customary to hire people directly from their undergraduate institution and route workers through their own training programmes, bypassing graduate education in exchange for lifetime employment. Universities can help to change the system: they can provide training and experience working in industry to mentor their PhD students and postdocs. To help to make this happen, we are introducing a scheme of cross-appointments of faculty-level experts in universities and companies. It will give trainees valuable skills and encourage companies to hire more PhD graduates and postdocs from universities.

JESSICA POLKA
Define purpose; demand decisions

Postdoctoral research fellow at Harvard Medical School, Boston, Massachusetts

What is missing from graduate education is a clear definition of its purpose. If graduate students are considered to be trainees, it behooves the funding agencies and everyone involved to make sure that their training is valuable to both society and the students. Graduate school is currently a research experience that is intellectually stimulating but not a clear stepping stone towards any career path. I question whether the graduate student–postdoc sequence is really necessary for training or whether it is a method of accruing credentials — and for getting science done at low cost. We should consider what benefit students gain from years four, five and even six versus their first three years. There needs to be a way to balance the needs of graduate students as students and not just as a research workforce.

To decide whether they will benefit from graduate school, people need to know where it may lead, and they need to stop thinking about faculty jobs as the probable end of the pipeline. The careers that people go into are diverse — many feel that they make use of their research training, but others do not. Mandates to create individual development plans for graduate students and to track their career outcomes would help to reveal what the job market actually looks like.

There should be more opportunities for people to make conscious career decisions. For example, I think master's degrees should be more prevalent. People who take a master's after passing a qualifying exam should be viewed as making a reasonable decision about whether to pursue a PhD, and not for failing to continue as expected.

MICHAEL TEITELBAUM
Track PhDs after their degrees

Senior Research Associate at the Labor and Worklife Program, Harvard Law School, Cambridge, Massachusetts

For decades, aspiring young scientists in PhD programmes have been unable to get a good picture of what their career opportunities might be — not even of what recent graduates have experienced. That is a recipe for them to become disappointed, disheartened and potentially forced out of science. It is the responsibility of doctoral programmes to do their best to improve this situation.

Most graduate schools seem not to try very hard to keep track of their former PhD students and postdocs. They might know where their PhD graduates go for a postdoc, but not what they are doing 5–10 years on. Faculty members may know what their lab alumni are doing, but these data typically are not centrally assembled. That information, if universities compiled it as systematically as they do for those who earn their undergraduate degrees, would be useful to prospective PhDs and postdocs who are thinking about their careers.

Universities should also consider limiting the length of the postdoc term. Many institutions have embraced formal limits — most commonly of five years — but these constraints can sometimes be sidestepped by a change in job title without a real change in role or prospects. Neither time constraints nor new job titles fixes the underlying problem of a lack of job options: the labour market for PhD scientists in most fields has not been robust. Understandably, they may want to continue for a sixth year in hopes that something will turn up, or stay for a seventh year and hope that they get that paper published in a top-tier journal.

If a postdoc wants to stay, if the principal investigator (PI) welcomes this and if there is research-grant money available, some ask why an arbitrary time limit should get in the way. But the dynamic is not working long term. Trainees need to understand that there could be diminishing career returns to opting for an extra year or two as a postdoc. Before they get to that point, PIs should be advising their PhD students and postdocs to broaden their skills beyond those typically taught in a PhD programme. Given the difficult current and prospective labour markets, well-advised PhD students and postdocs will probably realize that they need non-science professional and managerial skills if they wish to find attractive long-term careers that build on their scientific talents.

ROBERT TJIAN

Teach people management

President of the Howard Hughes Medical Institute, Chevy Chase, Maryland

My students and postdocs spend all their time focused on experiments, which is, of course, the top priority for young scientists who are building their careers. But something that we in the scientific community have not confronted very well is how to get them to focus on interacting productively with other people. Learning to manage teams and to work with others is going to become more important as science becomes more collaborative.

We are getting a little better at teaching students to write grant applications, but that is just a small part of running your own laboratory. The biggest part of leading a lab is getting the best work out of technicians, trainees and even colleagues. Typical graduate and postdoc programmes include little or no training in people management. I had to learn it by watching how my mentors ran their labs; there was no formal management training of any sort. It took a while before I learned how to guide students without tearing down their self-confidence or how to motivate students in different ways depending on their personalities.

Outside master's programmes in business administration (MBAs), there is little training in leadership, how to form the right team and how to run it effectively. But how teams work together can really influence the way you do science. Regardless of whether things are going really well or everything is messed up, you, as the lab head, must keep cool and positive. You are the proverbial cheerleader, and getting depressed — and showing it — is rarely helpful.

Better training in lab and people management will also help lab heads to guide students to choose good problems and avoid getting overly enamoured with a specific model or system, and teach them to do experiments with rigour. Universities have to recognize that leadership training is a valuable lab skill, and they need to learn how to address it.

JARI KINARET

Practise the art of incisive questions

Director of the Graphene Flagship, Chalmers University of Technology, Gothenburg, Sweden

One of the issues that is not systematically covered in most graduate programmes is how to identify good research topics. Of course, there is no single way to do this — for one thing, it depends on what you regard as a good research topic, and opinions clearly differ. For every individual, the answer evolves as one acquires skills and experience, makes new contacts and so on, but some questions remain constant. Is this worth doing? Who cares if I or we succeed? Can I do it, either alone or with colleagues? What is the competition? Is this a one-off problem or is there a future in the area?

It is not clear whether the skill of choosing good topics can be taught, but it can clearly be learned: some researchers make the right choice more often than others, and it is hardly a talent that they have from birth. The first step is for supervisors and graduate students to discuss the choice — frequently, openly and critically. I think that this aspect of graduate studies is on the decline because many researchers are bound by their grants, which are usually written and decided before the student is hired, and many graduate students must execute a pre-defined plan within strict time constraints. Planning in advance is essential, of course, but training to set — and alter — topics for study is, or should be, an integral part of graduate studies.

JO HANDELSMAN

Match training to job trends

Associate director for science at the White House Office of Science and Technology Policy, Washington DC

Because academic jobs are scarce, some analysts have proposed reducing the number of trainee positions in science, technology, engineering and mathematics (STEM). But this argument errs in its assumption that STEM students are — and should be — trained exclusively for faculty positions at research universities.

It is true that only a small proportion of those who start STEM doctoral degrees from US institutions today will go on to attain faculty positions. In biology, for example, fewer than 8% of new PhD students do so. Although that statistic might look alarming, it does not reflect the growing employment needs and opportunities that exist outside of traditional academia.

Today, the United States actually needs more, not fewer, PhD graduates in STEM fields. We must abolish the idea that these people will aim solely for academic research posts. More than 98% of STEM PhD graduates are employed, and in diverse careers. Furthermore, faculty positions are no longer the top career goal of many graduate students. A 2011 survey at the University of California, San Francisco, for instance, found that its graduate students are increasingly eager to manage research labs, direct education programmes, write, make public policy, start companies and teach at small universities. Few of these keen students, however, receive training in the skills necessary for non-conventional careers.

Graduate education in STEM should evolve to meet these needs. Courses in pedagogy, science writing, entrepreneurship or administration offered either on campuses or by professional societies would equip PhD students to confront the broad scientific job market.

The incorporation of more diverse educational experiences into US graduate training need not lengthen the time commitment. At the University of Wisconsin–Madison, for instance, some STEM graduate students have been required to do a three-month internship in industry or government. The internship did not affect time to degree, perhaps because the experience strengthened students' focus and motivation.

If graduate training were redesigned to better prepare graduate students for non-academic research careers, would they pursue more-varied career opportunities, and more confidently? Would they be more satisfied with graduate school? It's worth finding out. ■