Issue Brief

Biotech Manufacturing Apprenticeships

A Case Study in Workforce Innovation

Authors
Luke Koslosky
Steph Batalis
Ronnie Kinoshita

CSET CENTER for SECURITY and EMERGING TECHNOLOGY

August 2025

Executive Summary

This report explores how organizations in emerging technology fields can develop and deploy apprenticeship programs as a workforce development strategy by focusing on lessons learned from the North Carolina Life Sciences Apprenticeship Consortium (NCLSAC). It is intended as a guideline for stakeholders considering the creation of an apprenticeship program in biomanufacturing, and as a primer for policymakers to better understand the process.

The NCLSAC was developed in response to workforce challenges in North Carolina's biopharmaceutical manufacturing sector, a critical industry in the state's economy. It was one of several initiatives funded through the U.S. Economic Development Administration's (EDA) Build Back Better Regional Challenge (BBBRC). Through a case study based on interviews with key participants involved in the consortium's development, this report provides insights into how apprenticeship programs can help address skill gaps, build a resilient workforce, and supplement other workforce development initiatives, especially for emerging technology industries.

Key Findings and Broader Implications

While there is no one-size-fits-all roadmap for apprenticeship programs, the insights from the NCLSAC case study can serve as a helpful framework for organizations considering apprenticeships. These insights, structured around three key phases—program exploration, program design, and program implementation—provide guidance for evaluating workforce needs, designing a program that aligns with industry requirements, and executing it successfully.

- In the **program exploration** phase, companies should first assess workforce needs and gaps, evaluate whether apprenticeships are an appropriate solution, and begin building partnerships. Involving industry leaders, educational institutions, and community organizations from the outset is critical to aligning the goals of the apprenticeship program with the needs of all parties involved.
- In the **program design** phase, organizations must choose an apprenticeship model, ensure alignment with industry needs, and consider whether a pre-apprenticeship program is necessary to prepare participants. Different industries and regions may require tailored approaches to apprenticeship design and implementation. Flexibility in structure and content ensures that the program addresses specific workforce demands.
- Lastly, during **program implementation**, it is crucial to coordinate internal company logistics and recruit apprentices effectively. Continuous feedback from

apprentices, employers, and other stakeholders is vital for refining the program over time and ensuring it remains responsive to changing industry needs.

To assist companies in navigating these considerations, we have outlined a set of guiding questions that can be used at each stage of the apprenticeship development process.

Ultimately, while each apprenticeship program must be designed with its specific context in mind, the lessons learned from the NCLSAC case study provide valuable guidance for those seeking to leverage apprenticeships to meet workforce challenges and create new opportunities for diverse talent. By carefully considering the insights and questions outlined in this report, organizations can lay the groundwork to use apprenticeships to address workforce shortages, enhance U.S. competitiveness, and provide good jobs and valuable pathways to technically skilled careers for individuals.

Table of Contents

Introduction

To maintain global competitiveness and leadership in emerging technologies like biotechnology and artificial intelligence (AI), the United States needs a highly skilled workforce capable of navigating the complexities of these rapidly advancing fields. However, developing such expertise presents a significant challenge. While there are numerous strategies to address this skills gap, one promising solution is to expand apprenticeship programs, which provide hands-on, specialized training and offer a pathway to building the workforce of the future.

Registered apprenticeships are a workforce development model that combine classroom instruction with paid, on-the-job training. Apprentices benefit from training while they earn a good wage and work toward gaining a nationally recognized credential verifying their completion of the apprenticeship. It is also common for apprentices to then become full-time employees. Simultaneously, employers gain access to a structured, industry-driven talent development pipeline that provides them with workers who develop in-demand skills as they work.

Apprenticeships are an alternative to other training options such as associate's degree programs or short-term certificate programs, which may lack direct employer ties or guaranteed employment. For employers, apprenticeships build a loyal, skilled workforce tailored to long-term needs, whereas contract staffing agencies offer quick, short-term labor without the same investment or retention benefits.

Although apprenticeships can benefit both job-seekers and employers, they have been historically underutilized in the United States compared to countries like Canada, the United Kingdom, Germany, and Australia.[1] When they are used, the majority of apprenticeships in the United States are heavily concentrated in construction and the skilled trades.[2] This concentration means there is room for growth in other industries that could benefit from an expanded pipeline of workers with hands-on experience.

In recent years, U.S. policymakers have increasingly recognized the potential for apprenticeships to meet workforce needs in other critical industries. The Trump administration emphasized the importance of apprenticeship in an April 2025 executive order, and the Biden administration specifically highlighted biopharmaceutical manufacturing in the Advanced Manufacturing Workforce Sprint in January of 2024.[3]

The biological and pharmaceutical manufacturing industries (biopharmaceutical manufacturing) has unique workforce needs, because the manufacturing process is

technically complex and requires employees to have a working knowledge of STEM fields like biology and chemistry. Biopharmaceutical manufacturing technicians or operators are highly trained to ensure that the final medications are safe and effective. Day-to-day responsibilities vary depending on the specific product but generally include following standard operating procedures to prepare equipment and materials; operate equipment; monitor and document processes; collect, test, and analyze samples; and understand and comply with safety and quality standards.[4] Entry-level workers typically gain these skills through training and certification programs hosted by community colleges or universities, third-party programs, or employer-provided training, often without needing a four-year degree.

Biopharmaceutical manufacturing is an umbrella term we are using here to include two major pharmaceutical production processes: biomanufacturing, which produces desired molecules by programming living cells to produce them, and chemical manufacturing, which uses a series of chemical reactions.

In order to maintain and strengthen the United States' biopharmaceutical manufacturing base, this specialized workforce needs to expand. A number of U.S. policy initiatives have called to increase domestic biopharmaceutical manufacturing to reduce reliance on foreign suppliers, strengthen supply chains for critical products, and prepare for the next generation of new biopharmaceutical products that are expected to come to market.[5] Yet, the current workforce is already straining to meet industry growth.[6]

To learn more about how apprenticeships can contribute to workforce development initiatives, we conducted a case study based on a series of interviews with individuals involved in developing the North Carolina Life Sciences Apprenticeship Consortium (NCLSAC), a new apprenticeship program in North Carolina. Biopharmaceutical manufacturing is a major industry in the state, and the NCLSAC is one example of an initiative to address workforce challenges. It is a consortium-based apprenticeship program that brings together life science companies, academic institutions, and nonprofit organizations.[7]

The NCLSAC was one of a number of initiatives conceptualized, developed, and proposed by the Accelerate NC–Life Sciences Manufacturing coalition, a group of partners led by the North Carolina Biotechnology Center (NCBiotech).[8] NCBiotech is a nonprofit, public-private partnership organization primarily funded by the North

Carolina General Assembly to conduct life sciences economic development and advance statewide academic and industrial biotechnology capabilities.[9] In 2022, the coalition's proposal was awarded $25 million by the U.S. Economic Development Administration's (EDA) Build Back Better Regional Challenge (BBBRC) to strengthen the state's biopharmaceutical manufacturing workforce.[10] The NCLSAC is one of the initiatives in the consortium's action plan and aims to create new career opportunities in the biopharmaceutical manufacturing industry, particularly for individuals from historically underserved populations who have not traditionally been engaged in life sciences manufacturing.[11] As of September 2024, the NCLSAC is two years into its five-year implementation period, includes 14 member companies, and has provided pre-apprenticeship training to 214 participants.[12]

This report presents the findings from our case study of the NCLSAC program. It aimed to assess how apprenticeships can be leveraged for an industry with high workforce technical requirements. Through a series of semi-structured interviews with NCLSAC program developers, we gained insight into the thought processes and lessons learned that came from developing and implementing a new apprenticeship program. At the time that our interviews were conducted, the NCLSAC program was transitioning from the program design phase to the implementation phase and had not yet begun recruiting apprentices. This gave us the unique opportunity to understand program developers' perspectives, reasoning, challenges, and actions from a number of angles at a pivotal period of program creation. These insights can inform efforts in other geographic locations or industries that are looking to create new career pathways for emerging technology fields.

Methodology

We performed seven qualitative, semi-structured interviews to gain insights into the unique challenges and opportunities of biopharmaceutical manufacturing apprenticeships, and then performed thematic analysis to extract and compile themes.* Thematic analysis is a method for examining qualitative data to identify patterns and themes, capturing participants' experiences and insights in a structured way.†

Six of our interviews were conducted with individuals who had or currently have a variety of roles in the NCLSAC program's development. These include individuals responsible for conceptualizing and recruiting companies to join the NCLSAC, proposing and administering the BBBRC funding, facilitating the consortium operations, and leading statewide biopharmaceutical manufacturing workforce development initiatives. The seventh interview was conducted with a former biopharmaceutical manufacturing apprentice to gain insight from a participant's perspective.

Because our interviews were conducted before the NCLSAC program had finished recruiting its first cohort of apprentices, our questions focused on the process of establishing the program, securing funding, and building partnerships. The interview questions broadly explore themes related to the development, implementation, and outcomes of biopharmaceutical manufacturing apprenticeship programs in North Carolina. They cover motivations for program establishment, workforce challenges and industry dynamics, consortium design and industry partnerships, recruitment and outreach strategies, funding mechanisms, program logistics, success metrics, and participant experiences. The focus includes identifying critical knowledge, skills, and abilities for apprentices and administrators, as well as lessons and advice for replicating such programs in other industries or regions.

---

* This study was approved by Georgetown University's Institutional Review Committee (STUDY00006855).

† We engaged in thematic analysis and response coding to analyze these data (as per Charmaz, Kathy, *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*, SAGE, 2006). Throughout the data analysis process, we documented ideas, questions, and comments, and created a master list of themes, which was maintained during the coding process (Corbin, Juliet, and Anselm Strauss, *Basics of Qualitative Research*, SAGE, 2015). Finally, we collaboratively grouped the codes into overarching themes; in cases of discrepancy, we discussed and negotiated until agreement was reached.

Findings and Case Study

Our interviews and background research led us to identify eight overarching insights that will be discussed in this report, grouped into the three general phases of the development cycle: program exploration, design, and implementation.

Program exploration: the process of evaluating workforce needs and resources to decide whether or not to pursue apprenticeships as a workforce development tool. Key elements include:

- Assessing the current state of the workforce, including employer-identified gaps and needs.
- Determining whether an apprenticeship program meets the identified workforce needs.
- Assessing pre-existing resources and stakeholders, then building partnerships.

Program design: the decisions and actions to build an apprenticeship program. Key elements include:

- Choosing an apprenticeship program model and organizational structure.
- Integrating industry needs and feedback into program and curriculum design.
- Deciding whether to include a pre-apprenticeship program.

Program implementation: the steps to administer and carry out the program. Key elements include:

- Coordinating company logistics.
- Conducting extensive outreach.

Notably, we observed that the underlying themes within the eight key takeaways are not specific to the technical particulars of biopharmaceutical manufacturing. Rather, they contain generalizable insights that could be extended to the process of developing an apprenticeship program more broadly. For this reason, this report presents each key takeaway in two parts: an initial summary of the NCLSAC case study, followed by a description of the broader impact and corresponding suggestions for future program development.

Program Exploration

The process of evaluating workforce needs and resources to decide whether or not to pursue apprenticeships as a workforce development tool.

1. Assess the Current State of the Workforce

NCLSAC Case Study: NCLSAC interviewees explained that having high-quality data on biopharmaceutical manufacturing workforce dynamics ultimately motivated their decision to pursue new workforce development opportunities. Their efforts were built on a documented need to expand the biopharmaceutical manufacturing workforce, and designed to address specific gaps in the workforce development pipeline. These insights came from both NCBiotech's close relationship with industry and training partners, and from a workforce study conducted by NCBiotech in collaboration with other statewide organizations.[13] Their assessment of industry growth versus training capacity revealed that workforce demand would likely outpace supply in the near future, necessitating concerted efforts to recruit more potential employees.

> *"We sort of hit an inflection point where the number of new jobs were growing faster than we could keep up with on the workforce side."*
>
> *- NCLSAC Interviewee*

Interviewees explained that they designed the apprenticeship program to reach historically overlooked populations to meet growing workforce demand. More specifically, the program focused on underserved populations, such as individuals without bachelor's degrees who have been left out of traditional workforce pipelines. Interviewees identified two categories of barriers that prevent this population from participating in the biopharmaceutical manufacturing industry: a lack of awareness and a lack of access.

Program designers learned that job-seekers were either *unaware* of the industry as a whole, career paths within the industry, or training opportunities, or *unable to access* opportunities due to a lack of available training, the cost of training and certification programs, or the opportunity cost of giving up their current job to complete training.

The Bigger Picture: Responses from our case study indicate the importance of real-world workforce data to better understand whether more workers are actually needed, and if so, the specific roles and quantities required. Additionally, information about current gaps in workforce pipelines can help future initiatives in targeting the underlying problems that are hindering growth.

Before considering any workforce development initiatives, including apprenticeships, companies and stakeholders should conduct a thorough assessment of the current workforce dynamics within their industry. To begin, stakeholders should identify key employers in the targeted industry within their geographic area and assess the scale and type of workforce that local employers are looking for. Key features to note include the size, talent needs and pool, and market power of these employers. Program developers can inform their assessment by searching for local stakeholders who can provide insights into the current workforce challenges and needs.* Start dialogues with stakeholders by asking:

- What are the current workforce gaps in terms of roles and numbers?
- What roles are hardest to fill, and what specific skills are most in demand?
- What kind of background and level of training are employers looking for?
- What are the future workforce projections based on industry growth trends?
- Are current talent recruitment pipelines expected to meet demand? If not, what is the projected shortfall?

Conducting this comprehensive assessment through industry surveys, direct consultations, and partnerships will help make workforce development efforts well-informed, targeted, and effective.

2. Determine If Apprenticeships Could Meet Identified Workforce Needs

NCLSAC Case Study: Apprenticeships within the NCLSAC are for "manufacturing technician" roles at biopharmaceutical manufacturing facilities.† Interviewees explained that this role has many characteristics that make it a good fit for an apprenticeship program. One factor is that this role does not require a college degree, and the necessary skills can be acquired within the timeframe of the pre-apprenticeship and

---

* Local stakeholders can include industry leaders, HR professionals, regional business associations, workforce development boards, and economic development organizations.

† Also called "manufacturing operator" or "manufacturing associate."

apprenticeship through hands-on experience and related technical instruction (RTI). In addition, the basic responsibilities of the role itself and the skills that employers desire—such as following a standard operating procedure or working in a clean room—are relatively similar and well-defined across the industry. This meant that the NCLSAC could streamline its recruitment and pre-apprenticeship training to be relevant to any of the consortium's participating employers.

The Bigger Picture: Once a firm, or a consortium of firms, has identified their workforce needs, they can use that information to evaluate whether apprenticeships are an appropriate solution. While apprenticeships are effective in many situations, they are not the right workforce development tool for every type of job. Determining whether apprenticeships are the right option for a given industry and role hinges on a number of factors.

Parties considering an apprenticeship should determine whether the targeted role is already registered with the Department of Labor's Office of Apprenticeship by consulting its list of vetted and approved occupations. If a previously registered occupation fits the role of interest, even with slight modifications, the process is comparatively straightforward. By definition, the existence of the occupation on the DOL's list also indicates that the work role is suitable for an apprenticeship.

If the work role does not fit a previously registered occupation, the registration process will require significantly more time and money. The process of registering a new occupation requires knowledge of regulatory and compliance requirements, identification or creation of an occupational description, and development of a work process schedule and RTI instruction outline.

- A **work process schedule** is a detailed document outlining the specific skills, tasks, and competencies an apprentice is expected to learn and perform during the apprenticeship, as well as the time allocated for mastering each component. It serves as a structured framework to ensure consistent and comprehensive on-the-job training aligned with industry standards.
- **Related technical instruction (RTI)** is structured, classroom-based or online learning that accompanies on-the-job training and provides theoretical knowledge and technical skills to the apprentice. RTI may be provided at

community colleges, technical schools, online, or in some cases through the employer, and typically accounts for at least 144 hours of instruction per year.*

Resources from the federal Office of Apprenticeship (ApprenticeshipUSA toolkit), the Registered Apprenticeship Occupations and Standards Center of Excellence, and state apprenticeship agencies offer guidance for employers and other partners seeking to register an apprenticeship program.[14] Industry intermediaries (organizations explicitly created to guide employers through the process) are another valuable tool. Finally, educational institutions and training providers, workforce development boards, industry associations, and other similar stakeholders often have experience with the registered apprenticeship system and can offer guidance.

Deciding whether to register a new occupation also includes separate considerations. Does the role require practical knowledge suitable for on-the-job training, where apprentices can progressively develop competencies through practice and supplemental classroom instruction? Apprenticeships are most effective for work roles that require these task- and role-specific competencies.

Are there state and federal funding opportunities? Creating and registering a new occupation requires additional upfront investment in time and money. These costs can potentially be offset by state and federal programs, and initial costs should be recouped over time.

Are there existing curricula that adequately teach the necessary theoretical and background knowledge necessary for the role? If no such adaptable curricula exist, the coursework will need to be developed and approved.

3. Assess Pre-Existing Resources and Stakeholders, Then Build Partnerships

NCLSAC Case Study: A common theme among interviewees was that NCBiotech has an established reputation as a "connector" between relevant groups, including community colleges, industry, and state and regional economic development groups. Program organizers could draw on the organization's name recognition and relationships, experience with other workforce development programs, existing network of community colleges in multiple regions, and knowledge of North Carolina's biopharmaceutical manufacturing industry. Similarly, the program benefited from being

* Apprenticeships may be time-based, competency-based, or hybrid models; in competency models, apprentices may test out of their RTI before reaching 144 hours of instruction.

able to use an existing training program, BioWork, as a pre-apprenticeship to provide foundational instructional material.

BioWork is a certificate program that prepares participants for employment as a process technician for a biotechnology, pharmaceutical, or chemical manufacturing company. Participants learn industry-relevant skills like how to follow Current Good Manufacturing Practices (cGMP), operate process equipment, work aseptically in specialized conditions, and become familiar with a range of common chemical and biological processes.[15] Interviewees noted that, since the BioWork certificate was already established and offered at community colleges and recognized and accepted by the state's employers, they did not have to use valuable resources developing a new, bespoke training program.

In addition to existing resources, interviewees noted that gaining buy-in from key partners was essential to getting the apprenticeship program off the ground. In order for a group-led consortium to be successful, enough companies had to agree to participate to sustain the consortium. In addition to demonstrating long-term sustainability, it was essential for founding member companies to submit signed financial letters of support to meet the cost-matching requirement when applying for EDA funding.

Interviewees emphasized two factors that helped to achieve this level of buy-in: pre-existing relationships and clearly demonstrating the programmatic value to companies. Many of the individuals on the organizing team have developed these professional relationships across the industry during long careers in biopharmaceutical manufacturing. Because of these established relationships, decision-makers at participating member companies who knew the organizers were more likely to trust and believe in their vision. In some cases, these individuals became champions for the consortium and pushed to get their organizations involved. Secondly, interviewees highlighted the importance of identifying the key selling points that would appeal to employers. Key factors included streamlining the administrative and bureaucratic process for individual companies, increasing the combined impact of outreach and

> *"You have to really know what the value proposition is to companies and really convince them of that. But again, it's having one or two champions within the major employers that are like, 'Yes, this is important, we believe in it, we're gonna make this happen.' And that's all relationship building."*
>
> *- NCLSAC Interviewee*

marketing, and expanding the pipeline for employers who need a qualified workforce.

The Bigger Picture: The NCLSAC example demonstrates that collaboration is critical for success, and that achieving it may require additional steps. On the one hand, a network of pre-existing resources and partnerships meant that the initiative did not have to build a support system from scratch. On the other hand, integrating diverse needs and perspectives meant that the group had to invest time and effort in managing relationships between multiple stakeholders.

Apprenticeship initiatives exist at the intersection of industry, economic and workforce development, and education. Effective apprenticeship programs require the involvement and collaboration of multiple stakeholders from these fields.[16] By first assessing the existing funding sources and stakeholder ecosystem, organizations can identify key partners and build the necessary connections to ensure the program's success. This approach aligns the training with industry needs and leverages the strengths and expertise of each participant, creating a robust framework for developing skilled workers. Through strategic partnerships, apprenticeships can be tailored to meet local economic demands, provide relevant educational experiences, and foster sustainable career pathways for participants.

More specifically, employers or other organizations interested in the apprenticeship model—including apprenticeship intermediaries, economic development organizations, or workforce development boards—must consider specific questions before standing up a program. Does the employer interested in standing up a program have the in-house knowledge and expertise to do so? Are there other local employers, apprenticeship intermediaries, economic development organizations, and/or workforce development boards that have experience creating or helping to create an apprenticeship program in your industry?

Alternatively, policymakers or other organizations may be interested in supporting, facilitating, or creating an apprenticeship program as a workforce development initiative or to help grow a specific industry. In such cases, are there sufficient employers with workforce needs that could be filled by apprentices?

Another resource to evaluate is the existence and capacity of educational and training services. This can involve mapping out whether local colleges, universities, vocational schools, and other training organizations offer programs relevant to the industry. Alternatively, programs can explore whether online educational resources could provide necessary training, with the additional potential benefit of reducing costs and expanding access. Key questions to consider are:

- Do these institutions currently offer programs that align with industry needs?
- Are there gaps in the training provided that need to be addressed?
- Could these institutions expand or adapt their programs with additional support to better meet industry needs?

If sufficient educational and training infrastructure does not already exist, stakeholders need to assess other options, like designing new curriculum or exploring whether employers within the industry can provide the necessary technical instruction themselves. This requires evaluating internal resources such as training facilities, expertise among staff, and the ability to develop and deliver training programs.

The final resource to understand is funding sources. Creating an apprenticeship program costs money upfront, and it needs more money to maintain it over time. It is important to consider funding for both initial costs and long-term sustainment. Relying on a single source of funds, whether it is one company's own money or a single grant from an outside organization, creates financial vulnerability if the source of funding is reduced or lost. Multiple funding sources also increase the sustainability and scalability of programs in the long run.

Because of the benefit of multiple funding streams for a new program, organizations should review federal, state, and local funding opportunities applicable to their program. They could also work directly with their local American Job Center and workforce development board to gain access to Workforce Innovation and Opportunity Act (WIOA) funds.[17] Another route is to work with other employers and stakeholders on cost-sharing agreements. Finally, many philanthropic organizations can serve as an additional source of money.

Program Design

The decisions and actions to build an apprenticeship program.

4. Choose an Apprenticeship Program Model and Organizational Structure

NCLSAC Case Study: The NCLSAC is organized as a consortium in which each member company individually develops their own apprenticeship program and registers it with ApprenticeshipNC, North Carolina's state apprenticeship agency.[18] While each company still registers their apprenticeship individually, the goal of the consortium is to make the process easier by standardizing the format, creating centralized resource materials, and hiring a program administrator who coordinates logistics.

According to the program organizers, another benefit to the consortium was that the "strength in numbers" aspect could reduce administrative burdens for individual companies and maximize outreach and marketing efforts. For example, companies can reduce the time, effort, and money spent to recruit apprentices by having a unified outreach effort for the consortium at a career fair.

"So there were a lot of decent reasons to get involved with the consortium rather than do it yourself. Probably the only other option [for some companies] would be to not do apprenticeships."

- NCLSAC Interviewee

Forming a consortium was largely possible because member companies had similar production processes, allowing them to standardize apprenticeship design, pre-apprenticeship requirements, and marketing and recruitment materials. Interviewees also explained that the consortium model was a natural fit for the EDA BBBRC funding opportunity that NCBiotech was pursuing, and that it was feasible because NCBiotech already existed as a convening group that sat between industry, workforce development, training, community college, and outreach groups.

The Bigger Picture: While the interviewees in our case study chose to organize the NCLSAC as a consortium, it is not the only structure they could have selected. There are three broad types of apprenticeship models: employer-sponsored, employer

partnership with an intermediary, and consortium-based.* Stakeholders interested in beginning or leveraging an apprenticeship program must identify what type of apprenticeship model best suits their needs and strengths.

Employer sponsored:

In an employer-sponsored apprenticeship, the employer designs, registers, and oversees the full program. This includes recruiting and employing apprentices, providing the related-technical instruction or partnering with an education provider to do so, and fulfilling all regulatory compliance measures.

- PROS: full oversight of the program design allowing for alignment with business goals and specific workflow needs, integration into company culture and processes, direct feedback loop for continuous improvement.
- CONS: significant investment in time, money, and administrative effort, requires expertise in educational design, regulatory compliance, and training practices (lessened if role is comparable to a previously registered occupation with DOL as mentioned earlier), and the cost of startup, maintenance, and improvement might be difficult to scale for smaller firms.

Employer partnership with intermediary:

Alternatively, employers could partner with an intermediary to simplify the process. Intermediary organizations can be non-profit companies, industry associations, community colleges, labor unions, or other similar organizations. They often have experience with federal and state apprenticeship systems and can provide support throughout the process.

* These are broadly defined as an introduction to different program models for the purposes of this paper. For a more detailed overview, see Alexandria M. Wright, "Best Practices: Workforce Systems," Working Paper, Economic Development Collaborative, October 2019, https://edcollaborative.com/wp-content/uploads/2020/03/EDC-Workforce-Systems-Best-Practices-Apprenticeships-2019.pdf.

- PROS: Effective intermediary organizations have experience and expertise in designing and managing quality apprenticeship programs, will handle administrative and reporting requirements, often have access to established networks of stakeholders, and in some cases require no direct cost to the employer.
- CONS: Intermediary organizations may have less familiarity with the specific company workflow and culture, resulting in a less tailored program, and employers may have to pay intermediaries for their services.

Consortium:

Finally, employers can partner with other companies in their industry to form an apprenticeship consortium. A consortium may register the apprenticeship jointly, one company may lead registration, it could use an intermediary organization, or each company could register their own programs, as in the case of the NCLSAC.

- PROS: Resource-sharing including cost, lessons learned, and existing best practices helps create an economy of scale for a resilient program and increases networking opportunities for apprentices and educational institutions.
- CONS: Standardization across multiple companies can limit customization for each employer, the decision-making process can be slow and complex, and differing priorities and objectives may result in misalignment.

Choosing the right model for an apprenticeship program depends on the specific needs, resources, and goals of the employer. Creating an in-house program offers maximum control and customization but requires significant resources and expertise. Partnering with an intermediary can provide valuable support and expertise but may come at a higher cost and with less control. Joining a consortium allows for resource-sharing and collaborative learning but may limit customization and slow the decision-making processes. Each option has its own set of trade-offs, and the best choice will depend on the employer's specific circumstances and strategic priorities.

5. Integrate Industry Needs and Feedback

NCLSAC Case Study: Interviewees explained that it was important to incorporate industry input and feedback into the NCLSAC's program design to avoid building a resource that employers can't or won't use. Program designers held conversations with industry representatives early on to get a sense of what their actual needs were, and whether the proposed program would work for both parties. Interviewees point to the BioWork certification as an example of this principle. Because the training program was designed in collaboration with industry partners in the region, it is well-accepted by employers and meets their stated needs and skills for a biopharmaceutical manufacturing workforce.

"I think having industry at the table for the last 20 years has helped to make sure that everything we do is actually useful for companies. And so, when you're building something new like this, having companies involved from the very beginning is helpful."

- NCLSAC Interviewee

The Bigger Picture: Registered apprenticeships are most effective when the classroom instruction and on-the-job training are directly aligned with the workforce needs of employers. These needs can and do shift over time. Communication and collaboration between training providers and industry to ensure the program remains relevant is important for a sustainable and effective development program.

6. Decide Whether to Include a Pre-Apprenticeship

NCLSAC Case Study: Participants in the NCLSAC program are required to complete the BioWork certification program before beginning their apprenticeships. NCLSAC interviewees cited a number of reasons for choosing to include a pre-apprenticeship component in the program.

The most cited reason is that the pre-apprenticeship serves as a foundational step to prepare participants for success by equipping them with basic knowledge and skills relevant to the industry. BioWork provides standardized hands-on and classroom education that ensures participants meet a baseline level of competence, such as understanding clean room protocols or standard operating procedures, before entering the more specialized and employer-specific apprenticeship phase. This was echoed by a former biopharmaceutical manufacturing apprentice, who explained that she felt she was able to grasp certain processes faster during her apprenticeship because of her

prior BioWork coursework. Separating pre-apprenticeship from the apprenticeship allows employers to focus their resources on advanced, on-the-job training and RTI while ensuring a consistent level of preparedness across participants, reducing onboarding time and increasing the likelihood of success within the apprenticeship.

The NCLSAC organizers ultimately decided to provide the BioWork certification to more individuals than there were apprenticeship slots to account for participants who decide not to pursue an apprenticeship after completing the pre-apprenticeship. They described two reasons that a participant may make this decision. The first is that by incorporating hands-on training, the BioWork pre-apprenticeship shows participants what a "day in the life" in the industry looks like before they commit to an apprenticeship or career. This allows potential job-seekers to make an informed decision about whether the industry is a good fit for them, especially given that some participants may realize they dislike certain elements of the role, such as wearing protective equipment or working with chemicals. Allowing these individuals to "filter themselves out" earlier in the process, before investing multiple years in the apprenticeship itself, is beneficial to both the participant and the employer. The second is that some participants may decide to apply for an entry-level job after completing the pre-apprenticeship rather than pursuing the apprenticeship. Completing BioWork gives individuals the relevant skills and competencies to directly apply for a job at a biopharmaceutical manufacturing company, meaning that including the pre-apprenticeship training alone can grow the workforce regardless of whether the participant goes on to complete the full apprenticeship.

The Bigger Picture: Pre-apprenticeship programs are meant to prepare individuals whose skills and competencies fall just short of those needed to enter a registered apprenticeship. They are optional add-ons, are less uniform than registered apprenticeship programs, and vary in program design and duration. Some programs choose to incorporate pre-apprenticeships because they can help prepare participants for their apprenticeship through industry-specific education and training, a direct pipeline to a registered apprenticeship program, career counseling, and the opportunity to earn a credential upon completion. Effective programs often provide stipends or wages and simulate the work done in the target industry.[19]

Among other benefits, the Employment and Training Administration (ETA) has emphasized that pre-apprenticeships help students "gain industry exposure and proficiency in basic work readiness" and are an effective way to increase subsequent access to apprenticeship programs for underserved populations.[20] They also serve as a pipeline for a program sponsor's full apprenticeship program, and can increase brand awareness and reputation among potential employees.

If an acceptable pre-apprenticeship program does not already exist, creating one will require additional investment in terms of time, money, and personnel. Additionally, not every participant in the program will continue on to a full apprenticeship, and there is also the risk that participants who complete the program may pursue opportunities at a different organization.

Some apprenticeable work roles are more amenable to a pre-apprenticeship program than others. This includes roles that require specific knowledge or certification that can be learned or earned in a relatively short period of time. An example would be a program available to high school seniors, who can earn the credential in their last year of high school and immediately transition into work-based learning upon graduation.

Program Implementation

The steps to administer and carry out the program.

7. Coordinate Company Operations

NCLSAC Case Study: Given that the NCLSAC is a consortium of multiple companies, the program organizers expressed that it was more challenging than they had anticipated to navigate company logistics and identify the right company representative to participate at different phases during consortium development. Even if companies are willing and on board to participate, buy-in alone is not enough if the company does not have the personnel or internal structure to effectively execute the new program. Interviewees noted that the rapid growth within North Carolina's biopharmaceutical manufacturing industry meant that internal HR and recruitment personnel were already overwhelmed with existing efforts to expand their workforces. If there is not a dedicated individual to handle the logistics that an apprenticeship program requires, then the initiative could get "lost in the shuffle."

In addition to the workload that an apprenticeship program can create for a company, there was also the challenge of identifying the right individual to attend consortium meetings and act as their company's representative. In the early stages of program conceptualization, the company participants had to be relatively high-ranking individuals with the authority to sign off on the initiative and commit funding. As the consortium progressed to implementation phases, company representatives needed detailed knowledge of their company's inner workings and specific workforce needs in order to contribute to specific elements of the apprenticeship, handle bureaucratic internal processes, and register the apprenticeships with the state board.

The Bigger Picture: Regardless of whether a company develops its own apprenticeship program or partners with an intermediary or consortium, the NCLSAC case study highlights the importance of identifying and engaging the right internal employees to lead and engage in program development.

Selecting who to lead the effort internally can make or break the program's success. The "right" individual(s) needs to be sufficiently senior, or have a direct line to senior management, in order to have decision-making power and organizational buy-in. Yet, if this individual is too high up in the organization, they might not have sufficient subject matter expertise or time to devote to it. If they are too junior, they may not have the ability to make decisions, speak with authority, or actualize plans.

The end-to-end implementation of an apprenticeship program requires different individuals to be involved at different stages. For example, companies may have different individuals whose roles make them best suited to:

- approve the decision to fund an apprenticeship program
- register apprenticeships with the U.S. Department of Labor or state apprenticeship agency
- engage with external partners during the outreach process
- train and oversee apprentices in their day-to-day work

Deciding when to bring each of these individuals on board, and how to keep them coordinated throughout the process, is critical to the program's success. Organizations that choose to work with an intermediary or join a consortium, rather than develop their own program, must also maintain strong connections to ensure that internal and external partners are on the same page.

Companies must also identify and make available suitable mentors for apprentices to guide them through the on-the-job training. Mentors not only teach practical skills and everyday tasks, but they also help apprentices integrate into the company culture and learn soft skills. Furthermore, mentors can help apprentices with their personal and professional development.[21]

8. Conduct Extensive Recruitment and Outreach

NCLSAC Case Study: According to interviewees, the success of the NCLSAC depends on its ability to reach prospective apprentices. Regardless of how well the program itself is designed, it will only meet workforce needs if individuals hear about it and apply. Interviewees explained that the initiative had to include a "full package" of outreach approaches, especially given the goal of reaching and attracting new communities that have not traditionally been involved in the biopharmaceutical manufacturing industry.

This group chose to address this challenge by incorporating broader community engagement initiatives into its BBBRC funding proposal. One such initiative was the creation of the Life Sciences Manufacturing Ambassador program, designed to spread awareness of the entire industry and job opportunities within North Carolina. Ambassadors are community members who share resources about the biopharmaceutical manufacturing industry and career and training opportunities in their communities.[22] Interviewees explained that the goal of raising awareness among community leaders was to empower them to share that information with their

communities in a more “people-centric conversation approach” than traditional marketing efforts. The community engagement efforts were also designed to reach high school students through their schools by holding information nights and including teachers and guidance counselors in the ambassador program.

Interviewees added that the apprenticeship program’s marketing and outreach efforts could be potentially beneficial for the workforce at large. A student, parent, or community member who is more informed about the biopharmaceutical manufacturing industry in their region may choose to pursue career opportunities within the industry, even if they decide that an apprenticeship is not the right fit for them.

The Bigger Picture: Outreach and marketing efforts are a core component of a successful apprenticeship program. Even the best-designed apprenticeship program will be ineffective if potential apprentices are unaware of it—especially if the goal is to reach new populations that have not previously been engaged in the industry’s workforce pipeline.

The first step for effective outreach is to identify the target audience that the messaging is intended to reach. Who is the program designed to recruit, and where are these individuals now? The answers to these questions can inform a more specific approach by tailoring the method and content of outreach efforts.

The next step is to assess whether there are existing platforms, resources, or lines of communication to reach the intended audience of potential apprentices. For example, an apprenticeship program may be able to conduct outreach through forums like high school career counseling offices, community organizations, and local career centers.

Finally, it should be logistically simple for potential apprentices to learn more about, and enroll in, the program. Interested potential apprentices may drop out of the recruitment pipeline if the process is overly burdensome, disorganized, or unclear. One possible solution is to set up a streamlined and user-friendly online hub with all of the relevant information and an embedded sign-up form.

Apprentice Perspective

In addition to interviewing NCLSAC coordinators to learn about the program's conceptualization, planning, and implementation, we also interviewed a former biopharmaceutical manufacturing apprentice to learn what makes an apprenticeship program successful from a participant's perspective. Because we conducted interviews before the NCLSAC began recruiting apprentices, this individual participated in a company-led apprenticeship at a North Carolina biopharmaceutical manufacturing facility—not one developed through the NCLSAC consortium. As a result, these findings give us big-picture insights into an apprentice's experience rather than specific insight into the NCLSAC program. We used these insights to identify the following generalizable key takeaways about factors that contribute to an apprenticeship program's success:

- The apprenticeship was the former apprentice's entry point into the industry because she had not previously been aware of biopharmaceutical manufacturing. For her, the apprenticeship opened up a new career path. She reflected that, "I want my people to have different jobs than just what our parents do. [...] I want other first-generation students to know that this is something we can do, because it's not something that we get told that we can do."
- The BioWork training, which the NCLSAC includes as a pre-apprenticeship, helped her to better understand her work on the manufacturing floor, noting that "once I started working, a lot of the stuff that we went over in the class made so much more sense...I think it did help me kind of grasp everything a little bit faster."
- The former apprentice explained what types of programmatic support would be helpful during the apprenticeship. In her opinion, apprentices need centralized and standardized guidance, clear expectations and communication, and a contact to turn to with questions. She also noted that since apprentices are brand-new to the industry, mentorship that gives participants somewhere to turn for career and industry advice would be a valuable addition.
- Finally, the former apprentice explained that an apprenticeship program needs to offer additional value over that of a full-time job in order to retain participants. In her experience, she ended her apprenticeship early and transitioned to a full-time job at the same company because she reached a point when she could make more money doing the same job than she did as an apprentice. She explained that her managers supported her decision and still saw her apprenticeship as a success because the company ultimately gained a

trained and skilled employee. In her opinion, she would have needed the apprenticeship to offer her something that she couldn't gain otherwise in order to continue, like the ability to move through different job roles to try them out.

Zooming Out

Our case study of the NCLSAC apprenticeship program demonstrates a range of factors to consider when deciding whether and how to implement an apprenticeship program. For North Carolina's biopharmaceutical manufacturing industry, apprenticeships are a tool with the potential to introduce participants to new career pathways. At the same time, conceptualizing and implementing the program raised unexpected challenges and led to lessons learned.

Some of these insights may be beneficial to companies in other geographic locations or to emerging technology industries that are considering whether to leverage apprenticeships for workforce development. Importantly, there is no one-size-fits-all approach because each field and region has its own unique set of considerations, resources, and challenges. However, our case study revealed a set of generalizable considerations that can help a company decide whether apprenticeships are the appropriate workforce tool and how to implement them most successfully.

It is also useful to note factors that are unique to the NCLSAC and may not apply in other cases. For example, a common thread that arose in our interviews was that the NCLSAC benefited from being built on a platform of pre-existing resources and infrastructure. The program was able to leverage existing certificates and training curricula, led by a convening organization with deep industry insight and networks. Emerging industries, or those relying on nascent technologies or based in less-developed geographical areas, may face additional challenges. Workforce development efforts, including the creation of apprenticeship programs, could be aided by additional resources to build the connective infrastructure.

Finally, this case study was conducted during the NCLSAC program's early implementation phase and therefore does not examine challenges related to long-term sustainment or post-apprenticeship outcomes. Individuals setting up an apprenticeship program will also need to consider factors like securing long-term funding once initial financial commitments expire, wage competition and apprentice retention, and maintaining employer participation as economic conditions fluctuate. While these and other future considerations were beyond the scope of our study, they are critical to long-term success. It may be useful to examine how similar programs in other regions have addressed these aspects—for example, apprenticeship initiatives from Massachusetts' MassBioEd or BioFabUSA, a Department of Defense-sponsored Manufacturing Innovation Institute.[23]

We suggest that any company or initiative that is considering setting up an apprenticeship program use the following guiding questions, informed by our case study of the NCLSAC.

Guiding Questions Before Starting an Apprenticeship Program

Program Exploration:

- **Assess the current state of the workforce.**
  - What are the current workforce gaps in terms of roles and numbers?
  - What roles are hardest to fill, and what specific skills are most in demand?
  - What are the future workforce projections based on industry growth trends?
  - Are current talent recruitment pipelines expected to meet demand? If not, what is the projected shortfall?
- **Assess whether apprenticeships meet the identified workforce needs.**
  - Do the target roles require a 4-year degree?
  - Can the target roles accommodate a hands-on learning approach alongside classroom instruction?
  - Are there suitable training providers in the region, and do they have the capacity to host an apprenticeship program?
  - Are resources available (from diverse sources) for the upfront investment and continued support needed to sustain an apprenticeship program?
  - Does the industry already have occupations registered with the Department of Labor's Office of Apprenticeship? Are those registered occupations suitable for the in-demand roles?
  - If not, do targeted occupations have existing, industry-recognized credentials?
- **Assess the pre-existing resources and build partnerships.**
  - What existing training programs or certifications could serve as a foundation for apprenticeships?
  - What are the state, local, industry, and nonprofit entities that could contribute to the program?
  - Do relationships already exist with relevant partners?
  - Are there existing outreach programs, community organizations, or other resources to help reach the group you're targeting?
  - What is the value to the community, the employers, and the workforce at-large? How can you best convey that value to stakeholders?
  - Are there funding sources that could offset program costs and improve sustainability?

Program Design:

- **Choose an apprenticeship program model and organizational structure.**
  - What type of apprenticeship model best suits the organization's needs?
  - Are there enough local employers with similar workforce needs to sustain a consortium? If so, how standardized are the roles that they would be filling?
  - Does your company have the resources to develop and register an apprenticeship program from scratch?
  - Are there apprenticeship intermediaries with experience in the target industry?
- **Integrate industry needs and feedback.**
  - How will the program ensure that classroom and on-the-job training align with industry standards?
  - What mechanisms will be in place to incorporate employer feedback into the curriculum?
- **Decide whether to include a pre-apprenticeship.**
  - Is there a need for a pre-apprenticeship program to prepare candidates?
  - Does an adequate training program already exist?
  - What would it cost to create a training program?
  - What does an individual need to know before starting an apprenticeship? Is there a "baseline" of skills or knowledge that would apply to multiple companies within the industry?

Program Implementation:

- **Coordinate company operations.**
  - Who within the company (or companies) needs to be involved? What level of authority, subject matter expertise, and seniority should they have?
  - Who is best suited to plan and oversee the conceptualization phase, implementation phase, and day-to-day apprenticeship management phase? Are they the same, or will different individuals or parts of the company need to be involved at different stages?
  - Are there existing employees available and willing to mentor incoming apprentices?
- **Conduct extensive recruitment and outreach.**
  - Who is the program designed to recruit, and where are these individuals now?
  - How will potential apprentices hear about the program?
  - How can the value of an apprenticeship be marketed to potential participants?

Authors

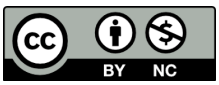
Luke Koslosky is a senior research analyst at CSET, where he focuses on workforce policy with an emphasis on increasing access to AI careers through alternative training pathways.

Steph Batalis is a research fellow at CSET, where her work examines a number of issues at the intersection of AI and the life sciences, including how emerging technologies will impact both biomedical innovation and U.S. biosecurity.

Ronnie Kinoshita is the deputy director of data science and research at CSET.

Acknowledgments

The authors are grateful to Biak Tial, Nina Yu, and Karla Talanian for their feedback on this report. For additional comments and assistance, the authors would like to thank Matthias Oschinski, Vikram Venkatram, Mia Hoffmann, Owen Daniels, Igor Mikolic-Torreira, Shelton Fitch, and Matt Mahoney. Finally, the authors would like to thank research assistant Cherry Wu for her contributions to this report.



Document Identifier: doi: 10.51593/20230054

Endnotes

[1] Robert I. Lerman, "Proposal 7: Expanding Apprenticeship Opportunities in the United States," Policies to Address Poverty in America, The Hamilton Project | Brookings, June 19, 2014, https://www.hamiltonproject.org/assets/legacy/files/downloads_and_links/expand_apprenticeship_opportunities_united_states_lerman.pdf.

[2] Construction-related occupations accounted for about two-thirds of apprentices in 2021. For more information see: Robert I. Lerman, "The State of Apprenticeship in the US: A Plan for Scale," Apprenticeships for America, July, 2022, https://dls.maryland.gov/pubs/prod/NoPblTabMtg/AppCmsn2023/State-of-Apprenticeships-in-the-United-States.pdf.

[3] "FACT SHEET: President Donald J. Trump Modernizes American Workforce Programs for the High-Paying Skilled Trade Jobs of the Future" (Washington, DC: The White House, April 25,2024), https://www.whitehouse.gov/fact-sheets/2025/04/fact-sheet-president-donald-j-trump-modernizes-american-workforce-programs-for-the-high-paying-skilled-trade-jobs-of-the-future/; "FACT SHEET: Biden-Harris Administration Highlights New Commitments Toward Equitable Workforce Development in Advanced Manufacturing" (Washington, DC: The White House, January 23, 2024), https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2024/01/23/fact-sheet-biden-harris-administration-highlights-new-commitments-toward-equitable-workforce-development-in-advanced-manufacturing/.

[4] Bio Jobs Hub, "Manufacturing Associate | Biotech Career Blueprint," January 6, 2022, https://biojobshub.wraltechwire.com/manufacturing-associate/.

[5] National Security Commission on Emerging Biotechnology, Interim Report, December 2023, https://www.biotech.senate.gov/press-releases/interim-report/; "Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy" (Washington, DC: The White House, September 12, 2022), https://bidenwhitehouse.archives.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/.

[6] John Balchunas, Jim DeKloe, Jenny Ligon et al., "Innovation of the Biopharmaceutical Manufacturing Talent Pipeline" (The National Institute for Innovation in Manufacturing Biopharmaceuticals, October 2022),https://www.niimbl.org/wpcontent/uploads/2024/01/Downloads/Innovation_of_the_Biopharmaceutical_Manufacturing_Talent_Pipeline_Oct2022.pdf; Office of Science and Technology Policy, "Building the Bioworkforce of the Future" (Washington, DC: The White House, June 2023), https://bidenwhitehouse.archives.gov/wp-content/uploads/2023/06/Building-the-Bioworkforce-of-the-Future.pdf.

[7] "Consortium Seeks to Build Life Sciences Talent Pipeline" (North Carolina Biotechnology Center accessed April 22, 2025), https://www.ncbiotech.org/apprenticeship-consortium-recruitment.

[8] "Build Back Better Award Fuels North Carolina's Life Sciences Manufacturing Talent Pipeline" (North Carolina Biotechnology Center, accessed April 22, 2025), https://www.ncbiotech.org/accelerateNC.

[9] "Our Mission" (North Carolina Biotechnology Center, accessed April 22, 2025), https://www.ncbiotech.org/transforming-life-sciences/about-us.

[10] "Accelerate NC - Life Sciences Manufacturing" (U.S. Economic Development Administration, accessed April 22, 2025), https://www.eda.gov/funding/programs/american-rescue-plan/build-back-better/finalists/north-carolina-biotechnology-center.

[11] "Build Back Better Award Fuels North Carolina's Life Sciences Manufacturing Talent Pipeline" (North Carolina Biotechnology Center, accessed April 22, 2025), https://www.ncbiotech.org/accelerateNC.

[12] "Accelerate NC - Life Sciences Manufacturing" (U.S. Economic Development Administration, accessed April 22, 2025), https://www.eda.gov/funding/programs/american-rescue-plan/build-back-better/finalists/north-carolina-biotechnology-center.

[13] NCBiotech, in collaboration with other statewide organizations, conducts a regular assessment to predict industry growth by combining historical and projected expansion and relocation announcements with surveys of existing NC sites. For more, see: "Window on the Workplace 2023" (North Carolina Biotechnology Center, December 2023), https://www.ncbiotech.org/sites/default/files/2023-12/WoW%20Report%202023%20%2822-145_LSED%29%20SINGLE%20PAGE%20FINAL_0.pdf.

[14] The Urban Institute, in collaboration with the Department of Labor, has created National Occupational Frameworks, organized by industry and sector, that provide occupational overviews, work process schedule outlining on the job learning, and recommend coursework for related technical instruction for employers and partners to use when standing up an apprenticeship program. For more, see the National Apprenticeship Resource Hub: https://apprenticeships.urban.org/.

[15] "BioWork" (NCBioNetwork, March 7, 2023), https://www.ncbionetwork.org/biowork.

[16] For a comprehensive description of different stakeholders, their strengths, and ways to facilitate collaboration, see: "Registered Apprenticeship Reimagined: Lessons Learned from the American Apprenticeship Initiative," National Governors Association, November 2020, https://www.nga.org/wp-content/uploads/2020/11/NGA_AAI_Report.pdf.

[17] For more information on braiding funds and functions with WIOA partners, see: Alexandria M. Wright, "Best Practices: Workforce Systems," Working Paper, Economic Development Collaborative, October 2019, https://edcollaborative.com/wp-content/uploads/2020/03/EDC-Workforce-Systems-Best-Practices-Apprenticeships-2019.pdf.

[18] Barry Teater, "Life Sciences Apprenticeships Planned for North Carolina" (North Carolina Biotechnology Center, May 13, 2022), https://www.ncbiotech.org/news/life-sciences-apprenticeships-planned-north-carolina.

[19] "Training and Employment Notice No. 23-23—Quality Pre-Apprenticeship Programs" (Washington, DC: U.S. Department of Labor, March 5, 2024), https://www.dol.gov/agencies/eta/advisories/ten-23-23.

[20] U.S. Department of Labor, "Training and Employment Notice No. 23-23."

[21] Stuart Bass, "Mentoring for Apprenticeship: Train-the-Trainer for On-the-Job-Training (OJT)," Keystone Development Partnership, February, 2017, https://www.expandapprenticeship.org/system/files/mentoring_for_apprenticeship.pdf.

[22] "Accelerate NC Community," accessed April 22, 2025, https://acceleratenc.community/.

[23] "Apprenticeship Program," (MassBioEd, accessed April 21, 2025), https://www.massbioed.org/apprenticeship-program/; "Building the U.S. Biofabrication Workforce Through the BioFabUSA Apprenticeship Program" (Washington, DC: Department of Defense, October 10, 2023), https://www.defense.gov/News/Releases/Release/Article/3552248/building-the-us-biofabrication-workforce-through-the-biofabusa-apprenticeship-p/.