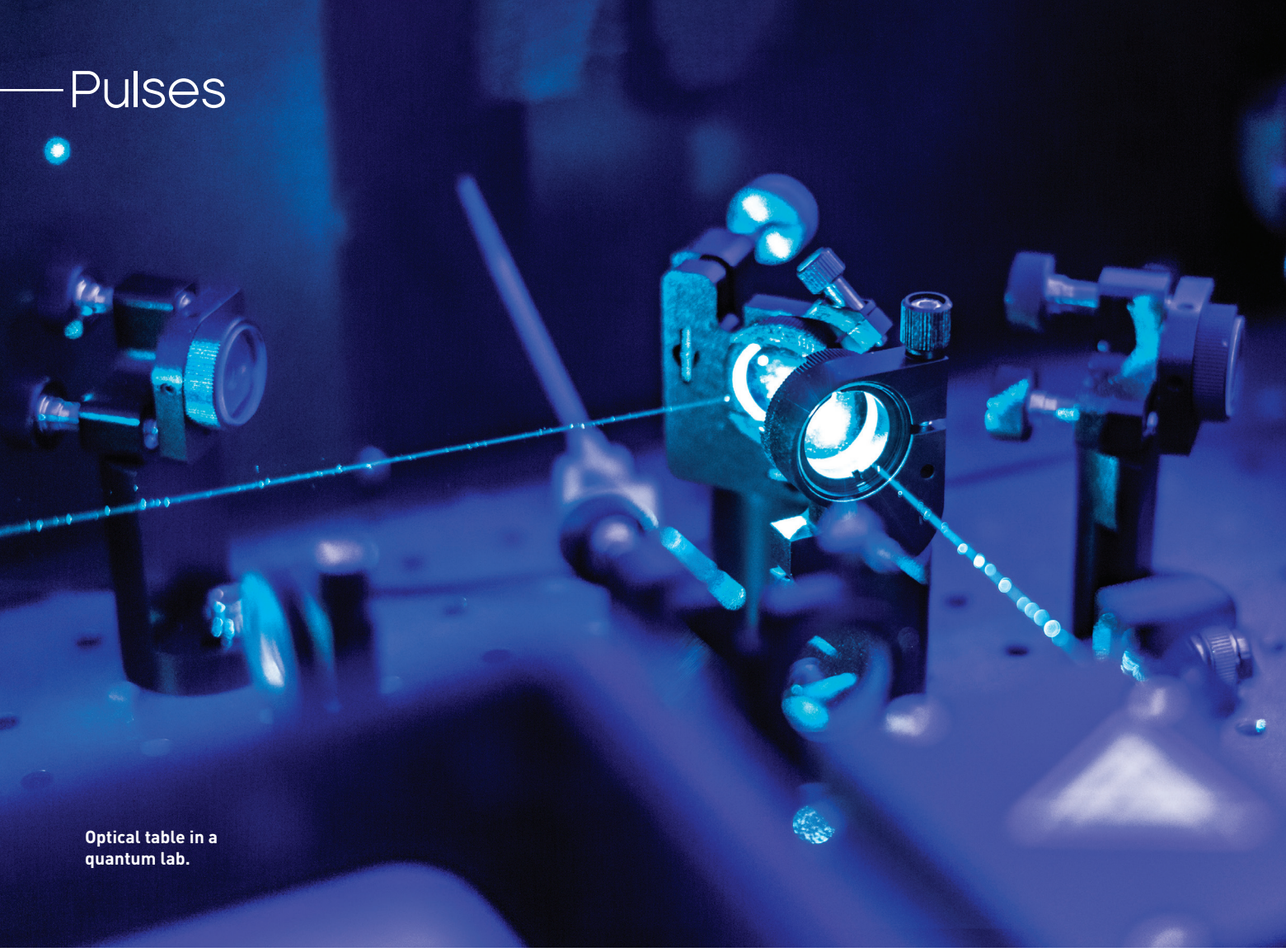


Optical table in a quantum lab.

Getty Images

INDUSTRY

Staffing the Quantum Revolution

How should the emerging quantum technology industry educate and train its future workforce?

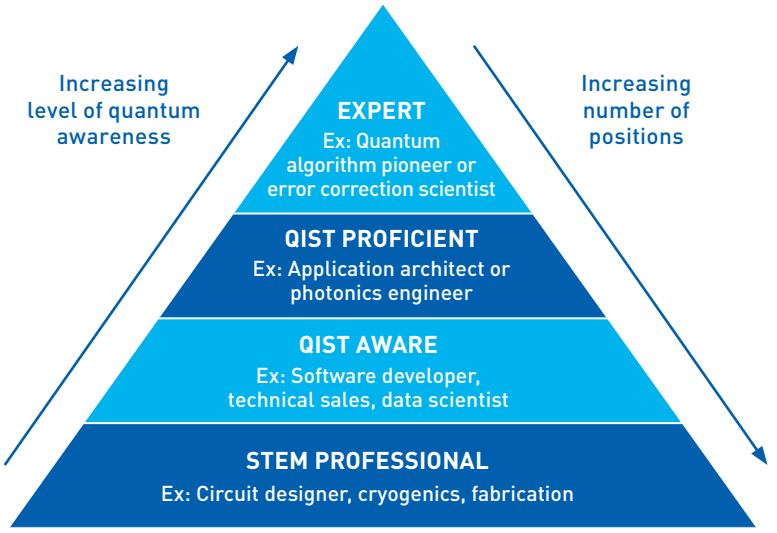
Stewart Wills

In the June 2022 edition of its periodic "Quantum Technology Monitor," the consulting firm McKinsey & Co. gushed about emerging investor and commercial interest in the sector. Start-up investment in quantum tech during 2021, the firm noted, had exceeded US$1.4 billion—more than double the 2020 level. And, as another sign of the area's emerging investment potential, McKinsey pointed to several quantum technology firms, such as the trapped-ion quantum-computing company IonQ, that had gone or would soon go public.

Yet McKinsey also warned of a "significant talent gap" that could blunt the quantum sector's advance. The consulting firm estimated that as of the end of December 2021, the number of job postings in quantum tech outstripped the number of university graduates qualified to fill those posts by three to one. And the company called for a greater emphasis on "upskilling" of existing graduates in a variety of quantum-adjacent and -relevant STEM areas to help fill that gap.

McKinsey may be a bit late to this particular party. Stakeholders across the nascent quantum technology industry have been preoccupied for the past half-decade or more with trying to define the sector's workforce needs—and how to meet them.

"This topic of talent is cross cutting and underlying all of the different parts of the innovation ecosystem, whether it's government or academia or industry," says Celia Merzbacher, the executive director of the Quantum Economic Development Consortium (QED-C), a stakeholder alliance set up under the US National Quantum Initiative Act, and managed by SRI International, that aims at boosting the US quantum industry. "They all are growing in this area very rapidly, and have their own workforce needs."



A strategic plan on quantum tech education from the US National Science & Technology Council identified four "levels of quantum awareness" that implied different training and education approaches.

NSTC, February 2022

Education versus upskilling

Some of the thinking about meeting those needs has focused on whether, and how, to build postgraduate programs specific to quantum information science and technology (QIST). For example, in a November 2019 symposium summarized in a 2021 paper on "achieving a quantum-smart workforce," discussion centered around the potential of master's-level programs in quantum science.

A mid-2022 *Optical Engineering* review of quantum education resources by Maninder Kaur and Araceli Venegas-Gomez of QURECA Ltd.—a UK-based consultancy specializing in quantum training, recruitment and business services—counted 40 universities providing such master's programs, mostly in the United States and Europe. Yet Kaur and Venegas-Gomez also noted that such academic degrees alone won't provide "industry-desirable, job-ready skills," for which actual industry experience is sometimes more important.

Instead—like the McKinsey study cited at the outset—the QURECA authors suggested that at least in the near term, the perceived quantum skills bottleneck might be better addressed by "upskilling the current workforce," rather than attempting to mint a cadre of new graduates specializing in quantum technology. And they highlighted a number of other kinds of initiatives out there—online courses; conferences, workshops and hackathons; even game-based learning—that could help "create and strengthen the pipeline between academia and industry."

"Only about half of the roles sought by industry require QIST proficiency," according a US government strategic plan.

How much quantum?

Further, Merzbacher notes that, while discussion of the quantum workforce tends to emphasize the needs of the "makers" of quantum technology, a much larger share of the required labor will ultimately consist of people hired by companies using quantum technologies for other work, from drug development to finance.

"It's sort of like IT people," Merzbacher says. "There are people who make IT systems, and there are some big companies there, of course. But *every* company has to have an IT department, and so there's lots of people who are IT experts and are working in the user community."

"I think quantum is going to be very similar," she says. "And the workforce needs for those people are going to be somewhat different from the skills that are needed by the people who are making the technology."

Along similar lines, a February 2022 "national strategic plan" for QIST workforce development by the US National Science & Technology Council (NSTC), a cabinet-level advisory board, usefully distinguished among four levels of quantum knowledge that might play into industry workforce requirements. At the top of the pyramid is *QIST expertise*, applicable to the relative handful of workers at the highest levels of quantum development and often requiring a postgrad degree. The next level, *QIST*

proficiency—relevant to a range of roles, including photonic engineering—could be addressable through undergraduate major or minor programs.

Beneath that level is *QIST awareness*, encompassing users of quantum tech such as data scientists and technical sales persons, who might, for example, require only a single, relatively general undergrad course in quantum. And the fourth, broadest level in the NSTC hierarchy, *STEM professional*, describes individuals with a range of skill sets relevant to quantum technology but not "quantum" in themselves.

"Only about half of the roles sought by industry require QIST proficiency," according to the NSTC report. "The remainder rely on workers with, at most, a basic awareness of QIST."

Building a "competence framework"

The European Union is also looking hard at the needs of a quantum workforce. One vehicle in the quest has been the Quantum Technology Education Coordination and Support Action (QTEdu CSA), a project financed under the EU Horizon 2020 framework that wrapped up in mid-2022.

QTEdu was designed to support the larger, €1 billion EU Quantum Flagship program by attempting to create "the learning ecosystem necessary to inform and educate society about quantum technologies." The ultimate aim is to build "a quantum-ready society" that would allow a quantum workforce to emerge. The work started in QTEdu continues as part of a new Quantum Flagship CSA, QUCATS, that runs to April 2025.

Franziska Greinert, a Ph.D. candidate in education research at Technische Universität (TU) Braunschweig, Germany, who's been involved with the project, notes that QTEdu has undertaken initiatives encompassing not only higher education, but also community-building projects, outreach activities, educational research, and diversity-and-inclusion components. QTEdu also launched 11 pilot projects, ranging from teaching materials for secondary schools, to a modular set of actions for augmenting existing bachelor's programs with quantum concepts, to a "Quantum Technology Open Master's" pilot.

Six quantum "proficiency levels" identified in the European Competence Framework for Quantum Technology.
QTEdu

The European Union is also looking hard at the needs of a quantum workforce.

Greinert's own work for QTEdu has been on the research side. As part of a team including TU Braunschweig colleague Rainer Müller, she has helped develop a "competence framework," based on questionnaires and interviews with industry and other stakeholders. "The competence framework is mainly thought of as a common language," says Greinert. It attempts to describe and organize the key concepts in quantum technology, and to lay out a set of "proficiency levels" ranging from basic quantum awareness to quantum expertise to quantum leadership and innovation.

The hope, according to Greinert, is that the competence framework will help to define the skills and knowledge required for different quantum jobs, and to map those qualifications to the specific educational tracks individuals might pursue to reach them—from tuck-in training at summer schools or workshops to a full-fledged university degree in quantum science. As one deliverable of the new QUCATS action, the group plans to develop a certification scheme based on the competence framework, "to make programs across Europe comparable," Greinert says.

A need for quantum technicians?

As the QTEdu project suggests, many interesting questions about quantum workforce education reside below the university level. One, which cuts across national boundaries, is whether there's a need for specialized "quantum technicians"—technical lab and shop-floor workers who have at least some familiarity with the weird world of quantum mechanics.

A shortage of qualified technicians is already a concern for optics and photonics generally, whether quantum or classical. In the United States, such personnel are commonly trained in two-year associate-degree programs at a handful of institutions across the country—and the number of graduates coming out of that pipeline falls far short of the industry's needs (see "Wanted: Optics and Photonics Technicians," OPN, February 2023). Now, the emerging quantum

technology industry and consortia like QED-C are asking whether these two-year technician-training programs need to include a sprinkling of quantum science as well.

Jacob Douglass—the quantum business development lead at Sandia National Laboratories, USA, who also took over this year as vice-chair of QED-C's workforce technical advisory committee—notes that in surveys of the consortium's membership, "the vast majority" of respondents "see a need for increased technician engagement, both immediately and in the coming years." QED-C plans a workshop this year, Douglass says, to understand industry needs and try to match them with the right sort of programs for augmenting technician knowledge.

Part of the goal of such programs could be to simply build confidence among technicians that they can indeed handle the quantum world.

Megan Ivory, an experimental physicist at Sandia who is also working on QED-C's efforts in diversity, equity and inclusion, relied on technicians when she worked at the quantum tech company ColdQuanta in the mid-2010s. All quantum technologies, she points out, involve "lots of hands-on work" from technicians, with much common ground across non-quantum-tech areas such as lasers, electronics and computer control. In terms of additional quantum training, Ivory says, "I honestly think just a familiarity, so that they have some confidence, can really go a long way … Just getting your hands on things in the lab, and realizing, yes, you can do this, and no, it's not intimidating."

A US National Science Foundation–funded project, EdQuantum, is developing one possible route toward upskilling photonics technicians looking to make that quantum leap. Led by Moamer Hasanovic—a professor involved with the two-year technician training program at Indian River State College, FL, USA—EdQuantum seeks to build a "fast-paced," three-course, freely available sequence that will "pioneer the introduction of quantum science into advanced technological education."

The hope, Hasanovic and colleagues suggested in a 2022 paper, is that the EdQuantum sequence will help spawn a generation of technicians "to face the challenges of the Quantum 2.0 Revolution and support the demands of the emerging quantum industry." OPN

Stewart Wills is the senior editor of *Optics & Photonics News*.

For references and resources, go online: **optica-opn.org/link/0323-q-workforce**.

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