CONNECTING THE DOTS

QUANTUM LEARNING THROUGH EXPERIENTIAL ACTIVITIES AND PRACTICE

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About QED-C

The Quantum Economic Development Consortium (QED-C) is the world's premier association of pioneers in the quantum technology marketplace. Members of QED-C enable the real-world application of quantum technology, and, in turn, grow a robust commercial industry and supply chain. For more information about QED-C, please visit https://quantumconsortium.org/.

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Executive Summary

As the quantum industry evolves from theoretical research to practical application, so do the requirements for a quantum-ready workforce. The Quantum Economic Development Consortium (QED-C), with support from the National Science Foundation, convened stakeholders from across the ecosystem to explore how experiential learning can bridge the gap between theoretical education and the hands-on skills required in industry. This report presents insights and recommendations to strengthen the quantum talent pipeline through targeted, accessible, and scalable experiential learning opportunities.

Key Findings

- **Industry Demand**: There is a growing need for talent across quantum computing, sensing, and networking roles, including technicians, engineers, and translators who can bridge technical and business domains.
- **Workforce Gap**: Existing educational systems fall short in providing practical training, particularly at the associate degree and technician levels.
- **Learner Needs**: Profiles developed during the workshop identified widespread barriers such as lack of mentorship, unclear career paths, and limited access to affordable, flexible training.

Programmatic Insights

- Learners benefit from **hands-on, job-ready training** through apprenticeships, capstones, lab courses, and short-term projects.
- A shift is needed from exclusive, late-stage education to **early and continuous engagement** that is **collaborative and application-oriented**.
- Programs should prioritize **accessibility, flexibility, and multidisciplinary skill development**, tailored to a wide range of learners including community college students and early-career professionals.

Recommended Actions

1. **Track and communicate current efforts in quantum workforce development**: Establish a central repository of efforts, opportunities, outcomes, and best practices to connect stakeholders and optimize training effectiveness.
2. **Develop and Deploy Pilot Programs**: Test scalable experiential learning models such as apprenticeship frameworks and industry-aligned certification programs.
3. **Coordinate Ecosystem Funding**: Monitor and identify opportunities to align public and private investments to strengthen program delivery and long-term workforce development.

Introduction

The workforce needs of the quantum industry are broad.[1] Various roles are required, from quantum algorithm developers to broader business and technical positions, including skilled quantum technicians. The different skills demanded for these roles necessitate tailored educational pathways to meet industry demands. "Quantum 2.0" technologies (that use the properties of superposition and entanglement) encompass quantum computing, sensors, and networking. While each of these technologies builds on a shared foundation of quantum knowledge as described previously[1], the implementation and specialties of specific companies also means that employees often require specialized training to become fully proficient in their employer's quantum work. The state of the technology is such that opportunities to gain hands-on experience in specific industry-relevant situations often go to graduate student interns and, more narrowly, to PhD students.

Two recent analyses provide complementary insights into quantum workforce needs.[2] Using different analytical approaches, both arrived at similar conclusions projecting 175–190K quantum-related jobs in the Midwest alone by 2035. The analyses report:

- a strong need for application-focused roles,
- lower projected requirements for graduate degree holders than previously assumed,
- significant opportunities for quantum "translator" roles bridging technical and business domains, and
- a substantial workforce gap, particularly at the associate degree level.

For Colorado, New Mexico, and Wyoming, demand for quantum-trained talent is estimated to exceed the current workforce by an order of magnitude within a comparable timeframe.[3] Investments by states such as South Carolina and Maryland into developing the quantum industry suggest similar potential for growth.[4]

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[1] See QED-C, *Assessing the Workforce Needs of the Quantum Industry.* Arlington, VA: SRI International, August 2021, https://quantumconsortium.org/assessing-the-needs-of-the-quantum-industry and C. Hughes, D. Finke, D. -A. German, C. Merzbacher, P. M. Vora and H. J. Lewandowski, "Assessing the Needs of the Quantum Industry," in *IEEE Transactions on Education*, vol. 65, no. 4, pp. 592-601, Nov. 2022, doi: 10.1109/TE.2022.3153841..

[2] See. "Quantum Job Projections," Chicago Quantum Exchange, accessed Mar 25, 2025, https://chicagoquantum.org/jobprojectiondata and "Chicago: An Emerging Hub for Quantum Innovation," World Business Chicago, August 5, 2024, https://worldbusinesschicago.com/quantum/.

[3] "Quantum: It's real. It's here. And Colorado is leading the way," Colorado Office of Economic Development and International Trade, May 17, 2024, https://oedit.colorado.gov/blog-post/quantum-its-real-its-here-and-colorado-is-leading-the-way.

[4] See "About," South Carolina Quantum Association, accessed Apr 15, 2025, https://www.scquantum.org/about; and "Governor Moore announces 1 billion 'Capital of Quantum' initiative," The Office of Governor Wes Moore, April 14,

Experiential learning has emerged as a linchpin to integrate workforce readiness with the industry's rapid technological advances. A survey of QED-C industry members in 2019 found that a key challenge to hiring quantum workers was lack of hands-on experience.[5] In a later study, QED-C found that "current hiring approaches often focus on recruiting candidates out of adjacent fields that have shared skill requirements (e.g., microelectronics, semiconductor, photonics) and rely on in-house shadowing programs to train new hires; however, a more coordinated approach specifically geared toward filling the quantum workforce pipeline could increase productivity and progress, especially in small companies."[6] Providing learners interested in the possibilities of a career in this emerging technology with opportunities to gain hands-on, real-world experience with quantum and quantum-adjacent technologies could create a more capable, more productive, and better-supported workforce at all levels.

To explore this idea, the Quantum Economic Development Consortium (QED-C) convened experts from industry, government, academia, and adjacent sectors for guided discussions examining how experiential learning programs could strengthen the quantum workforce pipeline, based on the following challenge:[7]

How might we *enhance experiential learning opportunities in quantum science and engineering (for students and early-career professionals)*

In a way that *bridges the gap between theoretical knowledge and practical application, makes quantum concepts more accessible and engaging, and aligns with real-world industry needs and practices*

So that *we can cultivate a diverse, well-prepared quantum workforce capable of driving innovation and meeting the evolving challenges of the quantum technology sector, ultimately accelerating the growth and competitiveness of the quantum industry.*

2025, https://governor.maryland.gov/news/press/pages/governor-moore-announces-1-billion-capital-of-quantum-initiative.aspx. South Carolina Quantum Association received a $15 million grant from the State of South Carolina with the mission to "advance a learning environment for Quantum Information Sciences, professional workforce development across all industries, and entrepreneurship for all." Maryland's Governor Wes Moore announced an initial $27.5 million dollar investment to turn Maryland into the "Capital of Quantum."

[5] The survey was conducted by the Workforce Technical Advisory Committee (TAC) and the results remain available to QED-C members on the TAC webpage.

[6] QED-C, *Guide to Building a Quantum Technician Workforce,* Arlington, VA: SRI, December 2023, p. 3 https://quantumconsortium.org/workforce23,

[7] Workshop participants are identified in Appendix A and the agenda is summarized in Appendix B.

Guidance for Hands-On Quantum Training and Workforce Development

A skilled, knowledgeable, and quantum-ready workforce is essential to support the continued growth of this industry. Identifying the types of learners interested in quantum and their career entry points and end goals establishes a perspective that designers of hands-on quantum training and workforce can use as a jumping off point.

Quantum Learner Profiles

QED-C developed learner profiles to consider ways to improve experiential learning and reduce both real and perceived barriers to entering the quantum industry for target populations (see Appendix C). The learner profiles represented students, technicians, early-career professionals, and established engineers, all with an interest in entering or advancing in the field. Their aspirations varied from an immediate practical job (e.g., technician, quantum software developer) to a leadership position in research or commercialization.

The following desires emerged across the designed profiles:

Desire for practical, job-ready skills. Many learners struggle with abstract theory and crave hands-on experience such as lab work, hardware manipulation, or algorithm implementation. They need experiential learning opportunities that help them understand how their existing STEM skills can translate into quantum roles.

Accessible entry points. Learners come from all levels—high school, community college, undergraduate and graduate school—and professional backgrounds. They need resources that are accessible regardless of their quantum experience. Learners favor flexible schedules (night/weekend classes, online tutoring, immersive short courses) and support structures like mentorships or community learning hubs. They also look for affordability (the cost of the program), reduced financial barriers (e.g., access to low-interest loans or supplemental income streams to reduce constraints for primary providers in families), and proximity to educational resources. Entry-level learners often lack awareness of available pathways and need clear guidance, early mentoring, and structured programs to break into the field.

Ways to overcome knowledge gaps. Common challenges among potential quantum workers include confusion about career trajectories and insufficient instruction in the necessary physics or engineering fundamentals. Learners cite the need for more integrative, user-friendly educational resources as well as mentorship to clarify industry expectations.

Multidisciplinary and transferable skills. Beyond pure quantum mechanics, learners recognize the need to augment their existing technical backgrounds (e.g., in electronics, computer science, mechanical engineering) with specialized quantum knowledge. They also acknowledge the importance of broader capabilities—communication, problem solving, agile thinking—to thrive in an evolving quantum ecosystem.

Clarity, guidance, and career mapping. Overall, job-seeking learners want greater clarity around current and future positions and career growth opportunities. Anecdotally, current employees and job candidates seek more transparent descriptions of quantum job roles, required skills, and expected educational levels. Effective career guidance, including information on how to transition from their current skills to quantum-specific expertise, is essential for retaining the interest of these employees and jobseekers and helping them move forward confidently.

Mentorship. Adding an aspect of mentorship into experiential learning programs has several benefits. Mentors provide learners with insights into career pathways, can help clarify expectations around knowledge and expertise, and serve as a support structure outside of the traditional learning environment. Mentoring can take several forms from the traditional one-on-one between a senior employee and a junior employee to group mentoring where a cohort may have access to many mentors, each with their own style and viewpoint.[8] That flexibility allows programs and learners to determine what model best fits their needs, offering a bespoke element that may otherwise be difficult for programs to provide.

In summary, learners across the spectrum need concrete, hands-on opportunities, comprehensive guidance, flexible and supportive training environments, and well-defined career pathways. Empowering them through early exposure to the field, integrated skill development, and access to mentors will help cultivate a talent pool ready to meet the quantum industry's emerging demands.

Program Design

Certain systemic shifts to education programs will enable learners to make career transitions. Analysis of the learner profiles in Appendix C suggests that certain transitional shifts, examples of which are considered in Appendix D, are needed to foster a more robust, skilled quantum workforce. Traditional education programs that support the quantum workforce would benefit from more collaborative, transparent, and data-informed strategies for programs that emphasize practical experience and early

[8] *What is Mentoring,* Association for Talent Development. Accessed Apr 15, 2025. https://www.td.org/talent-development-glossary-terms/what-is-mentoring.

exposure. The new approach would require coordination and synchronization of efforts by not only industry but all quantum 2.0 stakeholders.

From exclusivity to broad-based engagement. Instead of relying on a small pool of highly specialized talent, the industry needs to nurture a larger workforce pipeline and lower barriers, such as degree requirements, for quantum-related careers. This means extending experiential learning opportunities beyond master's- and PhD-level experts to include undergraduates, community college students, and professionals from various STEM backgrounds. It is also important to address fears about job security and career viability. Defined clearer pathways, more structured training programs, and visible industry commitment to long-term growth can help both professionals and students feel more confident about pursuing quantum-related careers.

From late stage to early and continuous exposure. Quantum concepts and hands-on training should be introduced earlier in educational pathways instead of waiting until advanced graduate programs. Early exposure, supported by faculty buy-in and informed, flexible curriculum development, ensures that learners gain practical skills and can avail themselves of various points of entry to the workforce that better align with industry demands and their own career goals.

From theoretical emphasis to applied, hands-on learning. Current early-stage and introductory courses often focus on abstract theory and the latest advancements in the field. Such training can be made more effective by integrating practical experience—internships, apprenticeships, project-based learning, and lab access—so that learners develop job-relevant skills. Emphasizing real-world applications helps bridge the gap between academic preparation and industry workforce needs.

From uncoordinated efforts to collaborative ecosystems. As interest in quantum technologies grows, more organizations and institutions are working to develop the workforce.[9] Establishing a new university program often requires years of complex planning, while smaller or more agile organizations may lack resources such as lab equipment or funding. Limited visibility into existing programs and their outcomes can result in redundant efforts. Creating mechanisms to improve coordination among educators, industry leaders, and policymakers by enhancing access to and awareness of resources and standardizing training has the potential to reduce costs and improve outcomes for both learners and industry. It would also help promulgate programs that are both targeted and scalable.

[9] *Quantum Technology Monitor,* McKinsey Digital. April 2024. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/steady%20progress%20in%20approaching%20the%20quantum%20advantage/quantum-technology-monitor-april-2024.pdf

From limited awareness to open participation. Quantum careers are often seen as niche and highly specialized, making it difficult for newcomers to see clear entry points. To build a stronger workforce with a wider pool of talent, it is essential for stakeholders, including educators and corporations, to create an environment where interest in quantum technologies can thrive. This means improving communication, increasing the visibility of and access to career paths, and providing resources for professionals looking to transition to quantum-related roles. Toward that end, the United Nations has proclaimed 2025 the International Year of Quantum, catalyzing a variety of initiatives to increase awareness and participation in quantum science and technology.

From one-off interventions to long-term, structured pipelines. Ensuring a steady flow of talent requires replacing ad hoc approaches to education and development with structured, continuous pipelines, characterized by clear educational tracks, standardized internships, and multiyear development programs. Over time, these pipelines will yield a workforce that can adapt to evolving industry needs.

In summary, the industry must embrace collaboration, early engagement, practical experience, data-driven strategies, and integration of multiple different types of workforce cultures (academic, industry, government, etc.) By doing so, it can create a coherent, sustainable ecosystem that consistently produces well-prepared professionals ready to meet the quantum sector's accelerating demands. It will require a broad coalition of support from stakeholders across industry, academia, and government. Professional associations such as APS, IEEE, and SPIE; consortia such as QED-C; and organizations with established relationships are well positioned to contribute to these efforts.

Criteria for Pilot Programs

The following practical steps and insights are intended to help educators design effective pilot programs. The proposed experiential learning initiatives feature the following components to bridge skill gaps, cultivate industry-ready talent, and make quantum education more accessible, hands-on, and relevant. A full list of program ideas is presented in Appendix E.

Hands-on, applied experience. Direct immersion in quantum work environments—through internships, co-ops, apprenticeships, and project-based mentorships—ensures that learners gain job-ready capabilities by developing practical skills like assembling quantum systems, running lab experiments, doing research, and developing quantum software.

Multiple entry points and audiences. Proposed initiatives target a wide spectrum of learners, from community college and undergraduate students to emerging technicians, early-career professionals, and even high school learners. This broadened focus aims to democratize quantum education, removing traditional barriers and nurturing a larger, more varied talent pipeline.

Structured pathways for career development. Programs such as quantum computing capstone courses, senior design projects, and registered apprenticeships offer structured routes from classroom learning to real-world applications. Integration of these practical learning modules in formal education and career pathways can help participants smoothly transition into quantum roles.

Industry-inspired training. Close ties to companies, industry mentors, and specialized resources ensure that curricula are relevant and reflect current industry demands—whether by upskilling technicians, helping learners master quantum software tools, or addressing vendor specific requirements.

Communication, collaboration, and cross-disciplinary training. Beyond technical proficiencies, several of the solutions highlight "soft skills" such as communication, creative problem solving, and the ability to collaborate across disciplines.[10] These skills prepare learners to adapt and innovate in the rapidly evolving quantum landscape.

Flexibility and accessibility. Short-duration microprojects, mentorships, and bootcamp-like programs allow participants to gain experience quickly and flexibly. Longer-term initiatives (e.g., 6- to 12-month apprenticeships or lab-based research experiences) provide in-depth engagement. Such variety accommodates different learning styles, time commitments, and resource levels, making quantum opportunities more accessible.

[10] See "Voices of Quantum: From Idea to Reality" and "Quantum Immersive Learning Platform" examples in Appendix E: Proposed Experiential Learning Solutions.

Recommendations

The following are potential ways to accelerate the development of a well-prepared and resilient quantum workforce. Doing so will provide a foundation for long-term industry competitiveness and continued innovation.

Track and Communicate Current Efforts in Quantum Workforce Development

Success requires attention to technological and organizational infrastructure, including assessment of laboratory equipment needs, development of virtual learning platforms, and creation of collaborative frameworks between education providers and resource owners that will provide learners with access to achieve the desired skills. Understanding stakeholder capabilities and constraints will inform a realistic implementation timeline.

To that end, the QED-C Workforce Technical Advisory Committee should continue to compile and share summaries of activities, successes, lessons learned, and best practices in developing and growing the quantum-capable workforce.

Professional associations, societies, and consortia with direct ties to relevant degree paths, educators, students, and companies are also well positioned to act as a bridge between faculty, industry, and jobseekers (both current and next generation) through panels and working groups. Through such groups, industry can communicate necessary skills and educators can match those needs with tailored programs.

Develop and Deploy Pilot Programs

Pilot programs are a useful way to test ideas for feasibility, scalability, and effectiveness. See Appendix E for a list of program concepts and Appendix F for a detailed list of topics that resonated with workshop participants. Priority in selecting pilot programs should go to initiatives that demonstrate quick wins while building a foundation for broader implementation. Programs of particular interest would focus on

- promoting and facilitating access to existing federally-funded quantum laboratory networks, including National Science Foundation (NSF) and Department of Energy user facilities, that serves multiple stakeholder groups,
- an apprenticeship program linking industry partners with educational institutions, and
- a standardized certification framework aligned with industry needs.

Effective implementation of a long-term sustainable pipeline for quantum requires a phased approach and coordinated engagement across the ecosystem. Industry partners play a crucial role in providing real-world training opportunities. Collaboration between industry and academia is necessary to ensure curriculum relevance. Academic institutions serve as one critical channel for delivering relevant education to learners while adapting traditional programs to include more hands-on components. Government and nonprofit organizations provide essential support through funding and certification standards.

A robust evaluation framework in collaboration between the program leadership and funding partners supports continuous improvement through both quantitative and qualitative metrics. Performance indicators could include program enrollment trends, job placement rates, candidate outcome tracking over time, and employer satisfaction levels. Regular data collection and analysis would enable evidence-based refinement of programs and approaches.

Any evaluation process should include quarterly reviews of key metrics, annual comprehensive assessments, and ongoing stakeholder feedback mechanisms tied to continued funding. This systematic approach ensures that programs remain relevant and effective while providing clear evidence of impact.

Survey Ecosystem Funding, Intended Outcomes, and Timelines

NSF should support the work of a convening organization such as the National Quantum Coordination Office or QED-C to regularly gather information on the global landscape of investments in developing a job-ready quantum and quantum-related workforce, including sources of funding, partners, and intended outcomes. Such a summary should be reviewed and updated on a regular basis.

This would address some of the concerns about lack of coordination, improve insights into potential funding partners and collaborators for proposers, and provide referential information on resource requirements for pilot initiatives and additional workforce efforts. By taking a global perspective, the report could enhance program effectiveness by enabling easier identification of international collaboration opportunities.

Appendix A: Workshop Participants

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Zizwe Chase, University of Illinois Chicago
Jake Douglass, Sandia National Laboratories
Faith Dukes, Lawrence Berkeley National Laboratory
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Hilary Hurst, National Quantum Coordination Office
Megan Ivory, Sandia National Laboratories
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Richard Nelson, Quantum Computing Inc (QCI)
Marek Osinski, University of New Mexico
Maxwell Parsons, University of Washington
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Richard Ross, University of California, Los Angeles
Alex Shih, Q-CTRL
Corey Stambaugh, National Institute of Standards and Technology
James Troupe, Air Force Research Laboratory
Yan Wang, Georgia Tech
Ellen Winsor, EMW Consulting
Wendy Wu, World Business Chicago

Appendix B: Workshop Agenda

Through panel sessions, breakout groups, and collaborative exercises, stakeholders shared insights on effective approaches to practical quantum education while considering the needs of learners at various stages.

8:00 - 9:00 *Registration/Breakfast*

9:00 - 9:15 **Overview of Event**

9:15 - 9:45 **Introductory Remarks**

9:45 - 10:15 **Panel Discussion "Addressing Skills Gaps and Training Needs"**

> Pedro Lopes, *QuEra Computing*, Jennifer Flatté, *QUANTCAD*, Corey Stambaugh, *National Institute of Standards and Technology*, Gwen Leifer, *Lockheed Martin*

10:15 - 10:30 *Break*

10:30 - 11:00 **Panel Discussion "Lessons from the Field: Adopting Best Practices"**

> Olivia Lanes, *IBM Quantum*, Heather Lewandowski, *University of Colorado*, Hilary Hurst, *White House Office of Science & Technology Policy*

11:00 - 12:00 **First Breakout "Mapping the Talent Landscape: Jobs, Skills, and Gaps"** → *Learner Profiles*

12:00 - 1:00 *Lunch*

1:00 - 1:30 **First Breakout Report Outs**

1:30 - 2:30 **Second Breakout "Creating the Talent Pipeline: Brainstorming Initiatives"** → *Initial Experiential Learning Solutions*

2:30 - 2:45 *Break*

2:45 - 3:15 **Second Breakout Report Outs**

3:15 - 4:15 **Third Breakout "Bridging the Gap: Putting Quantum Workforce Ideas into Practice"** → *Selected Solutions Refined*

4:15 - 4:45 **Third Breakout Report Outs**

4:45 - 5:00 **Workshop Wrap-up**

Appendix C: Learner Profiles

Based on their experiences as hiring managers, educators, and mentors to learners and jobseekers, workshop participants designed and discussed various learner profiles. The learner profiles below are designed based upon the understanding and experience of the workshop participants. Each profile describes a prospect seeking training or upskilling to gain employment in the quantum industry.

Military/Electronics Engineer

- **Background**: Military service, electronics assembly experience
- **Aspirations**: National security-related quantum role
- **Barriers**: Lacks clear pathways and understanding of the field
- **Needs**: Hands-on environment, measurable outcome (job placement)

Community College Student

- **Background**: CC student, no expertise
- **Aspirations**: Not specified
- **Barriers**: Lack of access, low awareness
- **Needs**: Programming skills, supportive learning environment

Eager Industry Subject Matter Expert

- **Background**: Expert in STEM/analytics, new to quantum
- **Aspirations**: Enter VC/PE with quantum expertise
- **Barriers**: Needs rapid upskilling in quantum
- **Needs**: Hands-on, collaborative learning, breaking outdated mental models

Community College Student

- **Background**: Community college (Shidler), basic STEM/CS classes
- **Aspirations**: Wants to engage with quantum learning opportunities
- **Barriers**: Lack of resources
- **Needs**: Mentorship, workshops, internships

Computer Science Undergrad (Aspiring Quantum Software Developer)

- **Background**: Programming skills, undergrad in CS
- **Aspirations**: Become a quantum software developer, inspired by medical news
- **Barriers**: Quantum physics knowledge gap
- **Needs**: Online tutoring, physics fundamentals, apply skills to secure a job

Systems Modeler

- **Background**: PhD in Structural Reliability related to QC
- **Aspirations**: Contribute meaningfully to quantum computing
- **Barriers:** Programming quantum computers, learning new tools
- **Needs**: Flexible learning, agile execution, practical output-driven success

Some College and Job Experience

- **Background**: 2 years college (dropped out), 5 years engineering experience, some EE and physics
- **Aspirations**: Quantum technologist, potentially a startup founder
- **Barriers:** Budget constraints, needs immersive online learning
- **Needs**: Quantum physics and programming skills, IBM Quantum-related opportunities

R&D Engineer

- **Background**: Software & hardware experience
- **Aspirations**: Work in energy tech, sees quantum as emerging area
- **Barriers**: Limited code sharing, new concepts hard to access
- **Needs**: Increase learning velocity, graduate-level PM sessions, open environment

Appendix D: Learner Profile Transition Opportunities

Workshop participants discussed the learner profiles in the context of career transitions into the quantum industry.

- Military → Quantum Lab at Nat. Lab: Transition from military service to research-focused quantum environment.
- Community College (CC) Student (no awareness) → Ability to pursue a quantum career: Gaining awareness, skills, and direction.
- Not Using Quantum → Fluent in Quantum: Moving from uncertainty and no QC use to confidence and fluency.
- College Dropout → Quantum Technician (From no degree to advanced degrees): Transforming background limitations into advanced quantum qualifications.
- No Quantum → Less Uncertainty with Quantum: Reducing uncertainties by achieving quantum literacy and competence.
- Lack of Time, Money, Access → Empowered Community College Students toward Technician Roles: Overcoming resources barriers to support community college learners.
- Inability → Providing Mentored Learning: Addressing skill exclusion and providing structured training opportunities.

Overall Themes:

- Strong emphasis on bridging skill gaps: identifying workforce needs, addressing technician-level skills, hands-on training, and apprenticeships.
- Common target groups: Early to mid-career professionals, recent graduates, and community college students transitioning into quantum roles.
- Identified barriers: Lack of clarity on pathways, resources, financial support, and mentorship.
- Preferred solutions: Short-term (1-3 month) to medium-term (3-6 or 6-12 month) immersive experiences, mentorship, apprenticeships, bootcamps, and community-building programs.
- Goals: Developing fundamental and applied quantum skills, enabling career advancement, increasing industry readiness, and fostering more inclusive and accessible learning opportunities

Appendix E: Proposed Experiential Learning Solutions

Workshop participants proposed the following programs. Participants' proposals generally emphasize a move toward more practical, inclusive, and industry-aligned quantum education. Their collective vision is to cultivate a well-rounded workforce capable of contributing to quantum innovation from multiple entry points, reinforcing the ecosystem's growth and resilience.

	Pitch Title	Problem Statement	Solution Proposed	Notional Market Application	Additional Notes
Apprenticeship	Quantum Apprenticeship Pathways	Need for structured workforce pipelines in quantum	Regional apprenticeship model with industry buy-in	Workforce development, government, education	Requires Department of Labor approval
Apprenticeship	Registered Apprenticeships	Cumbersome certification process by Department of Labor; high barriers to execution	Use data to justify need for registered apprenticeships	Structured on-the-job workforce development for immediate labor advantage	Seeking funding for research and implementation
Capstone	Capstone-Level Quantum Education	Lack of hands-on quantum training	Affordable, modular learning with practical tasks	Academic institutions, technical workforce	Combines foundational learning & hands-on work
Capstone	National Quantum Capstone Program	Need for structured quantum projects in universities	Standardized course with industry participation	STEM students, quantum companies	Course-based experience for credit
Capstone	Open Quantum DIY Device Program	Lack of practical quantum device engineering skills	Capstone program to design/build quantum hardware	Universities, tech colleges, open-source hardware	Focus on optical and atomic devices
Capstone	Senior Design Projects in Quantum	Electrical engineers lack quantum exposure	Integrate quantum-focused capstone projects	University engineering programs	Uses existing capstone structures

	Pitch Title	Problem Statement	Solution Proposed	Notional Market Application	Additional Notes
Funding and Resource Access	Break Into Q	Insufficient funding for quantum research pipeline	Seed funding for underfunded quantum research laboratories	Academia, quantum industry, talent pipeline	Supports new students in quantum field
	Infrastructure for Quantum Tech Programs	Need for hardware and supplier support for training	Partner with suppliers for equipment discounts	Underfunded institutions, quantum companies	Addresses cost barriers for non-R1 schools
	Quantum Immersive Learning Platform	Lack of experiential learning for quantum technicians	Combine VR & LMS to provide immersive learning	Quantum technician training, online education	Includes real-time video assistance
	Quantum Lab Experience for Undergraduates	Limited hands-on training in quantum technology	Semester-long lab program with industry partnerships	Community colleges, non-R1 institutions	Focuses on affordable, hands-on experience
Professional Development	Outcome-Based Quantum Learning	Companies need ROI on training investments	Identify project-specific skills before training	Corporate upskilling, workforce productivity	Focus on practical business applications
	Quantum Continuing Education for Professionals	Professionals displaced by tech shifts	Two-part quantum training: fundamentals + specialized	Pharma, tech, early-adopter industries	Focuses on mid-career professionals
	Quantum Upskilling for Business Development	Business professionals lack quantum literacy	Specialized upskilling program	Government contracting, proposal writing	Tailored for business dev. professionals
	RF Engineering for Quantum Technology	Lack of RF engineering expertise in quantum sector	Course on RF signal processing for control and readout of quantum systems	Quantum hardware companies, early career engineers	Equipment-intensive, may need donations
	SME Quick Quantum Improvement	Business experts struggle to bridge quantum knowledge	Masterclass/black belt training for industry experts	Corporate training, finance, high-level execs	Inspired by Six Sigma programs

	Pitch Title	Problem Statement	Solution Proposed	Notional Market Application	Additional Notes
	Internal Corporate Pipeline for Quantum Reskilling	Need for company-specific quantum upskilling	Consulting teams create customized training programs	Corporate R&D, proprietary tech companies	Industry-focused pipeline
Mentorship	ERG-Driven Quantum Collaboration	Employees work in silos, reducing knowledge sharing	Create ERG subcommittees focused on quantum	Corporate diversity, team building	Leverages existing ERG structures
	Quantum Methods Exposure	Lack of quantum-specific training	Hands-on mentorship-driven problem solving	Quantum startups, academic research, industry	Consultants & training-focused
	Quantum Software Mentorships	Need for structured mentorship in quantum software	Paper reading, code implementation, mentorship	Universities, quantum consortia, industry partners	Scaling mentorship programs
	Small Cohort Mentored Projects	Skills gaps in quantum field	Pair individuals with complementary skills for projects	Professional development, mentorship programs	Creates future mentors through participation
	Year-Long Pilot with Academia & Industry	Lack of structured mentorship and career paths	Cohort-based program with academia, industry, and National Labs	Workforce development, National Labs, career paths	Year-long engagement model
Outreach	Quantum Summer Internship Program	Need for real-world quantum exposure for students	Internship program pairing students with companies	Quantum startups, business development	Focus on commercializati on skills
	Community Outreach Quantum Education	Lack of quantum awareness in certain demographics	Engage communities via existing social institutions	Community centers, schools, vocational training	Targets nontraditional learners
	Quantum Without Math	Perception that quantum is too math-heavy	Accessible quantum education without formulas	Finance, business, policy sectors	Aimed at non-technical audiences

	Pitch Title	Problem Statement	Solution Proposed	Notional Market Application	Additional Notes
	Teacher Training for Quantum	High schools lack quantum education programs	Train teachers rather than students directly	High school, STEM pipeline, education reform	Addresses funding and standards gaps
	Voices of Quantum Student Internship	Lack of accessible quantum internships for students	Cohort-based internship program with company partners	Undergraduate students, STEM fields	Seeks public-private partnerships
Scaling & Best Practices	National Co-Op Research Expansion	Limited scale of current quantum co-op projects	Expand to all major quantum companies & universities	Industry-academic collaboration	Builds on existing small-scale co-ops
	Quantum Forge National Collaborative	Scaling quantum education programs	Centralized framework to scale educational innovation	STEM students, academia, national education policy	Wrap-around evaluation for effectiveness

Abbreviations:
ERG – Employee Resource Group
LMS – Learning Management System
RF – Radio Frequency
SME – Subject Matter Expert
VR – Virtual Reality

Appendix F: Refined Experiential Learning Proposals

Workshop participants refined the program proposals considered in Appendix E; the following are those that highly resonated with participants.

1. Reskilling Miscellaneous Technicians

- **Type**: Hands-on Training (1-3 months)
- **Skills Addressed**: Experimental setup, maintenance, assembly
- **Beneficiaries**: Early Career, Mid-Career
- **Resources:** Funding for lab facilities, materials
- **Industry Need:** Technician roles

2. Identify and Map Workforce Gaps Program

- **Focus**: Identify key workforce gaps, map required skills, form partnerships, and fund programs
- **Outcome**: Align training with industry-defined skill shortages

3. Quantum Lab Experiences

- **Type**: Hands-on, industry inspired lab training (3-6 months)
- **Skills Addressed**: Technical leadership, foundational hands-on quantum skills
- **Beneficiaries**: Early Career, Mid-Career, Recent Graduates, Students
- **Resources:** Facilitated access to existing federally-funded user facilities
- **Industry Need:** Technical skill building at non-R1 institutions

4. Machine Learning (Quantum Context)

- **Type**: Experiential (3-6 months)
- **Skills Addressed**: Broad "rescue" (improvement) skills; possibly ML/quantum integration
- **Beneficiaries**: Early Career, Mid-Career, Recent Graduates, Students
- **Resources**: Necessary lab equipment
- **Industry Need:** Broad tech workforce development

5. Registered Apprenticeships

- **Type**: Apprenticeship (1-2 years → potentially longer)
- **Skills Addressed**: Determined by company needs (well-evidenced)

- **Beneficiaries**: Pre-Career, Mid-Career, Recent Graduates, Students
- **Resources**: Data advocacy, DOL process support
- **Industry Need:** Evidenced-based apprenticeship pathways

6. Quick Quantum Immersion

- **Type**: Micro Quantum Projects (1-3 months)
- **Skills Addressed**: Career exposure, solving small real-world problems quickly
- **Beneficiaries**: Early Career, Mid-Career, Recent Graduates, Students
- **Resources**: Quantum community access, quantum experts, centralized admin for applications and projects
- **Industry Need:** Immediate industry problem-solving experience

7. Unaligned Adiabatic Optical System Assembly

- **Type**: Short Experience (1-3 months)
- **Skills Addressed**: Adiabatic optical systems
- **Beneficiaries**: Early Career
- **Resources**: MIT Open Quantum Learning
- **Industry Need:** Quantum computing manufacturing, robotics controls

8. Developing Quantum-Ready Community College Students

- **Type**: Work Experience (6-12 months)
- **Skills Addressed**: STEM foundations, communication techniques
- **Beneficiaries**: Early Career, Recent Graduates, Students
- **Resources**: Education program development, community connections
- **Industry Need:** Building industry pathways from education to career

9. Six-Month Cohort Program

- **Type**: Cohort-based Internship + Mentorship
- **Duration**: ~6 months (summer internships, mentorship, community building)
- **Skills Addressed**: Professional skills (project management, presentation, writing), tech awareness
- **Beneficiaries**: Students, Emerging Professionals
- **Resources**: Internship placements, mentorship, community network
- **Industry Need:** Quantum talent pipeline development outside of technical skills, hands-on experience, bridging education to employment

10. Enterprise E6 Quantum Up

- **Type**: Mentorship, Bootcamp (6-12 months)
- **Skills Addressed**: Hands-on quantum lab skills, security, tech
- **Beneficiaries**: Early Career, Mid-Career, Recent Grads, Students
- **Resources**: HR partnership, local site pilot, role redesign
- **Industry Need:** DOD/Aerospace security, national security skill-building

11. The "Inability" of Quantum Computing

- **Type**: Mentoring/learning (6-12 months)
- **Skills Addressed**: Quantum computing and AI programming, addressing skill exclusion
- **Beneficiaries**: Early Career, Mid-Career, Recent Grads, Students
- **Resources**: Training materials, funding
- **Industry Need:** Financial sector dynamism, addressing skill gap