DAY ONE PROJECT

Meeting Biology's "Sputnik Moment": A Plan to Position the United States as a World Leader in the Bioeconomy

Natalie Kuldell

April 2021

Summary

Biology is becoming a defining technology of the modern era: the bioeconomy is expected to contribute nearly 1.1 million jobs to the United States by 2030.[1] Preparing the skilled workforce that our nation will need to fill these jobs requires a fundamental shift in how the field of biology is viewed. Biology is not merely a collection of facts to be memorized in school. Rather, it is a dynamic economic sector that provides opportunities for Americans of all skillsets, and that can generate creatively engineered solutions to persistent global challenges.

The Biden-Harris Administration can position the United States as a world leader in the emerging bioeconomy by funding modernized biology education, establishing world-class entrepreneurial hubs for biotechnology in non-traditional regions of the country, and supporting equitable access to industry-recognized certificates and work-based training. Through this comprehensive **Built with Biology Plan**, the federal government can prepare and invite more Americans into skilled jobs that support the bioeconomy. The social imperative for investing in the bioeconomy is at least as great as the economic one. We will build a better future for all Americans—including people of color, people with disabilities, and people from economically disadvantaged backgrounds—only by harnessing regional talent and growing robust bioeconomies in all 50 states.

Challenge and Opportunity

Scientific and engineering advances have positioned biology to become a core technology of the modern era. Sequencing the human genome is 10 million times cheaper than it was twenty years ago.[2] Genome editing, which includes technology to read *and* write genetic codes, has redefined DNA as a programming language for cells: one that engineerable and available for updates in the same way that a computer's code can be. Companies, universities, and government agencies are applying genome-editing tools to meet global needs in healthcare, agriculture, sustainable energy production, and environmental remediation. The economic impact of these efforts is already valued at nearly $1 trillion[3] and is projected to increase for at least a decade.[4]

The COVID-19 pandemic has placed the importance of the bioeconomy into stark relief. The pandemic proved without a doubt that biological threats can send the world into turmoil. But the development of multiple astonishingly effective COVID vaccines in record time—and the

[1] Rogers, J.N.; et al. An Assessment of the Potential Products and Economic and Environmental Impacts Resulting from a Billion Ton Bioeconomy. *Biofuels, Bioproducts and Biorefining*, 11(1): 110–128.
[2] Gertner, J. (2021). A DNA Sequencing Revolution Helped Us Fight Covid. What Else Can It Do? *The New York Times*, March 25.
[3] The National Academies of Sciences, Engineering, and Medicine. (2020). *Safeguarding the Bioeconomy: Finding Strategies for Understanding, Evaluating, and Protecting the Bioeconomy while Sustaining Innovation and Growth*. Washington, DC: National Academies Press.
[4] Bioeconomy Capital. (2019). Bioeconomy Dashboard.

associated ramp-up of biomanufacturing plants to mass-produce vaccine doses on a global scale—also proved that bioeconomic innovations can solve society's most pressing challenges. The unprecedented impacts of COVID-19 make today biology's "Sputnik Moment." 70 years ago, the manned moon landing elevated the status of math and physics, triggering lasting change in public education and motivating young people across the country to become scientists and engineers. So too has the pandemic emphasized the pressing need to modernize biology education, training, and investment.

Indeed, as the bioeconomy has grown, so too have its difficulties hiring appropriately trained workers. A recent survey, for instance, found that nearly 80% of industry leaders in the biopharmaceutical sector struggle to find workers with science, engineering, and technical skills.[5] Other countries are rushing to fill this talent vacuum. China's investment into the bioeconomy is especially noteworthy. An April 2020 report from the Brookings Institution noted that China "intends to own the biorevolution...and they are building the infrastructure, the talent pipeline, the regulatory system, and the financial system they need to do that."[6] In the United States, conversely, most high schoolers and college students are still performing the same rote biology experiments that they did decades ago.

We as a nation must rethink how we teach and talk about biology in order to remain competitive. We need new curricula that integrate digital technologies and computational thinking[7] alongside core biology concepts. We need to invest in regional infrastructure—including labs, startup space, product accelerators, and more—that will support robust and inclusive bioeconomies to flourish in all 50 states. And we need to create career pathways that enable all Americans to participate in the industry that has anchored the battle against one of the greatest challenges of our time. Concerted federal investment in the bioeconomy will simultaneously advance U.S. scientific capacity, modernize U.S. education, bring good jobs to more people, cement U.S. leadership in key industries, and improve our nation and our world.

Plan of Action

The Biden-Harris Administration should support a four-part **Built with Biology Plan**. Modeled on Obama-Biden Administration initiatives related to computer science (CS4All), technical education, and entrepreneurship, the plan will accelerate the U.S. bioeconomy through investment in "M.O.R.E." educational and workforce programs that build lasting knowledge, skills, and professional competencies in bioengineering, biotechnology, biopharmaceuticals, and related fields. The plan will also help advance many of the Biden-Harris Administration's top

---

[5] National Institute for Bioprocessing Research. (2020). Biopharma Trends Annual Survey.

[6] Moore, S. (2020). China's Role in the Global Biotechnology Sector and Implications for US Policy. Brookings Institution, April 27.

[7] National Research Council. (2010). *Report of a Workshop on the Scope and Nature of Computational Thinking*. National Academies of Science, Engineering, and Medicine. Washington, DC: National Academies Press.

priorities, from mitigating climate change to implementing lasting economic relief. M.O.R.E is an acronym for changes in:

- **Mindset.** From middle school through college, biology must be taught not merely as a collection of facts, but as a technical foundation for creatively engineering solutions to the world's most pressing problems.
- **Opportunities.** American companies must be incentivized to recruit and retain local talent so that world-class bioeconomies can grow in all 50 states.
- **Recognition.** A coherent set of certificates and credentials must be developed to facilitate professional advancement in the biotechnology industry and in academic settings.
- **Entrepreneurship.** Bioeconomy hubs must flourish in places and for people traditionally underrepresented in science and engineering.

The sections below present recommended actions to catalyze change in each of these categories.

Part 1: Mindset

The federal government should move to establish biotechnology training as a core competency. In particular, the federal government should allocate persistent funding for relevant teacher training and high-quality instructional materials at the high-school level. A good goal would be introduce at least one million high school students each year to a modern mindset in life science by the year 2025.

Approaches to teaching high-school biology are remarkably similar around the country, and have remained relatively unchanged for the past 30 years.[8] This temporal and spatial consistency both helps and hinders needed progress. Standardized education means that modernized approaches that succeed in one classroom are likely to succeed in another. But schools and educators alike may be resistant to depart from established curricula—especially when limited resources are available to help them make a shift.

The Next Generation Science Standards (NGSS), for instance, were intended to improve K–12 science education for all students. But only 20 states have adopted these standards since they were introduced by the National Research Council in 2013. States forgoing adoption cite limited resources, underprepared teachers, and insufficient classroom time to implement new ways of teaching.[9] Most enrichment programs that provide teacher training are expensive and require updated classroom and lab equipment, adding thousands of dollars to school budgets unless the programs are underwritten by private foundations.[10]

---

[8] Taylor, G.S. (1989). Different Schools: Same Barriers. In: Rosen, W.G. [Ed.]. *High-School Biology Today and Tomorrow: Papers Presented at a Conference*. National Research Council (US) Committee on High-School Biology Education. Washington, DC: National Academies Press.
[9] Thompson, G. (2019). Update on Next Generation Science Standards (NGSS). A Pass Educational Group, LLC, May 5.
[10] For example, creating two "Project Lead The Way" BioMedical Pathway high-school classes capable of serving 110 students per year and training four teachers requires an additional expense of $75,000. To support biotechnology training for approximately 1500 teachers at schools in California Florida, Massachusetts, Pennsylvania, and Puerto Rico, the Amgen Foundation pledged

A modern mindset in life science education—in which biology is perceived as both fascinating and engineerable—requires a pedagogical change beyond the NGSS. Simply updating standards is not enough. The challenge is to use existing, free, and/or low-cost resources to creatively reimagine how biology is taught, while respecting the constraints of overburdened educators and overstretched science programs.

The BioBuilder Educational Foundation serves as an excellent example of how this can be done. BioBuilder is a 501c3 organization that provides open-source curricular materials for teaching engineering biology at the secondary and post-secondary school level. BioBuilder trains teachers, provides online biodesign lessons for students, and develops investigative laboratory activities and simulations. Its open-access textbook has been translated by the publisher into Japanese and Russian and translated by local educators into Mandarin and Spanish. BioBuilder's approach is a proven way to increase student engagement and open new opportunities in the bioeconomy for students who would otherwise face limited access (Box 1).

Box 1. BioBuilder in Tennessee. BioBuilder's curriculum has been adopted in middle-school, high-school, and early college classrooms throughout the country and around the world. At Dobyns-Bennett High School in rural Tennessee, for instance, school administrators in 2019 (with financial support from the Eastman Foundation) committed to offering BioBuilder training to all of their life-science teachers and to making BioBuilder content available to all their students. School administrators now anticipate that every student will graduate with some hands-on training in modern biotechnology, and that these students will further their education and career goals in local industry and at the state university. As one Dobyns-Bennett High School teacher put it, "We've seen the full spectrum of students doing the BioBuilder labs, and they all enjoy it. They're asking, 'When do we get to do the next one?'" A five-year grant awarded to the Niswonger Foundation in December 2020 from the Department of Education is expanding BioBuilder's reach to students attending other high schools in rural Tennessee, and is enabling the Niswonger Foundation to study the extent to which such training improves student achievement and translates into meaningful post-high-school employment.

To introduce a BioBuilder-like curriculum into every public school in America, the federal government should enhance the Department of Education budget with an additional $500 million to cover expanded investment in biotechnology education. This funding would supplement the Career and Technical Education (CTE) State Grant and the Elementary and Secondary Education for the Disadvantaged (ESED) Block Grant programs for teaching engineering biology in vocational and comprehensive public schools. The federal government can also move to establish a national initiative for DNA coding modeled on the Obama Administration's "CS4All" initiative. CS4All aimed to provide computer-coding experiences to all students by activating funds in the Department of Education and at the National Science Foundation, as well as by directly funding states to support computer-science education.

$16.4 million in September 2020 to support an online open-access platform containing content and hands-on experiences for incorporation into molecular-biology curricula.

Part 2: Opportunities

The federal government should launch an interagency Biology Career Pathways initiative that helps connect biology learning to real-world opportunities. Coordinated by Department of Labor, Department of Education and the NSF, this initiative would support paid high-school internships, technical training pathways, and first jobs in the bioeconomy.

In 2012, the Departments of Labor, Education, and Health and Human Services issued a joint letter[11] to promote the use of Career Pathways, which they defined as "well-executed alignment of education, training, and employment" in ways that help students gain marketable skills. A substantial body of research indicates that meaningful work helps students explore careers, put classroom learning into context, and build professional capacities needed for future jobs.[12,13]

Unfortunately, many career-training programs are developed without partnership from future employers. Inefficiencies and mismatches frequently result. For example, the Massachusetts Life Sciences Center, an economic-development and investment agency funded through public-private partnerships, connects high school and college students with prospective employers through an online platform and subsidizes up to 12 weeks of summer wages. But company policies often limit appetite and ability to hire summer interns.[14] Similarly, dual-enrollment and career-pathway programs, along with more traditional types of career and technical education, enable high-school students to earn class credit while training in high-demand technical fields. However, job-placement options for students during these programs and upon graduation depend on the abundance and strength of local industry.[15] This presents a "chicken-and-egg" issue for the emerging bioeconomy and limits options for students in rural or economically struggling areas where bioeconomy-employment opportunities tend to be scarce.

The Biden-Harris Administration should inventory, improve, and expand funding for programs that offer industry-informed work experiences in the bioeconomy as a way to recruit and retain regional talent. Lessons can be learned from successful models such as the NSF's Advanced Technological Education (ATE) program and the Department of Labor's Youth Apprenticeship. Both programs emphasize collaboration among academia, industry, nonprofits, and government. Industry partners co-develop and co-deliver technical training offered through the programs, and then commit to hiring program graduates. This collaborative model has enabled community-college students to perform industry-relevant product development for credit at school, while incentivizing employers in high-growth sectors to offer work-based learning experiences for high-school, out-of-school, and working youth.

---

[11] U.S. Department of Education. (2012). Education, Health and Human Services, and Labor Release Joint Career Pathways Letter. April 12.

[12] Goger, A. (2021). Desegregating Work and Learning through 'Earn-and-Learn' Models. Brookings, March 15.

[13] Kruglaya, I. (2019). MDRC Research on Career Pathways. MDRC, March 28.

[14] Schwartz, R.; Hoffman, N. (2015). Pathways to Upward Mobility. *National Affairs*.

[15] As an example, in 2018 the robust bioeconomy of Massachusetts had five times as many jobs posted for hiring into colleges, companies, and clinical labs than did Tennessee in the same year. (Source: MassBioEd. (n.d.). Labor Market Information.)

Coordination and partnership do not happen by chance. Federal support is needed to provide organizational solutions, convene stakeholders, build consensus, manage and evaluate programmatic efforts, and accelerate the adoption of successful models. The Biden-Harris Administration should therefore increase funding for key bio-focused federal programs. We recommend allocating an additional $50 million to the Department of Education budget for Biotech Innovation and Modernization, an additional $25 million to the Department of Labor's Apprenticeship Program for paid bioeconomy internships, and an additional $35 million to the NSF to support bioeconomy education and workforce development.

Part 3: Recognition

The federal government should establish a new competitive grants program to create bioeconomy-specific certificates and credentials that validate the quality and experience of their holders. This effort should be administered by the NSF, with guidance from the Department of Labor, the Department of Health and Human Services, the National Institute of Standards and Technology, and the White House Office of Science and Technology Policy.

Individual advancement in the bioeconomy currently relies heavily on previously established professional networks and "pay-to-play" experiences, putting students who are traditionally underrepresented in science at a disadvantage. An accessible, industry-recognized credential is needed to level the playing field. An international competition in biotechnology called iGEM provides an example of what a bioeconomy credential might look like. The stated mission of iGEM is to educate students in modern biotechnology and to train them as independent researchers. But the value of participating in iGEM has grown beyond that. Past participation in iGEM is often used as a marker of commitment to biological engineering by undergraduate and graduate university admissions committees, and as a filter to narrow the field of applicants for internships and jobs at biotechnology companies.

But the cost for iGEM participation (estimated in 2015 to be $50,000 per team[16]), as well as the technical sophistication required to be competitive, makes iGEM inaccessible to students from most high schools and colleges. Inequities are hence exacerbated by widespread use of iGEM participation as a de facto qualifying credential for academic programs and jobs in the bioeconomy.

A more inclusive alternative is needed. The federal government should work with industry leaders in the U.S. bioeconomy to define a recognizable credential, akin to Occupational Safety and Health Administration (OSHA) certification and modeled on the Biotechnician Assistant Credentialing Exam (BACE) certificate,[17] that is accessible to all U.S. students. With a modest allocation of $5 million (the same amount of funding it would take to support two iGEM teams per state for one year), federal agencies can create such a credential[18] and develop a digital

[16] Waterloo iGEM. (2015). An iGEM Critique.

[17] Biotility. (n.d.). BACE Specifications.

[18] There is precedent for this type of action in advanced manufacturing. In January 2021, the Department of Labor awarded $5 million to a consortium of eight North Carolina community colleges to work with state employment services, K-12 institutions, four-

platform that connects (i) certificate-seekers to training providers, and (ii) certificate-holders to companies. In addition, open-access publications such as BioTreks, a peer-reviewed journal for high-school biological engineers, could be cultivated as an academic credential. Federal funding to index BioTrek issues and to provide small research grants that support high schoolers in carrying out scientific experiments will make it possible for all interested students to explore and publish their ideas.

Part 4. Entrepreneurship

The federal government should increase funding for the Department of Commerce Economic Development Association (EDA) to support regional programs and infrastructure needed to grow bioeconomy hubs. When combined with non-federal cost-sharing from states, companies, universities, nonprofits, and venture-capital groups, allocating $25 million per year for 3–5 years should be enough to kick-start bioeconomy hubs in a dozen new regions across the United States.

Successful precedent for this type of investment exists. A public-private investment of $10 million in 2013 established LabCentral as a shared lab and office facility for startup life-science companies in Cambridge, MA. Since then, LabCentral-incubated startups have raised $5.9 billion in private financing and created more than 2,000 jobs in Massachusetts. Other move-in-ready laboratory facilities for life-science startups have been built around the country, albeit mostly in locations with existing biotechnology clusters (e.g., North Carolina, California, and New York).

To encourage nationwide entrepreneurship[19] and establish bioeconomy hubs in more rural communities and communities of color, additional funding should be allocated to a Department of Commerce grant program for regional alliances of academic, philanthropic, and business entities that aim to establish world-class biotechnology launchpads.[20] This funding could, for instance, fund entrepreneurship workshops and grants, subsidize construction of shared lab space for startups, or provide incentives for faculty at local academic institutions to further develop their research discoveries into pilot programs, patents, and products. Over time, flourishing regional bioeconomy hubs will enable local students to pursue technical careers close to home wherever home may be, thereby distributing the benefits of the growing bioeconomy throughout the country.

year educational partners, and local industry to identify key advanced-manufacturing skills, such as in in machining, welding, and industrial maintenance. The consortium will develop courses based on these skills, and award competency-based digital badges to students who complete the courses.

[19] Since 2016, China introduced compulsory courses in innovation and entrepreneurship into 82% of its universities. (Source: National Governors Association. (n.d.). State Roadmap for Preparing the Future Workforce Now.)

[20] This new grant program could be modeled on the Department of Commerce Economic Development Administration (EDA)'s Build to Scale Program.

Conclusion

The Biden-Harris Administration can position the United States as a world leader in the bioeconomy through a four-part **Built with Biology Plan** that (1) revises legacy approaches to biology education, (2) promotes work-based learning, (3) develops accessible and meaningful credentials, and (4) invests in regional bioeconomy hubs. As the editors of *Nature Biotechnology* wrote in a March 2021 letter,[21] U.S. investment in the bioeconomy must "not only promote technical excellence, but also foster equity, ethics, dialogue and social responsibility in how the fruits of…research are deployed." Changes to biology education and investments in career pathways and entrepreneurship, as outlined in this memo, are central to achieving those goals.

[21] *Nature Biotechnology*. (2021). The next 25 years. 39(249).

Frequently Asked Questions

What exactly is the bioeconomy?

A committee of the National Academies of Sciences, Engineering, and Medicine published a consensus study report entitled "Sustaining the Bioeconomy" (Feb 2020).[22] In it, they recommend defining the bioeconomy as "*economic activity that is driven by research and innovation in the life sciences and biotechnology, and that is enabled by technological advances in engineering and in computing and information sciences.*" Maturation of the bioeconomy will positively impact agriculture, biomedical science, information science and computing, energy, and other key sectors of the U.S. economy.

How is biological engineering different from genetic engineering, biotechnology, or biomedical engineering?

All of these fields involve manipulating biology in some way and all require a workforce with a diverse skillset that relies on biological, physical, chemical, and computer sciences. The fields differ in their goals and in their approaches to meet those goals.

- **Genetic engineering** typically modifies living organisms using molecular-biology techniques such as PCR, DNA restriction analysis, and DNA sequencing. Genetic engineering often requires that researchers make intuitive adjustments to a relatively small number of genetic components.
- **Biotechnology** is the use of living organisms as a platform to make useful products. By this definition, bacteria that make human insulin and fast-acting dry yeast used to bake breads at home are both examples of biotechnology.
- **Biomedical engineering**, sometimes called bioengineering or abbreviated BME, combines biology and engineering to improve health or save lives. Advanced prosthetics, surgical robots, and kidney-dialysis machines are just a few examples of how biomedical engineering has revolutionized human health.
- **Biological engineering** is the application of engineering methodologies to make, model, manipulate, mine, and measure biology to positively impact many fields. While biomedical engineering refers to the application of this approach to health, biological engineering refers to the application of this approach broadly. Synthetic biology, in which practitioners aims to (re)design and construct novel biological systems that meet practical and useful endpoints, is one prominent example of modern biological engineering.

[22] The National Academies of Sciences, Engineering, and Medicine. (2020). Safeguarding the Bioeconomy.

What lessons can advances in computer-science technology, education, and training offer for anticipated advances in biological technology, education, and training?

Dr. Jason Kelly, the founder of Ginkgo Bioworks, has described synthetic biology as "the ability to program cells the way we program computers."[23] Because computers and cells both run on code (the former on strings of ones and zeros; the latter on strings of nucleotides), it is possible to change the output of either "machine" (computer or living) by changing the code inside. Both computer chips and biotechnologies (such as DNA sequencing and DNA synthesis) have improved exponentially in recent decades.[24]

When technologies improve exponentially, there is significant "first mover" advantage. Thanks in large part to early federal investment in computer research and development, the United States is home to globally dominant information-technology (IT) companies. Consequently, computer scientists are in high demand and well compensated for their work.[25] However, the abundance of high-paying IT jobs has produced a looming capacity crisis in computer-science education: there are not enough qualified computer-science teachers to train the rapidly growing number of computer-science students.[26] At the university level, enrollment in computer-science classes has surged (increasing 300% from 2006–2015),[27] but teaching positions in computer science have not kept pace. At Stanford University, for instance, it is estimated that 2% of the faculty are now teaching 20% of the students. This asymmetry continues to grow because there is a shortage of qualified faculty candidates. At the secondary-school level, computer science is offered at fewer than half of U.S. high schools, in part due to the limited number of qualified teachers. The less training students receive at the high-school level, the greater the capacity crisis at the college level. Government intervention can help break this cycle.

Biology companies are poised to match—or even overtake—IT companies as dominant players in the global markets of tomorrow. The United States risks being left behind international rivals as this shift occurs. China, for instance, is currently out-investing and out-training the United States when it comes to the bioeconomy.[28] As Raphael Reif, the president of MIT, has observed, "the U.S. needs to do more to capitalize on our own strengths" in order to stay ahead.[29] The four-part Built with Biology Plan outlined in this memo will enable the United States meet biology's "Sputnik Moment" by modernizing biology education, promoting work-based learning, developing accessible and meaningful bioeconomy credentials, and investing in regional bioeconomy hubs. Early federal support for computer science is a key reason why the United States is a world leader in the field. Federal support for the bioeconomy is equally essential now.

---

[23] U.S. Senate Committee on Commerce, Science, & Transportation. (2020). Securing U.S. Leadership in the Bioeconomy. March 3.
[24] Bioeconomy Capital. (2019). Bioeconomy Dashboard.
[25] U.S. Bureau of Labor Statistics. (2021). Computer and Information Research Scientists: Occupational Outlook Handbook. April 9.
[26] Computing Research Association. (2017). Generation CS: Report on CS Enrollment. April 3.
[27] The National Academies of Science, Engineering, and Medicine. (2017). *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments*. Washington, DC: National Academies Press.
[28] Cumbers, J. (2020). China's Plan To Beat The U.S. in the Trillion-Dollar Global Bioeconomy. SynBioBeta, March 21.
[29] MIT News Office. (2020). President Reif Testifies before Congress on U.S. Competitiveness. February 27.

What is the total cost for policymakers to implement the suite of actions?

Initiative	What/Who	Funding
To establish biotechnology training as a core competency	Grant Program led by Department of Education	$500M
	National DNA coding initiative led by Dept of Ed and the NSF	$135M
To launch an interagency Biology Career Pathways initiative	Curriculum Modernization led by the Department of Education	$50M
	Youth Apprenticeship led by Department of Labor	$25M
	Education and Workforce development grants from NSF	$35M
To create bioeconomy-specific certificates and credentials	NSF, Department of Labor, the Department of Health and Human Services, the National Institute of Standards and Technology, and the White House Office of Science and Technology Policy	$5M
To support regional programs and infrastructure needed to grow bioeconomy hubs	Grants from Department of Commerce EDA	$25M/year for 3-5 years

DAY ONE PROJECT

About the Author

Dr. Natalie Kuldell leads BioBuilder, a nonprofit organization that inspires the next generation of innovators with synthetic biology curriculum, giving students a leg-up and a way in to the bioeconomy. A BioBuilder textbook was published by O'Reilly Media. In 2017, BioBuilder opened a community lab in LabCentral, an entrepreneurial hub in Cambridge, MA.

Dr. Kuldell studied Chemistry as an undergraduate at Cornell, completed her doctoral and post-doctoral work at Harvard Medical School, and taught at Wellesley College before joining the Department of Biological Engineering at MIT in 2003. She is the 2020 recipient of the Million Women Mentors STEM Trailblazer Award.

About the Day One Project

The Day One Project is dedicated to democratizing the policymaking process by working with new and expert voices across the science and technology community to develop actionable policies that can improve the lives of all Americans. For more about the Day One Project, visit dayoneproject.org