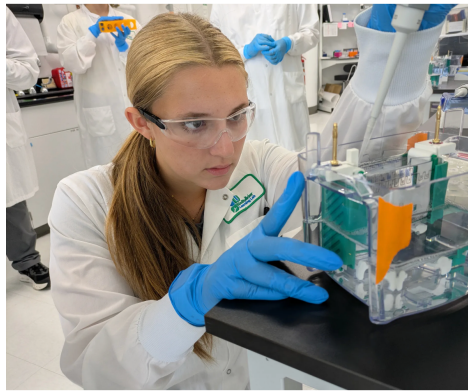


Learning Biotechnology Through Hands-On, Real-World Projects

Author: Natalie Kuldell



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Science takes a lot of time and many steps to master.

Students can understand how a micropipette works and still need practice before they can deliver ten microlitres reliably. They can understand the logic of an experiment and still struggle to understand what happened when the results don't look the way they expected. And they can memorize a remarkable amount of biology without thinking of that knowledge as something they could use to solve a problem they care about.

This summer, I was able to watch what happens when skills, understanding, and purpose are all part of the same scientific work.

Solving Real Problems

[BioBuilder](#) is a non-profit that gives high school students opportunities to learn biotechnology through hands-on, real-world projects. One of those opportunities is our Summer Research Program, where students learn core biotechnology skills and then develop projects of their own.

Three high school students in this summer's program decided they wanted to work on endometriosis. They knew it can go undiagnosed for years, and wondered whether they could design a biological system that might provide an earlier warning. Their idea was to engineer a standard strain of kitchen yeast to detect two inflammatory signals, IL-6 and IL-8, and then fluoresce green when both were present. They imagined embedding the engineered yeast in a menstrual cup.

They didn't build an endometriosis diagnostic in two weeks. They designed one possible approach and a straightforward experiment to test whether the yeast would glow only when both signals were present.

Students in the BioBuilder Summer Research Program all start with the same core lessons: genetic circuits, microbial culture, aseptic technique, DNA and protein analysis, how to use basic laboratory equipment, how to read a scientific journal article, and how to communicate their ideas effectively. Once they had some scientific tools to work with, we asked what they wanted to use them for. That choice gave the learning somewhere to go.

This summer, student projects included an RNA-based approach to ALS, a wearable sweatband biosensor, a way to detect peanut proteins, an approach to early Parkinson's diagnosis, and the endometriosis project. Eleven teams arrived at eleven very different ideas, all of which were aimed at solving a real-world problem.

It Takes Practice

Giving students more ownership doesn't make instruction less important. If anything, it makes good instruction even more vital. Once students care about the scientific result, they discover that ideas aren't enough. Their lab technique has to be accurate. Their experimental controls have to make sense. The data have to be interpretable. When something doesn't work, they have to figure out why.

Scientists traditionally learn much of this through apprenticeship, passing laboratory competence from one person to another. Someone experienced stands beside a learner at the bench, watches what that student does, catches the small mistakes, and says, "Try that again."

It's an extraordinarily effective way to learn, but difficult to scale. Not every student can have an experienced scientist to stand beside them while they practice, and even the best classroom teacher can't watch every student's hands at the same time.

That challenge is what we're aiming to solve.



This summer, through a collaboration with [Transfyr.ai](#), BioBuilder students could opt into a system designed to observe them as they practiced physical laboratory skills such as pipetting and aseptic technique. The idea wasn't to have AI do the science or thinking for them. The goal was to have AI help students get better at doing the science themselves. Through cameras placed at the lab benches, their work helped train an AI model to recognize things like inconsistent hand position or incorrect equipment use.

With an AI model to guide and assess laboratory skills, students should be better able to make the small corrections that can mean the difference between a failed experiment and a successful one. Eventually, demonstrated skills could also connect to credentials students can carry with them, making the same sort of individualized feedback and benefits from scientific apprenticeship available to students who might never otherwise have access to it.

A Solid Understanding Can Hold up to Scrutiny

Getting the technique right isn't the same as understanding the science. Students also have to make sense of what happened, explain the choices they made, and recognize what their results do and don't allow them to say.

This summer, all eleven teams presented their projects to scientists, educators, mentors, families, and each other. They answered questions about why they had chosen a particular approach, what evidence they would need to see, what limitations they could already see, and what they would try next.

The endometriosis team, for example, could explain why they had chosen IL-6 and IL-8 as signals, why yeast made sense for their design, and why they needed controls that tested each signal independently. Just as importantly, they were clear about what they had actually accomplished. They hadn't built a diagnostic. They had designed one possible approach and a proof-of-concept experiment that could begin to test it.

That's a lot for three high school students to be able to explain and defend after two weeks. At the end of the program, one student said, "I was surprised that I could apply a lot of what I learned in school to what we did in the lab."

Perhaps that surprise gets at what made these projects work. The students were drawing on knowledge they already had, learning new skills because their projects demanded them, practicing those skills with feedback, and then making sense of it all well enough to explain their thinking to someone else. That combination of purpose, skill, and understanding allowed the students to take on scientific questions they genuinely wanted to answer.



Dr. [Natalie Kuldell](#) is a molecular biologist, educator, and founder of the [BioBuilder Educational Foundation](#), a non-profit organization which offers hands-on laboratory experiences and biotechnology design challenges to help students access meaningful futures in life science. After studying chemistry at Cornell University and completing her doctoral training at Harvard Medical School, Dr. Kuldell joined the faculty of Massachusetts Institute of Technology, where she founded BioBuilder and began pursuing her long-term goal of making biotechnology education available in every high school in America.