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A Great Bioeconomy for the Great Lakes

The Great Lakes region can build on biotechnology educational models found elsewhere, but it will require interventions that are finely calibrated for local communities and resources.

Nourished by academic research, venture capital investments, and a vibrant community, the bioeconomy is emerging as a transformational force in places such as Boston and San Francisco. Not surprisingly, today's bioeconomy reflects the priorities of those regions, producing more than seven times more patents for pharmaceuticals than those for, say, plants, pesticides, and herbicides.

We believe that, with proper attention and investment in building a community for bioinnovation, a bioeconomy could take root in the Midwest and Great Lakes area, transforming the region's stagnating economy and addressing some of its unique ecological challenges, including the legacy of pollution from earlier industries. Importantly, a bioeconomy attuned to this region's priorities could shape the national industry as a whole, opening up new areas of innovation.

In agricultural production, for example, the cumulative output of five states (Illinois, Indiana, Michigan, Ohio, and Wisconsin) in the Great Lakes region surpasses California, with a total 16% share of the nation's output versus 10.4%. Engineered biological technology that fosters agriculture and reduces contamination could gain a strong foothold here, while providing an expanded template for the bioeconomy in other agricultural areas.

Despite this potential, there are many more biotechnology firms in Massachusetts alone than in those five Great Lakes states combined. Venture capital investment in Massachusetts was more than $4,350 per capita, according to a 2021 analysis, while Michigan's rate was $110. Achieving the kind of holistic, decentralized, and integrated bioeconomy that has been promoted by the Biden administration will not happen without deliberate actions to overcome specific regional obstacles.

States in the region have done work to foster the bioeconomy. For example, Michigan has made significant investments in its bioeconomy. Starting in 2012, the Michigan Translational Research and Commercialization Program established innovation hubs across the state, with the Michigan State University Innovation Hub for AgBio tying the university to regional research and commercialization. Other programs directly aid early-career researchers and support early-stage proof-of-concept development of technologies within the state.

As two educators and a high school student who are passionate about biotechnology, we have witnessed the excitement around the regional bioeconomy as well as its hurdles in the Great Lakes region. We have given a lot of thought to how to nurture a bioeconomy where we live, and we suggest that this effort begins in both college and high school classrooms and then builds connections to a community that spans students, scientists, entrepreneurs, and administrators alike.

This is similar to the community-based model that has built the nexus of bioeconomy innovation and activity in Massachusetts and California over the last two decades. Investment in educational institutions, coupled with established connections to venture capital, helped to

germinate successful enterprises, which spawned further interest and growth in the local bioeconomy, inviting younger participants into the excitement.

In 2008, researchers from the Massachusetts Institute of Technology founded Ginkgo Bioworks in Cambridge. As the company grew, it helped to create more local opportunities through the usual business practices of partnerships, start-ups, and acquisitions. At the same time, Ginkgo and its community have invested resources in outreach activities that welcome young synthetic biologists into the field. For example, Ginkgo's founders have long been involved with the International Genetically Engineered Machine (iGEM) competition, which has historical roots in the Boston area. Over the last two decades, the annual iGEM competition has become the world's largest for synthetic biology, with more than 400 teams from 45 countries submitting projects in 2023. Ginkgo's founders were also involved in creating the BioBuilder Foundation, which brings educational activities involving synthetic biology to high school students and educators in nearly every state and 55 countries.

Here in the Great Lakes, building a similarly supportive community of industry and educators will take time and will necessarily look quite different from communities in areas with a more established bioeconomy. Our experiences have given us ideas about how a thoughtful, local biotech community might be built in our area by focusing on engaging educators and students starting in middle and high school.

First off, students in our region are interested and motivated to be involved in biotechnology when given the opportunity. In 2023, Ohio State University, Wisconsin Lutheran College, the University of Chicago, Wright State University, the University of Michigan, and Alma College all fielded undergraduate teams to the iGEM competition, while the Illinois Institute of Technology fielded a graduate team.

At Alma College, a small liberal arts school in rural Michigan, one of us (Camenares) helped lead development of a synthetic biology curriculum that is integrated within biochemistry courses and extracurricular activities. Since 2017, this curriculum has included a special one-month course during the college's signature spring semester when students work on the year's iGEM competition project. Camenares's experiences with the project have been striking, in part because of the way they have revealed students' hunger for involvement with this potentially transformative technological field.

In 2019, Alma College's iGEM team challenge was focused on combating atherosclerosis. Students connected with the challenge because of family histories with the disease, and some were inspired by family members who had worked at Dow Chemical, also located in Michigan. They presented their work at the end of the month to an audience that included their parents and other students.

One student was a graduating senior who took the course despite not needing to. After the presentation, the student's parents pulled Camenares aside to say that they initially doubted their child's decision to take the course, but upon seeing the final project—a genetically modified probiotic to eliminate an atherosclerosis-promoting metabolite from the diet—they understood the exciting and empowering work their child had become immersed in by taking the course. In places with a low concentration of science, technology, engineering, and math—STEM—careers, the field may be seen as abstract or elitist; but by exploring social concerns, the challenge enables students to envision themselves using biotech to care for their families and communities. Importantly, students who participate in competitions have been found to be more likely to express interest in pursuing a STEM-related career than those who do not, and participating in multiple competitions strengthens that interest.

Another benefit of the iGEM competition is that it connects students to regional, national, and international students, helping them understand the global nature of biotechnology research and business.

It must be said, however, that iGEM also lets students see how other places are preparing their peers to participate in this growing field. Of 124 high school teams competing in 2023, just 10 were from the United States, and 6 of those were from California. The polish and success of the team from Lambert High in Suwanee, Georgia, always stand out (the school has been participating since 2013). But there have not been any high school competitors from the Great Lakes states since 2019, when Dayton, Ohio, fielded a team. Once students have understood the bioeconomy as a growing global phenomenon, they worry about it passing them by. Students frequently asked Camenares why their high school didn't have a program or an iGEM team. "Why am I only learning about this fantastic and accessible field now?" they wondered.

Far from being a rhetorical question, we see it as a call to action. Students call on us to find ways to adopt iGEM, BioBuilder, or similar programs in many more high schools in our region. They also inspire us to confront the barriers to bringing this experience—and the bioeconomy—to all students who are interested.

At the moment, these barriers are so profound that only the most determined surmount them. In 2021, when one of us (Subramanian) was a freshman at Waubonsie Valley High School in Aurora, Illinois, he cold-emailed community college professors in hopes of finding research to participate in. He was able to connect with a researcher at West Chicago's BioBlaze Community Bio Lab who

was working on a commercial enzyme project for the iGEM competition. When the community lab closed, Subramanian searched again for biotech opportunities before finally becoming involved as an individual in the iGEM community in 2023.

Ideally, students would have access to synthetic biology in high school and college classrooms, but many educators lack confidence that these programs can be conducted at smaller institutions. Although examples like Alma College and BioBlaze Community Bio Lab show what is possible, it is difficult for educators with limited knowledge of synthetic biology to teach this field without access to a community of peers. When we have corresponded with local educators, many have said that without easy ways to engage with a community or explore the subject, they are hesitant to invest time and resources in this emerging field. They worry that the benefits to their students may not be worth the considerable investment.

To encourage more widespread adoption of synthetic biology educational programming, educators need to be convinced that the work is worth it, and perhaps not as difficult as it seems at first. A common theme among educators we have spoken with is that, given all the challenges in both secondary and higher education and the many demands on their time, they hesitate to change their practices, even though they are aware that synthetic biology could advance a regional bioeconomy.

One way to support educators is to build a regional community to provide resources and encouragement for such programs to flourish. Such communities can help build a pipeline from junior high school through college, so a student's positive experience in synthetic biology need not be their last, but rather can feed into even more exciting opportunities in research, academia, industry, or the larger community.

Another way to build educators' confidence is to contextualize synthetic biology within existing educational models, such as those that rely on the engineering design process (EDP). These principles and practices were originally developed for industry, but have since been adapted in various forms for the classroom. There is research suggesting that employing EDP in biology classrooms leads to improvement in critical thinking, application, and problem-solving.

However, there are other ways to establish the carefully interwoven relationships at the local level that a budding bioeconomy requires. In contrast to supporting an iGEM team, which requires a significant investment of time, resources, and expertise, educators may find that supervising students as they establish connections with local experts from industry, research labs, or local biofoundries can be enriching and easier to navigate. Importantly, building these connections helps students learn how to interface with and listen to local stakeholders, contributing to the growth of bottom-up bioeconomies. Nurturing these relationships can help students learn more about what is going on around them and actually help bring about innovative solutions to problems, drawing on regional identities and values.

The three of us recently formed the Great Lakes SynBio Association to try to bridge the gap between students, educators, and industry. As we work to build partnerships in the area, we hope that this group can be the start of a vibrant community that leverages the strengths and energy of the place we know and love.

Creating a bioeconomy in the Great Lakes region can build on models found elsewhere in the country, but it will require interventions that are finely calibrated to local people and resources. Rather than adopting programs like iGEM as a one-size-fits-all curriculum, it may be helpful to create regional initiatives that foster local communities among education, industry, and government or nonprofit organizations first. This may take different forms in different cities, counties, and regions. But this targeted approach reflects a bigger truth about the bioeconomy: unlike past types of industrialization, it may succeed the most when it is hyperlocal. The insight that every region has unique problems and opportunities is central to the goal of spurring development of the bioeconomy everywhere.

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