



BioBuilder provides a comprehensive approach to teaching and learning in the emerging field of synthetic biology through exceptional programming available for both students and educators. For students, we offer the chance to explore biology and engineering through practical, hands-on lessons and club activities. For educators, we provide a vital opportunity for relevant professional development that fosters methods of teaching designed to engage and inspire the young scientists in their classrooms.

Our flagship programs serve students and teachers through teacher training in our *Professional Development Workshops*; student engagement and research in our *BioBuilderClubs*; community engagement and early introductions to synthetic biology through our *Learning Lab* at LabCentral in Cambridge, MA; and workforce development for students from underserved schools in the Boston area through our *High School Apprenticeship Challenge*.

# Professional Development Workshops

Our three-day workshops provide direct experience to teachers with BioBuilder's curriculum and laboratory content. Co-taught by a practicing synthetic biologist and a high school teacher, workshops combine classroom, laboratory, and design activities. Teachers return to their respective schools with ready-to-teach lessons that bring engineering into biology classrooms, labs, and clubs.



## Highlights

Since 2011, BioBuilder has trained **over 500 teachers** through **more than 50 workshops** held around the United States and in Mexico. Teachers have come from **32 US states and 7 countries**.

**"I have attended countless workshops during my 20-year teaching career, but few compare to the quality of instruction, experience, and curriculum offered by Dr. Kuldell and her team. [...] Being challenged to create different types of lessons generated internalization of the content and nurtured enthusiasm for teaching synthetic biology."**

## Outcomes

After attending a workshop, teachers report:

- ◇ Higher levels of comfort in teaching and/or understanding synthetic biology;
- ◇ A greater likelihood of integrating elements of the workshop into future work;
- ◇ The value of gaining new professional contacts.

In the 2018-19 academic year, it's estimated that **more than 5,000 students** engaged with BioBuilder curriculum.

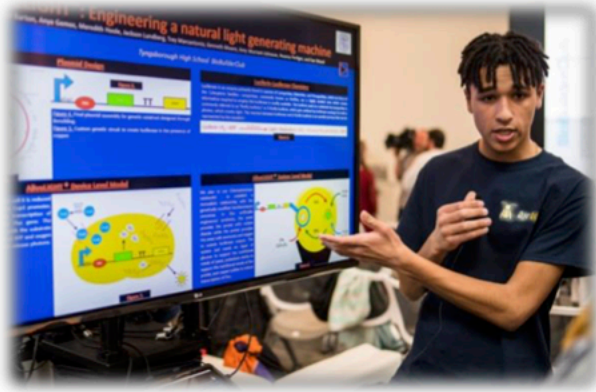


# BioBuilderClub

The BioBuilderClub allows students to learn in a flexible and collaborative environment through their own project designs, with the support of mentoring from practicing bioengineers. Clubs are provided textbooks and laboratory kits and engage with each other through a virtual kickoff as well as monthly online group meetings. The program culminates with a Final Assembly where teams present their progress.

## Highlights

Since 2013, **more than 175 teams** have participated in the BioBuilderClub, engaging **more than 1,600 students** from **22 US states and 7 countries**.



## Outcomes

Among Club participants in the 2018-19 academic year:

- ◇ **Students reporting a good understanding of synthetic biology more than doubled**, from 33.4% to 73.3%;
- ◇ **92% of students reported a desire to pursue a career in STEM**;
- ◇ Students gained essential skills in collaboration, presentation, problem-solving, project management, research, and teamwork.

**“I’ve learned more about the sheer opportunities that synthetic biology and biotechnology offer to our society as a whole”**

*BioBuilderClub student*

# Learning Lab

Located inside the entrepreneurial community of LabCentral in Kendall Square, Cambridge, MA, the Learning Lab is bringing BioBuilder into a place where science is happening, enabling us to run year-round programming. We offer opportunities for local students during the school day, after school, on weekends, and during school vacations. The Learning Lab is also home to our local professional development workshops, specialty seminars, and classes for STEM professionals.

## Highlights

Since opening in 2017, the Learning Lab has hosted **more than 1600 participants** through **more than 110 programs**.

The Learning Lab serves participants across the spectrum:

- ◇ **Over 250 local students**, including home-schooled and those from underrepresented groups and underserved schools;
- ◇ Educational tours for domestic and international secondary and college students;
- ◇ Community programs;
- ◇ **More than 100 teachers** for professional development opportunities.



## Outcomes

"...observed increased levels of confidence and ability over the course of the term, especially when pushed to decode, comprehend, and execute the protocols independently."

*BioBuilder Teaching Fellow, regarding local middle school students*



# High School Apprenticeship Challenge

The High School Apprenticeship Challenge (HSAC) is an eight-week, lab-readiness training program for low-income students from diverse backgrounds and underresourced schools in the Boston Metro area. Held at the Learning Lab, accepted students commit to learn laboratory and professional skills that prepare them for summer internship opportunities and eventual careers in local academic labs and life science companies.

## Highlights

Since 2016, **more than 250 students have applied for the HSAC**. With an acceptance rate of 42%, over 100 students have gone through the Apprenticeship Challenge, and **58% of Apprentices were offered and accepted summer internships**.



"The rigorous activities, unique interactions, and overall vibrant ambiance of the program was just a huge help, and I will never find the right words to express just how truly grateful I am for it."

*2019 Apprentice*



## Outcomes

Following the program, Apprentices reported improved math skills, an increased preparedness to work on a project team, and learning from the laboratory component of the program. **In 2019, all Apprentices surveyed plan to attend college and major or work in life sciences.**

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# BioBuilder

Educational Foundation

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## BioBuilder alumnae inspire with stories of life-changing experiences as interns



*Caption: This inspirational group of local women, all recent alumnae of the BioBuilder high-school internship program, now major in biochemistry and biomedical engineering at colleges around New England. From left to right: Susana Donkor (Boston Latin/ MassBiologics intern); Pamela Shehu (West Roxbury Academy/Codiak intern); Prachee Mazumder (Cambridge Rindge and Latin / Broad Institute intern); Melissa Aguirre-Pinillos (Melrose High / BioBuilder intern)*

**Cambridge, MA, May 22, 2019** – Four recent alumnae of the BioBuilder internship program inspired next-generation students with their success stories during the program’s spring celebration at the BioBuilder

Learning Lab at LabCentral in Cambridge last week. The emerging scientists spoke of the tremendous impact BioBuilder's hands-on science training had on their personal and academic paths.

*Susana: "I'm glad to see that the program is helping other students like myself and I am forever grateful for the opportunity [BioBuilder] gave me."*

The 16 students in this summer's internship class listened carefully as the internship alums recalled special moments in the lab, tales of challenges "on the job," and descriptions of what it is like to continue their science learning at the college level.

*Christopher Fernandez from East Boston High School and a member of the current internship class commented, "I appreciate you guys [sic] taking your time to teach us and giving us this opportunity to learn more about what you do in these types of jobs."*

Each year in the spring, a group of Boston-area students is selected for BioBuilder's High-School Apprenticeship Challenge. Over 8 weeks in April and May, the students work after school in BioBuilder's Learning Lab at LabCentral in Kendall Square to build the knowledge, techniques, research-based thinking and professional skills they will need. BioBuilder then facilitates - and often underwrites - a summer internship with a local bioscience company or academic lab for each student.

Created by an award-winning team at MIT, BioBuilder offers new ways to teach, learn, and explore cutting-edge science and engineering. BioBuilder provides students the chance to integrate biology and engineering through practical, hands-on lessons, club activities, and school-to-work experiences. Teachers learn new methods of teaching that engage and inspire the young scientists in their classrooms.

LabCentral offers fully permitted laboratory and office space for as many as 60 startups in its 70,000 square-foot facility in the heart of Kendall Square. LabCentral also houses the BioBuilder Learning Lab, comprised of a working wet lab and adjoining classroom. New England Biolabs® has become the primary sponsor of the Learning Lab where BioBuilder to delivers educational programs for students and teachers.

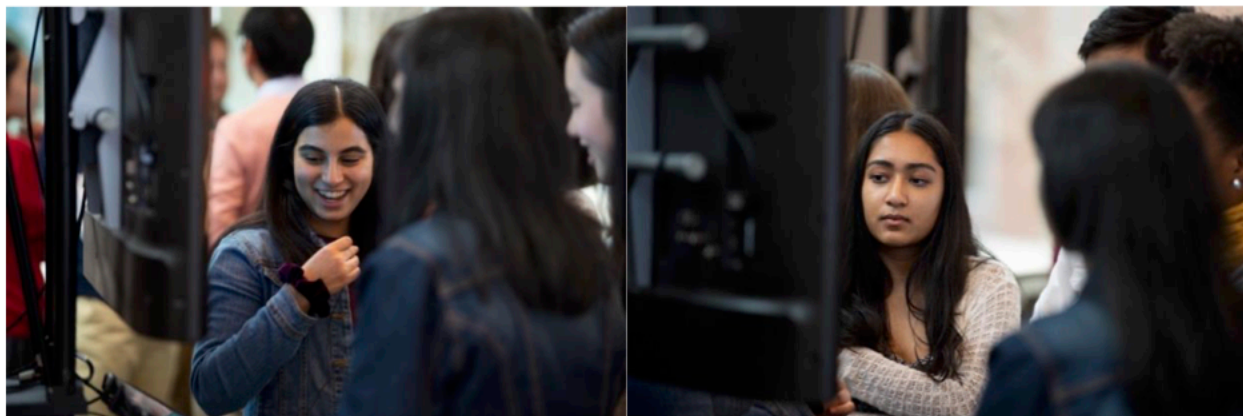
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## BioBuilderClub Team from Andover High School Selected as Finalist for Clean Tech Competition



*Caption: Puloma Bishnu (10th grade) and Veni Dole (11th grade) are first year BioBuilderClub members from Andover High School. They presented their plastic-degradation project at the BioBuilder Final Assembly held at LabCentral on May 16<sup>th</sup>, 2019, a project that was selected as a finalist from hundreds of entrants in the Spellman HV Clean Tech Competition.*

**Cambridge, MA, May 20<sup>th</sup>, 2019** -- Two BioBuilderClub team members from Andover High School in Andover, Massachusetts, have recently been selected as finalists for the 2019 Spellman Clean Tech Competition. Their project was one of hundreds submitted for consideration for one of the top 10 projects in the Mitigating the Effects of Climate Change Category.

The BioBuilderClub is a hands-on STEM design challenge for high school teams around the country and throughout the world. Supported by volunteer mentor scientists and a lead teacher from their schools, teams of students design (and possibly build, then test) a synthetic biology project that addresses a real world challenge.

The two Andover students designed a spore forming bacteria to break down plastic in the ocean. (Poly)ethylene terephthalate (PET), the plastic that water bottles consist of, is not naturally degraded and accumulates in oceans around the world, increasing pollution and significant environmental damage. Their





design uses a strain of gram-positive, spore-forming, genetically engineered halophilic bacteria, *Bacillus tianshenii*, that can break down PET in the presence of salt water.

Bishnu and Dole are invited to the finals event in New York City on July 17, 2019 at The Cooper Union for the Advancement of Science and Art. There they will compete among the top 20 finalists for 10 cash prizes. The team will receive a \$200 stipend with which to build a prototype.

When asked about their experience in the BioBuilderClub, the two team members wrote, “We learned that researching requires the ability to question and analyze, beyond the scope of what we may feel comfortable or familiar with. Researching is something that will lead you to dead ends before you reach a door, and it requires an immense amount of dedication and patience.”

The Andover High School BioBuilder Club started with 10 students and two projects in 2016-2017, and has since expanded to 40 students and 9 projects in 2018-2019. Last year, the Andover High School BioBuilder Club published three design papers to the synthetic biology journal, Biotreks. The team is led by teacher Lindsey L’Ecuyer, the 2018 recipient of the MassBioEd “Champions for Biotechnology” award for her advocacy of biotechnology education among students and educators.

BioBuilder bridges the gap between high school classrooms and university research by connecting the science and engineering done by professionals to the way these subjects are taught in high schools. By presenting authentic research questions in accessible, modular, and teachable form, BioBuilder fulfills its mission to spark interest, engagement and understanding in STEM fields. Conceptualized at MIT in 2007 by Dr. Natalie Kuldell and incorporated as a MA public charity in 2011, BioBuilder currently focuses on the emerging field of synthetic biology and brings investigative curriculum to high school students and teachers. Starting with 27 teachers in its first year, BioBuilder has grown rapidly to now involve more than 500 teachers in 40+ states and more than a dozen foreign countries.

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## Testimonial

*From: Tom Martinez -- BioBuilder Master Teacher and Biology Instructor, Glenbard East High School, February 2017:*

Hi Natalie:) I wanted to pass this along to you. This is an example of what BioBuilder and our efforts can do. Steven was a young man who barely passed my Honors Biology class because he refused to write like a high school student. Liz said he wrote like a 4th grader when I showed her his work. He hated me and his parents were enraged by the fact that I held him accountable to be able to write in science. Steven was with us at the first BB final assembly and he spoke on our behalf because the group was so big. He obviously has grown up and his letter is an amazing verification of what BB can do for kids who are interested. [H]e is my fourth former student who is pursuing molecular bio/engineering because of BB:) I'm so happy that you have come into my life so I can lead and encourage students to pursue their interests! Thanks so much Natalie! Can't wait to see you at Lab Central! [...]

Thanks so much,

Love you, Tom

----- **Original Message** -----

*Hey Bob!*

*I hope you and Liz are well. My mother sent me some newspaper clippings of the [Biobuilder] team, and it reminded me of how much my experiences in the Bio/Biotech/[Biobuilder] trifecta have helped me kindle a love for synthetic biology, and succeed here at Iowa State. In my first semester, I realized just how much research happens here. Our chemical and biological engineering department alone is home to several renowned synthetic biologists. Starting my second semester I accepted two different research positions, one in an analytical chemistry lab studying DNA extraction using magnetic ionic liquids, and another engineering yeast to produce biorenewable chemicals in a research-based class for freshman. I give credit to you, because my experiences in your classroom left me with "the resume of a grad student" according to my mentor Dr. Anderson. Both positions taught me a lot, and I have continued working with Dr. Campbell engineering yeast this year. I came into her classroom with knowledge and technical skills that set me apart from my peers and provided a strong foundation to build upon. The class revolved around a series of hands on modules starting with plating techniques and going through the GFP lab, plasmid isolation, PCR, DNA assembler for plasmid assembly, DNA purification, primer design, and DNA sequencing. In between these labs, we had presentations by various faculty teaching concepts and techniques as they relate to current research. These labs were followed by the design of a research project, carrying out said project, and a poster presentation. Fall semester this year I started a paid research position in her group studying lipid profiles in yeast that have fatty acid biosynthesis regulating genes replaced with similar genes found in*

*maize, and this semester I am working as a teaching assistant for the class I took one year ago. I have mostly been involved in the teaching and organization of these hands on modules, but my big project this semester was to create a hands on lab module teaching gene disruption using CRISPR-Cas9 in yeast. This involved a presentation, making a comprehensive lab manual, and carrying out the preparation for several of these steps. As of now, the students have just finished the final steps of this lab and will (hopefully) have proof of their knockout strains by next Wednesday. It is a great feeling to transfer knowledge on a subject that is both complex and extremely relevant, and I owe so much to you and Dr. Kuldell for providing me with everything I needed to succeed. You inspired me with your passion for the subject, and gave me direction when I had none. Your teaching impacts many, and it is greatly appreciated. I hope you continue to grow your biotech and [Biobuilder] curriculum, and know that you really are making a difference. Have you added anything major to your curriculum? In the newspaper I had been reading about cell-free logic gates! I don't know whether or not you have talked about CRISPR, but attached is the CRISPR lab manual if you want to share it with your current students for a little bit of extra reading.*

*Thank you, Steven*



## End-to-end Adoption of BioBuilder curriculum in Kingsport, TN

The goal of end-to-end adoption is to first build teacher skills and confidence, then leverage that talent to build student interest and skill, and finally support activities from high school on to college and workforce placement, preparing students for opportunities in the emerging bioeconomy at both the academic and professional levels.

BioBuilder, supported by the Eastman Foundation, has implemented a process for students, teachers and STEM professionals in the Kingsport City Schools to engage with synthetic biology in a deep and meaningful way. By training and supporting teachers, BioBuilder provides professional satisfaction for our world's best educators, reigniting their love of teaching and learning. They, in turn, ignite and fan the spark of interest in their students. These efforts will produce the next generation of global innovators, encouraging those who will bring their best ideas to science and engineering for a better world.

### **PHASE 1: Building Teacher Skills and Confidence**

BioBuilder deliberately engages local educators, leveraging their talent and love of learning to transform classrooms and schools. In 2019, Dobyys-Bennett High School teachers attended specifically designated BioBuilder professional development workshops to enrich the ongoing engineering practices in their biology classrooms.

### **PHASE 2: Building Student Interest and Skill**

BioBuilder has leveraged teacher engagement and the excitement of problem-based learning to spark interest in students through the integration of its content into the DBHS 9<sup>th</sup> grade curriculum. BioBuilder will provide additional and more advanced school-based programs for interested students, such as support of a DBHS BioBuilderClub and an upper-level capstone class in biological engineering.

### **PHASE 3: Workforce and Higher Ed Placements**

Given the emergence of biology as a technology for the 21<sup>st</sup> century, BioBuilder will prepare students to translate their learning into workplace opportunities and college careers. BioBuilder will provide a school-to-work and school-to-college model through relationships within Eastman Chemical and East Tennessee State University, offer BioBuilder's Apprenticeship Challenge to students each year, and assist in student placements into the workforce and higher education, while mentoring these students even after they graduate from DBHS.

#### **PHASE 4: Scaling the model of BioBuilder in Kingsport**

Our model for fostering local talent and opportunity can be deployed in additional ways, such as:

- Deploying BioBuilder’s end-to-end model in other schools and near Eastman’s locations world-wide;
- Partnering with entrepreneurial communities like LabCentral in other states and countries to offer a wrap-around educational experience. Our Learning Lab at LabCentral in Cambridge, MA has shown us how the placement of content in context can powerfully teach scientific ideas, the engineering approach, and entrepreneurial drive.

#### **Feedback from the Kingsport adoption team:**

I’m always interested in doing things that touch all of the students we teach. A lot of times you can implement a program that maybe supports higher functioning students. [...] We have, for example, biology classes that are co-mixed with special needs students. And they’re also getting to experience the same activities. ....our teachers are really bought into the idea that all students should experience something like this. Not just a few.

- *Brian Cinnamon, Chief Academic Officer at Kingsport City Schools*

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What we love about programs like Biobuilder is it teaches students how to solve real world problems through advanced sciences that they may never realize otherwise. [...] We met Natalie [Kuldell], we got to know Biobuilder and really realized that we had a unique opportunity to integrate some of this thinking into our curriculum.... The metric is that in four years... every student at [DBHS] will have the opportunity to participate in a Biobuilder lab. That’s over 3,000 students. It’s amazing. [...] It has delivered unique opportunities to our schools, to our students, for our parents. It’s been really great.

- *Maranda Demuth, Corporate Public Affairs Manager, Eastman Foundation*

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Before BioBuilder, if someone had said to us, “Hey, we need you to teach your kids synthetic biology,” I’m pretty sure we’d have looked at them and laughed! [...] I think many of us were a little surprised at how well the labs fit into our curriculum. It wasn’t as difficult as some may think it would be.

When we do the lab, we ask the kids, “If you were creating, what would you do? What problem would you solve? Where would you want to go?” Your kids become the scientist in that role. They are the problem solvers. It gets them to start thinking in scientific and engineering ways, and it has been really exciting to see. I think their whole approach understanding is stronger because they have this experience that ties the things together.

- *Amanda Blackburn and Evie LaFollette, high school science teachers at Kingsport City Schools*