Building new pathways for quantum technicians

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ABSTRACT

Over the past few years, some work has been done to develop a curriculum for training quantum technicians[1, 2, 3]. However, the multiple fundamentally different technologies involved in many of the applications including quantum computing, communications, and sensing pose a challenge to these efforts. Technician training, including laser and optics technicians, is typically completed in 2 years or less at local community colleges, with associate degrees being the top-level credential available. Other shorter programs lead to certificates in the specific area of training. An umbrella concept that emerged from a QED-C workshop [3] was that creating awareness of introductory quantum topics for students in adjacent technology programs, like lasers, optics, and nano- and micro-electronics could be implemented by adding one or more quantum courses to these programs, based on the requirements of local industry, academic and government laboratory needs. Continuing to build on these efforts, this paper highlights details of a few programs as examples to provide models for other programs to use in their local communities. Two key concepts addressed are how to recruit students to these programs from local communities and recommendations to help guide program development for new entrants to the field.

Keywords: Quantum education, career pathways, outreach, high school, college, students, lasers, fiber-optics

1. Introduction:

Advancements in quantum information science and technology (QIST) have the potential to yield next-generation technologies that will transform the world as we know it, revolutionizing various aspects of society through advancements in quantum sensing, computing, and networking capabilities. Quantum sensing technologies[15] will create new opportunities for GPS denied navigation and medical diagnostics, quantum computers will help us solve previously unsolvable problems in areas like drug discovery, cryptography, and climate modeling, and quantum communication will help us create more secure networks for critical infrastructure and enable more sophisticated environmental monitoring.

As this nascent and rapidly expanding field forms, communities across the globe have seen the critical need for investment in both research and workforce development to stay at the forefront of this transformative field. Governments and institutions around the world have spent the last decade launching QIST programs and supporting expanded participation in the field from all sectors, as failure to invest in the field could jeopardize their role as leaders in discovery and innovation, national security, and research and development competitiveness. Through the National Quantum Initiative (NQI), the US government has established 13 QIST Centers focused on research, discovery, and for ensuring the US maintains leadership in the field as it expands [12]. Tremendous progress has been made over the past 5 years in the development and maturation of key quantum technologies, but with the rapid advancement of the field and large influx of funding, the broader field of QIST is experiencing a workforce gap[16] that will continue to grow as technologies mature.

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We are at a point in the field where certain technologies have matured enough and are being commercialized in a meaningful way that the general makeup of the quantum workforce is shifting. Quantum industries have grown rapidly with both well-established multinational companies and quantum startups playing significant roles in the ecosystem. This trend is expected to continue for decades to come, and if quantum technologies are fully realized, we will see the emergence of a significant number of jobs and opportunities for those interested in working in QIST[17].

While there is still very high demand for individuals with PhDs, we are seeing more opportunities for workforce entrants without advanced degrees in the field. However, due to the nascency of the field and lack of quantum centric workforce development programs, the field has a workforce supply and demand gap which will only worsen without intentional programming to address current gaps and predict future workforce program opportunities. This paper will explore opportunities for the creation of quantum technician programs and recommendations for entrants looking to join the field.

2. Background:

Quantum information science is an interdisciplinary field that combines the power of quantum mechanics with the field of information science. By merging these two fields we can process and transmit information in fundamentally new ways and give us new toolsets and opportunities to create technologies that were previously out of reach. The field is generally broken down into a few major areas, including quantum computing, quantum algorithms and software, quantum sensing and metrology, quantum communication, and quantum materials. Figure 1 shows an overview of various applications of quantum sensing, computation, and communication technologies that are currently under development and being implemented globally.

Figure 1: An overview of various applications of quantum technologies.

3. Analysis of Existing or Adjacent Pathways:
Quantum technologies are continuing to mature and grow, and there is a clear need for a quantum-ready workforce across the board[18]. While many educational institutions have been developing advanced programs at the graduate and undergraduate levels[19], there are very few programs being developed at the community college technician level[1]. Fortunately, these new quantum technician programs at local colleges are receiving support from industry, government agencies and the quantum communities at large. Two examples are EdQuantum[6] at Indian River State College (IRSC) and the Quantum Learning Lab (QuLL) Program[7] at Central New Mexico Community College (CNMCC). Additionally, there are many examples of quantum adjacent programs like the Optics Technology Certificate program at Front Range Community College (FRCC) in Colorado and the Micro Nano Technology Education Center (MNTEC) program at Pasadena City College[20]. The QuLL and FRCC efforts are examples of programs that support regional workforce development needs through targeted partnerships. They are both key programs highlighted by the Elevate Quantum[9] consortium and will be leveraged by the 120+ member institutions to help grow the quantum workforce in New Mexico, Colorado, and Wyoming.

In addition to these examples, we include a summary of the analysis of existing and adjacent quantum technician programs in figure 2. This overview helps show other community engagements in quantum technician education programs across the United States.

Example Training Programs
Not Exhaustive

Quantum-Specific Programs

- EdQuantum – Indian River State College
- QuSTEAM partner universities and colleges – both 2-year and 4-year programs offered
- University of Waterloo Schrödinger's Class
- MIT xPro
- Chicago Quantum Exchange / University of Illinois programs
- Colorado School of Mines Quantum Engineering minor
- Purdue University quantum micro-masters (through EdX)
- "Quantum Mechanics for Everyone" – Jim Freericks course on EdX

Optics / Lasers Programs

- Optics Technician Program – Front Range Community College
- LASER-TEC Program – Indian River State College
- Optical Systems Technology and Optical Fabrication Programs – Monroe Community College
- Optics Technology Program – Sussex Community College

Nano / Microelectronics Programs

- Advanced Technological Education (ATE) Program – Pasadena City College / Micro-Nano Technology Education Center (MNT-EC)
- Microelectronic Technology Program – Portland Community College
- Semiconductor Manufacturing Program – Maricopa Community College
- Advanced Manufacturing Program – Onondaga Community College
- Vacuum and Thin Film Technology Program – Normandale Community College
- Electro-Mechanical Engineering Technology Program – Columbus State Community College
- Semiconductor Manufacturing Technology – Mohawk Valley Community College
- MEMS and Electronics Programs – Lorain Community College
- Advanced Manufacturing & Materials Engineering Technology Program – Edmonds College

Figure 2: Example training programs from the QED-C Guide to building a quantum technician.

Two of the programs listed in figure 2 of note are those held at FRCC and IRSC, as they are both associated with existing Laser Technician programs that are part of Laser-Tec[10] that has about 44 colleges in the US that make up the Optics and Photonics College Network (OPCN). The OPCN is an Association of Postsecondary Photonics Technician Educators that was formed in 2009 by OP-TEC, the previously nationally funded program for training optics technicians. The Laser-Tec program will be phased out as its funding cycle ends, and its assets will be transferred to AmeriCOM[11], a newer program established to provide advanced technician training for precision optics manufacturing. The fundamental technologies taught in these programs are closely adjacent to technologies that are taught in the current quantum technician programs and can be used to leverage more quantum technician programs. This concept was reported on in [3] and figure 2 shows more examples of quantum specific and adjacent programs.

Figures 3 and 4 below show how the locations of the Laser-Tec programs and a Quantum Workforce Hiring Heatmap overlap that further emphasize the positive relationships that exist.

Figure 3: Map of LASER-TEC OPCN partners and collaborators [10].

4. Identifying current and future needs for quantum technicians

As reported in [3], the need for quantum technicians varies quite a bit depending on the audience and communities engaged. Since manufacturing of quantum systems, whether they be quantum computers, sensors, or communication systems, are not yet scaled to high volumes, much of what would traditionally be categorized as technician work is being done by people with more advanced degrees. This includes, by way of example, people with PhDs spending much of their time doing soldering of wires and other assembly tasks. Figure 5 shows the results of a survey taken by QED-C indicating how many technicians with quantum knowledge are currently employed in research labs or production facilities; and the anticipated need to employ technicians with quantum skills.

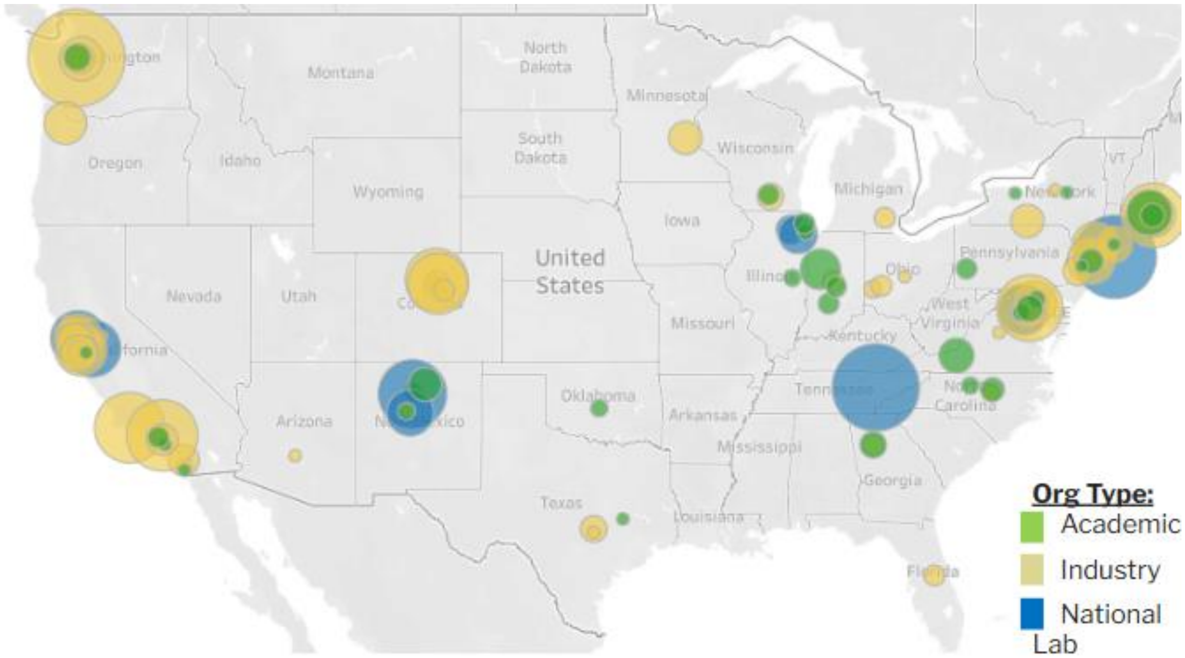

Figure 4: Quantum workforce hiring heatmap across the US from a survey conducted at Sandia National Laboratories of 991 respondents between May 2021 and January 2022.

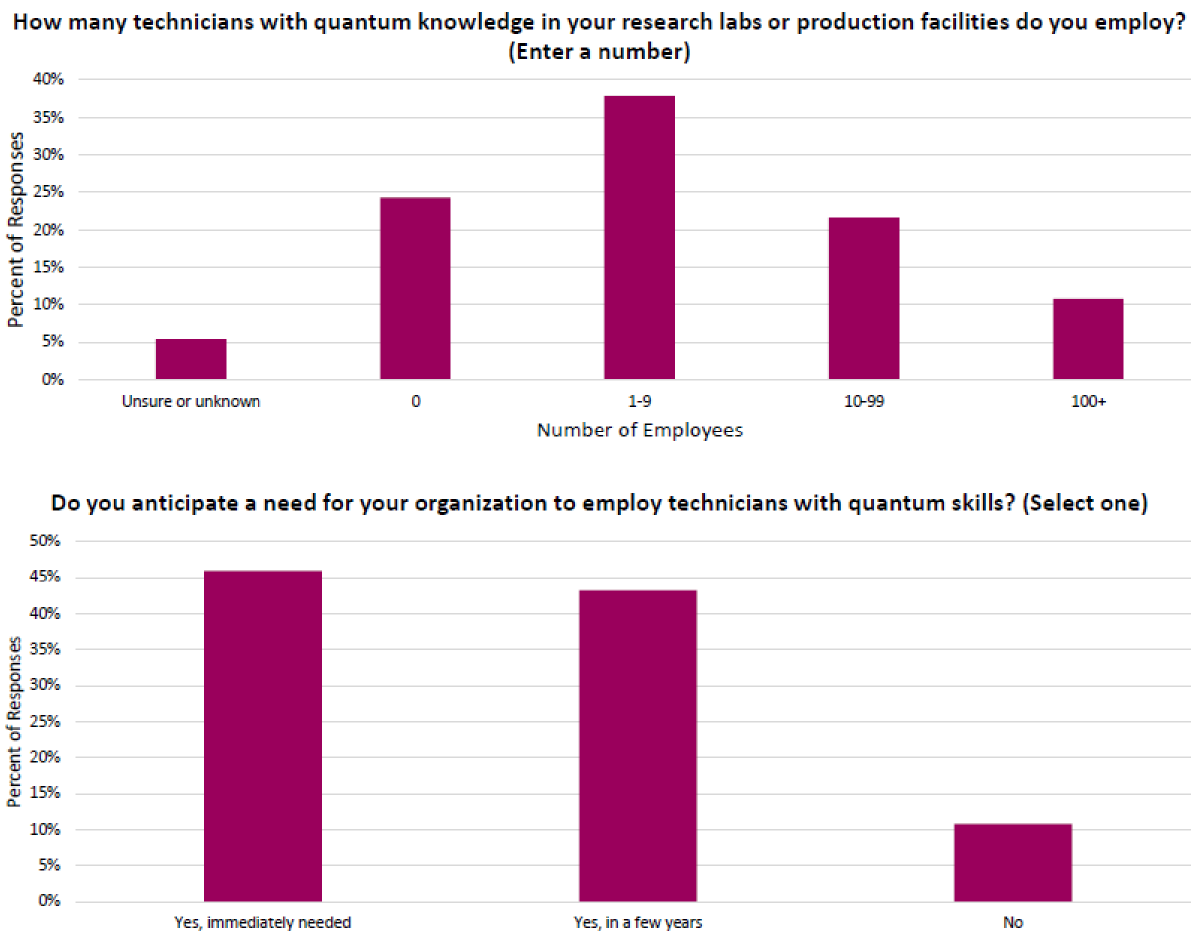

Figure 5: Summary of quantum technician survey results from [3].

The QED-C survey captured information about the top 12 highest priority gaps and anticipated challenges in addition to describing and sharing some current best practices. These are shown in figure 6 below.

Another outcome from the QED-C survey is a listing of the highest priority Knowledge Skills and Abilities (KSA) categories from the 23 workshop participants. These survey results are shown here in figure 7. During this section of the workshop, there was an interesting discussion (or debate) about the importance of quantum technicians' ability to understand the fundamental principles of quantum concepts such as entanglement and superposition. In-depth understanding of these concepts was deemed less important than general awareness and the ability to help with activities such as system assembly and maintenance.

Gap	Share of Workshop Participants' Votes	Notes
Funding	14	More federal spending on quantum education (not just research); include more community engagement and outreach programs to reach more students and teachers
Assets	13	More distributed access to experimental setups to facilitate hands-on learning; identify what lower-cost demos could be used and / or options to share between institutions
Quantum Awareness / Communications	11	Clearer definition of skills that are needed and sufficient to overcome "quantum-phobia;" opportunity to expand marketing (e.g., podcasts, newsletters, centralized jobs database)
Expanding Workforce Pool	9	Improve diversity, equity, and inclusion; opportunity to recruit veterans for clearance-holding roles specifically; need to create asynchronous learning opportunities to reach more students
Programming & Credentialing	8	Expand options for micro-credentialing or certifications and improve accessibility to hybrid learning opportunities; limit number of pre-requisites
Teaching	7	More faculty training and support through additional funding and / or engagement with national lab and industry staff
Market Insight	6	Clearer quantification of workforce demand to motivate development of curricula and to recruit students; opportunity to establish co-located industry and community college programs
Standards & Accreditation	6	Standardize curricula and establish accreditation programs that would build confidence that new programs are aligned with industry needs
Culture Change	5	Improve acceptance of community college-trained technicians and other non-PhDs
Integration of Certificates & Degrees	5	Identify ways to integrate quantum courses into existing programs for adjacent industries (e.g., electricians, HVAC, plumbing, etc.)
More Internships & Co-Ops	4	Expand access to intereships and co-ops to build hands-on training experience; extend to non-PhD and non-Masters students
Lack of Clear Career Path	3	Need to present vision to students about the growth opportunities that are available; connection between quantum and other fields to de-risk any concerns about job stability

Figure 6: Top 12 highest priority gaps from the QED-C survey [3].

Additional technician skills survey results have been previously reported[1] and can help address the question of, “What should we teach students who want to be quantum technicians?” as well. To keep the focus of this report on the results of the QED-C workshop outcomes we omit the results here but encourage readers to review the outcomes. High level take-aways from the report were that optics and photonics, spectroscopy, quantum theory, hardware, and fundamentals were all high on the priority list for their respondents.

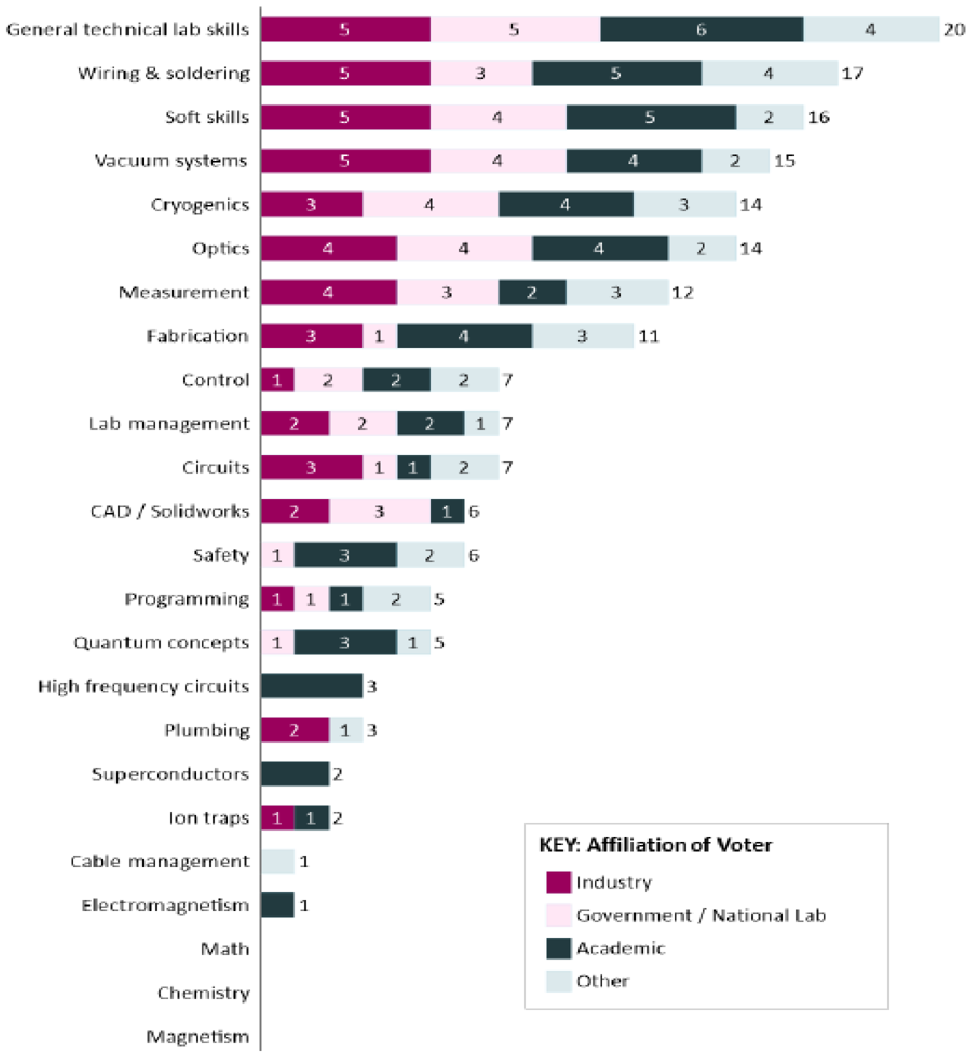

Figure 7: Highest Priority Technician KSA Categories.

Another key takeaway from this workshop is the number 2 highest priority, Assets (see figure 6), where it is noted that ‘*More distributed access to experimental setups to facilitate hands-on learning; identify what lower cost demos could be used and / or options to share between institutions.’* This is a key challenge for those looking to engage in establishing new programs for quantum technicians due to the incredibly high cost of entry. However, participants noted how critical it is for students to get hands-on experience to be successful in their positions. Many efforts to stand up programs are focused on this particular challenge now. One concept explored is to set up access to high-cost experimental lab set ups so students at colleges through experimental setup sharing programs, where systems can be taken to communities across the country so that students can experience working on these quantum systems first-hand. Some examples of these systems are currently at the EdQuantum facility at IRSC, shown in figure 8. While it may be very challenging to implement a “traveling lab” model, it may be less costly for the funders to do that rather than purchase systems like these for many colleges.

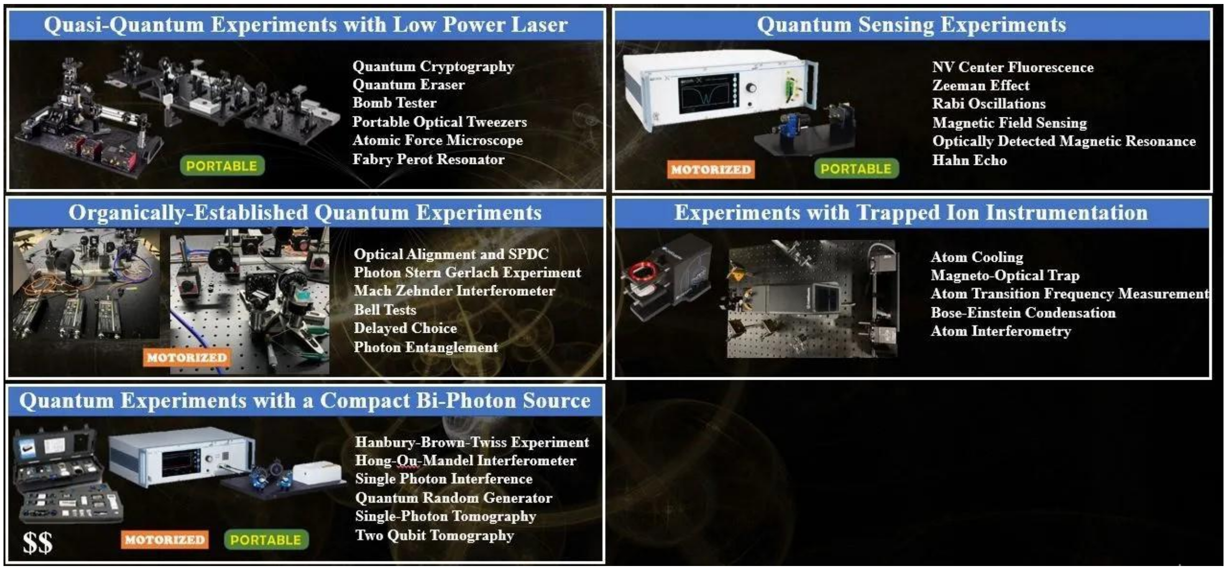

Figure 8: EdQuantum experimental quantum learning systems.

The participants of the QED-C workshop and subsequent report agreed that while there is demand for technicians, the nascency and rapid pace of development in the field make for a complex ecosystem that is hard to standardize and understand. There was discussion on naming conventions for quantum technician roles, where industry is currently hiring from, and what adjacent fields could be tapped to help fill current gaps.

5. Recommendations for establishing new programs

The ultimate outcome of the QED-C workshop and subsequent discussion was the publishing of the Guide to building a quantum technician workforce: Reskilling and upskilling recommendations to prepare a workforce of quantum technicians [3]. The group made the following eight recommendations for communities looking to develop new programs:

1. Create a framework to define the types of quantum technician roles and invest in marketing to build awareness about career trajectories.
2. Map existing training programs versus defined KSAs. (Knowledge, Skills, and Abilities)
3. Build local partnerships between higher education, industry, and national labs.
4. Establish an accreditation program for quantum technology curricula.
5. Expand teacher training programs across disciplines.
6. Increase access to assets to enable hands-on learning opportunities.
7. Expand co-ops and internship opportunities to non-graduate degree students, with greater emphasis on diversity, equity, and inclusion.
8. Allocate more funding for institutions focused on training and education rather than research requirements.

Additionally, the following concepts articulate some examples from the authors’ experiences. Since quantum is so multi-disciplinary there are many options to engage in the field. Focus your efforts on areas where your institution has current programs that are particularly strong. If you have an optics program then focus your program on atomic, molecular, and optic (AMO) quantum system programs. Alternatively, if you have a nano-tech center focus on solid state programs. Examples of regional narrowing of technologies that might be covered in specific community college programs that already exist in adjacent fields like lasers, fiber optics, nanotechnologies, control electronics, etc. By doing this you can reduce the barrier to entry, provide expanded opportunities for your students, and align with current teaching expertise.

The authors also suggest careful examination of the current industry needs of your region. While your institution may be well positioned to create new programs, it is critical that they have job opportunities in the region when they graduate, as the target communities for these types of programs are often those with strong regional ties and they may not have the opportunity to leave to other job markets. Close connections with industry partners in your region will help further refine the need and pathways to new program creation. While this may seem obvious, the quantum industry is still nascent and highly regionalized. Most of these job opportunities will be associated with industry demand, and workforce forecasting for the field has not yet been fully tackled, though there are groups that are actively pursuing this now.

Finally, it is critical to connect with other groups with goals similar to yours. There are many national programs that have been working for years to introduce quantum to new communities and break down the barriers to entry, including the Q-12 national education partnership, the QuSTEAM Initiative, and the QED-C Workforce Technical Advisory Committee (TAC). There are also many regional groups looking to build local quantum ecosystems, including the Elevate Quantum consortium, the Chicago Quantum Exchange, South Carolina Quantum, Mid-Atlantic Quantum Alliance, Northwest Quantum Nexus, and more. Finally, there are ongoing efforts at many of the National Quantum Initiative Centers focused on expanding participation in the field, including programs run by the DOE-SC supported Quantum Systems Accelerator and the NSF supported Q-SEnSE program [13, 14].

By partnering with these groups, you can accelerate your understanding of the needs of your region, align efforts with like-minded institutions, and gain access to a wealth of expertise and materials that could catalyze your efforts to launch new quantum technician training programs.

6. Conclusion/Summary

While there is still much work to be done in understanding the quantitative and qualitative needs of the quantum workforce, quantum technologies remain a top priority for governments across the world and there are great opportunities to get engaged across the workforce spectrum. We see a particularly compelling opportunity to help fill current and future workforce gaps through the training of quantum technicians across quantum technologies, especially if it is done in regions with both established and growing quantum industry sectors. Focus your program development efforts on areas that you institution is already strong in, connect with others who are interested in developing new pathways into the field, and find ways to make small changes for big impact. The quantum future is bright, and we have an opportunity to bring more communities into the field in an equitable way from the get-go if we act now.

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