

The Lawrence Hall of Science

UNIVERSITY OF CALIFORNIA, BERKELEY



Exploring Biotechnology in Middle School: Inspiring Future Problem Solvers

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Introduction

Biotechnology is a transdisciplinary field that combines biology, genetics, engineering, and other sciences to develop new products and technologies by using living organisms or their components. This field is already proving critical in enabling individuals and communities to address challenges ranging from personalized medicine to climate change; to wit, the development of vaccines against SARS-CoV-2 gave the world a key tool toward ending the COVID-19 pandemic. The huge societal impact and economic potential of biotechnology highlight the need for scientifically literate citizens who can engage in the new and complex decisions that face them.

Biotechnology plays an increasingly important part of the US economy, proving resilient through economic downturns (TEconomy Partners LLC, 2020). These gains have been especially pronounced in California, which has the largest number of biotech companies in the country. Further, the highest concentration of those companies is found in the San Francisco Bay Area. At the same time, the biotechnology industry struggles with employing a workforce that is representative of the country and the communities surrounding biotech hubs (Center for Talent Innovation, 2020), which, in turn, stifles innovation. Activating a greater diversity of youth toward engagement with biotech is particularly critical given the importance of biotechnology for improving

health and environmental outcomes. Broadening participation of marginalized communities in the biotech workforce is a key first step to ensuring that these communities benefit from biotechnology advances.

Why This Program?

The Exploring Biotechnology program of The Lawrence Hall of Science (The Lawrence) aims to address these challenges in the Bay Area by introducing students to the world of biotechnology and the wealth of local career possibilities just as they begin their middle school years. The middle school years have been shown to be a critical time to support engagement in science as it is often a time that science interest begins to wane for many students (Tai et al., 2006; Cannady et al., 2014). Accordingly, we pay special attention to providing a rich set of experiences with which students could make personal connections and begin to shift their identities toward increasingly central participation in educational and workforce pathways that could enable them to take advantage of the growing local bioeconomy.

The first offering of the Exploring Biotechnology program served over 1,300 students and 19 teachers in Berkeley and San Leandro Unified School Districts. Both cities are home to a variety of biotechnology firms, and both school districts serve large numbers of students from communities that are underrepresented in those firms.

Program Overview

A key learning goal of the Exploring Biotechnology program was that students could explain how the parts and processes of living organisms could be adapted to solve a wide range of important problems ranging from medical innovations to sustainable food and agriculture and even sustainable fashion. The program featured the following three lessons:

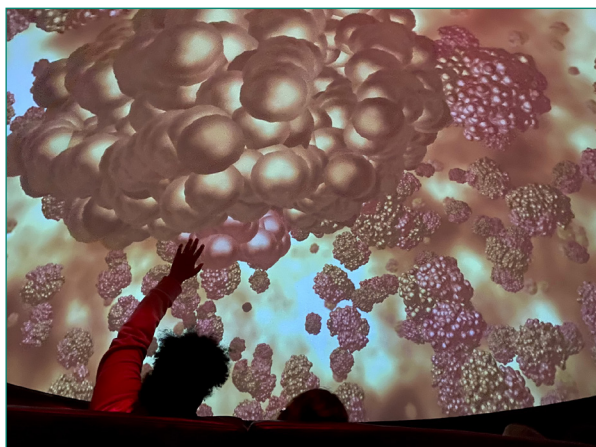
- **Introductory in-class lesson:** Students engaged in a hands-on experiment.
- **Field trip to The Lawrence:** Students participated in experiences in the planetarium and the Bayer Fund Science Discovery Lab.
- **Final in-class lesson:** Students shared personal connections they made with biotechnology ideas.

INTRODUCTION: IN-CLASS LESSON

This introductory lesson featured a hands-on experiment in which students discovered that two varieties of yeast make carbon dioxide at different rates. This simple model for the ways that genetic engineering can be used to create designer organisms for different purposes served as tangible context for a discussion about the many ways microbes are being used by local biotech companies to make consumer products ranging from pigments and moisturizers to high-performance skis and snowboards.

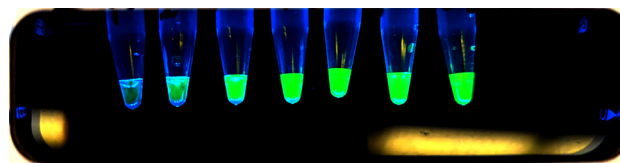
FIELD TRIP TO THE LAWRENCE

The program's field trip featured an immersive experience in The Lawrence's planetarium where students zoomed in to the body of a simulated sickle cell patient to see the cellular and molecular cause of the disease and how the revolutionary gene-editing technology called CRISPR, developed at UC Berkeley, could provide a cure.



I loved what they experienced with the CRISPR model in the planetarium. I loved how well it meshed with the curriculum in sixth grade . . . I was able to reference their experience at the museum with what we're learning now, and they got it. And that was awesome!
—Teacher, Berkeley Unified School District

While at The Lawrence, students also performed an experiment in the Bayer Fund Science Discovery Lab. They used real tools and practices of biotechnology to make a green fluorescent substance—a high-tech example of how tiny molecular machines called proteins could be used to quickly transform substances.



STUDENTS' PERSONAL CONNECTIONS TO BIOTECHNOLOGY

Back in their classrooms, the final lesson offered students an opportunity to share personal connections they were making with biotechnology ideas. Groups of students decided what problems they would solve, using biotechnology. In small groups, students shared their ideas in response to the prompt: *If you had a biotech science wand, what would you use it for?* Many groups chose to dedicate extra effort to creating art projects to showcase their ideas (see pages 3 and 4), which will be on display at The Lawrence beginning on March 22, 2023 and continuing through the summer. Students' ideas ranged from the personal (cancer cures inspired by loved ones) to societally transformative (microbes to solve climate change).

Student drawings, San Leandro Unified School District

GAILLEA SANCHEZ **Climate Change!**

Solution 2
We want to create food that makes cows have less gases that affect the atmosphere.

Diagram
A cow is shown eating from a red bowl. A cloud labeled "hoof!" is above it. A red bowl labeled "Non-farting food" is in front of it.

Diagram
A cow is shown eating from a red bowl. A cloud labeled "hoof!" is above it. A red bowl labeled "Non-farting food" is in front of it. Below the bowl are red circles labeled "Gases" and green plants labeled "Biotech organisms".

Solution 1
We want to add organisms that will eat the gas and that can or could stop cows from farting.

Problem
Our problem is when cows fart, their farts affect the atmosphere and that will cause climate change.

Leah Ferrando **Climate Change!**

Solution 1
We want to create a food that would give cows less gases and atmosphere.

Diagram
A cow is shown eating from a red bowl. A cloud labeled "hoof!" is above it. A red bowl labeled "Non-farting food" is in front of it.

Problem
Our problem is when cows fart, their farts affect the atmosphere and that's not good.

Solution 2
We want to add organisms that will eat the gases and that can or could stop cows from farting.

Sophia C's Biotech Magic Wand

Deforestation

Deforestation is a big problem for the environment. We need trees for lots of things, like paper, timber, and food. They also give us carbon dioxide, so it will be hard to breathe if we cut them all down. Animals need trees to live in, too. Cutting down trees will cause many issues, but where will we get the resources we need?

Solving with Biotechnology

2 ways I thought about that could help solve deforestation: The first way is that we could make trees grow faster, so that neither us or animals will run out of wood. The second way is to make artificial wood so we wouldn't have to cut down as many trees. We should balance the use of trees for humans and animals.

Student drawings, San Leandro Unified School District

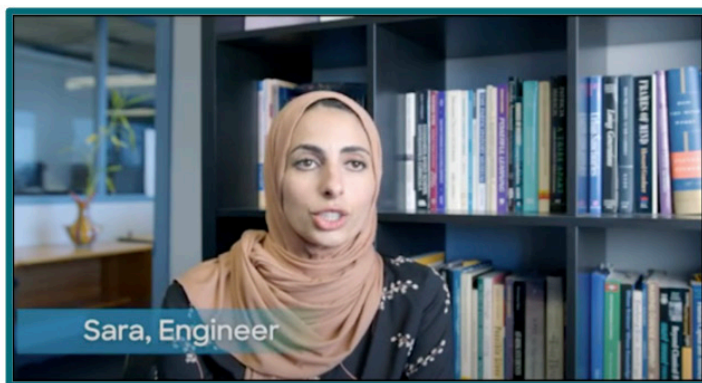
Salvador Zuniga Science Wand

<p><u>Written Problem</u></p> <p>My problem is asthma a lot of the world has this like me this is so sad I would love to join cross country but I can't I was about to pass out there were many pep out there that what to run we need to carry a in later it came of sucks!!! thats for Reading!!</p>	<p><u>Visual Problem</u></p>
<p>My solution for this problem is to build a machine so you go in and it helps your lungs get better and get out the bad cells and bad things out of body. How it looks like you ask when you walk through it a red light scans you.</p>	

<p><u>The Problem</u></p> <p>Water pollution! There is so much pollution in the ocean, and one major threat is plastic. It is harmful to animals and the ocean, even the environment on land.</p>	
<p><u>The biotechnology Solution</u></p> <p>Plastic eating bacteria! This bacteria breaks down and consumes the plastic polyethylene terephthalate (PET), and uses it as a carbon source as well as energy source.</p>	<p>These bacteria will eat up all the plastic in the ocean, then we can work on not putting more in.</p>

Biotechnology videos. During each of these lessons, students were able to view and discuss videos featuring a diverse set of local professionals talking about their work and why it is important to them. We selected local biotechnology companies that featured very different kinds of problems that biotech could solve, including medical innovations (Bayer Corporation), sustainable food (Impossible Foods Inc.), sustainable fashion (Bolt Threads Inc.), and sustainable agriculture (Pivot Bio).

It was nice to connect something that kids were learning in the classroom to what’s actually going on around them. I think the kids got totally into it. –Teacher, Berkeley Unified School District



Lesson videos featuring bay area scientists—Neal, Biologist at Pivot Bio; Sara, Engineer at Bayer Corporation; Smita, Biologist at Impossible Foods Inc; Cordelia, Associate Quality Engineer at Bolt Threads Inc. This *Biotechnology Careers* video series can be viewed on The Lawrence’s website (<https://lawrencehallofscience.org/>).

Program Impact

We evaluated the effectiveness of this program through student and teacher surveys, as well as interviews with teachers. We found that the program positively impacted both students and teachers and resulted in increased student engagement with biotech ideas, greater awareness of biotech careers for both students and teachers, and greater confidence in teaching biotech ideas among teachers. We were pleased to find even a short-term program like this one can be an effective way to increase engagement with science

ideas and careers. This is significant because shorter-term programs can be easier for teachers to integrate into their curriculum and require less professional development, support, and cost to implement. The relatively low cost and time commitment, therefore, make this program a feasible option for school districts looking for effective ways to integrate biotech learning. The four subsections that follow provide a summary of the program’s impact on students and teachers.

STUDENT ENGAGEMENT WITH BIOTECH IDEAS

We wanted to understand the impact of the program on students’ interests and ideas around biotech, so we needed a survey instrument to be able to ask students how they felt about biotech before and after the program. However, such an instrument did not yet exist. As a result, we adapted a previously developed survey instrument developed by researchers at The Lawrence to measure youths’ science fascination, science values, and science competency beliefs (Dorph, Cannady, and Schunn, 2016). After making initial adaptations, we constructed three modified scales: Biotech Fascination, Biotech Values, and Biotech Competency Beliefs. We tested the modified survey with middle school students to gather their feedback and improve the questions. The resulting Student Engagement with Biotech survey instrument (on next page) has overall good reliability—meaning that it is able to produce similar and consistent results, an important indicator of a reliable instrument. Example survey questions are included below.

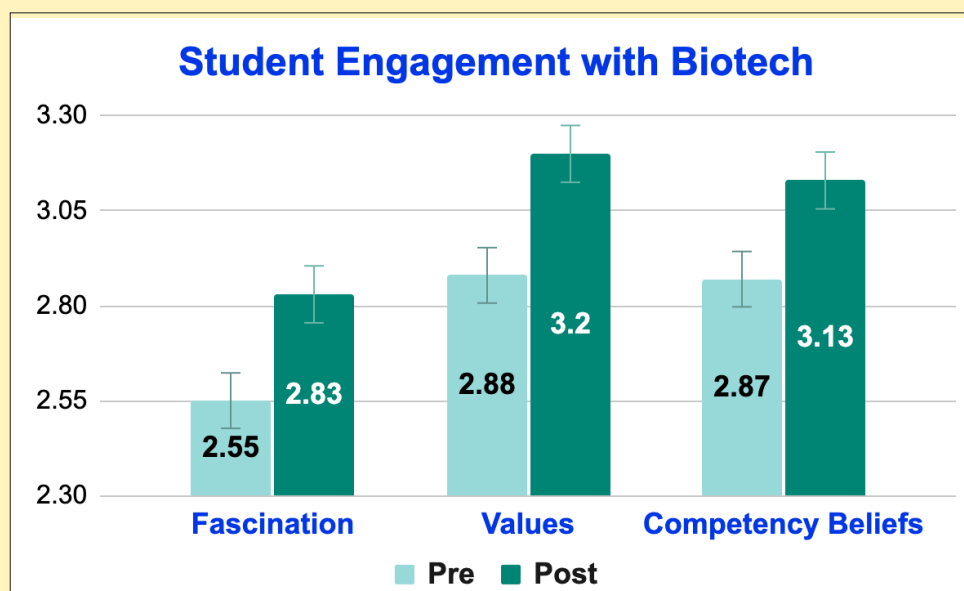
This survey asks you about what you thought and felt **BEFORE** and Lawrence Biotech Program and how you think and feel **NOW**.

Please indicate how you thought **BEFORE** the program and how you think **NOW**.

BEFORE the program					NOW			
NO!	no	yes	YES!		NO!	no	yes	YES!
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I like to figure out how things work.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	After a really interesting biotech activity is over, I can't help but think about it.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Problem-solving with living things fascinates me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I talk about biotech with friends or family.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

STUDENT ENGAGEMENT WITH BIOTECH IDEAS (CONTINUED)

We were pleased to find that the program increased students' fascination with biotech, increased the value they placed on the biotech field, and increased their own feelings of competency. The program was also similarly impactful across gender identities.



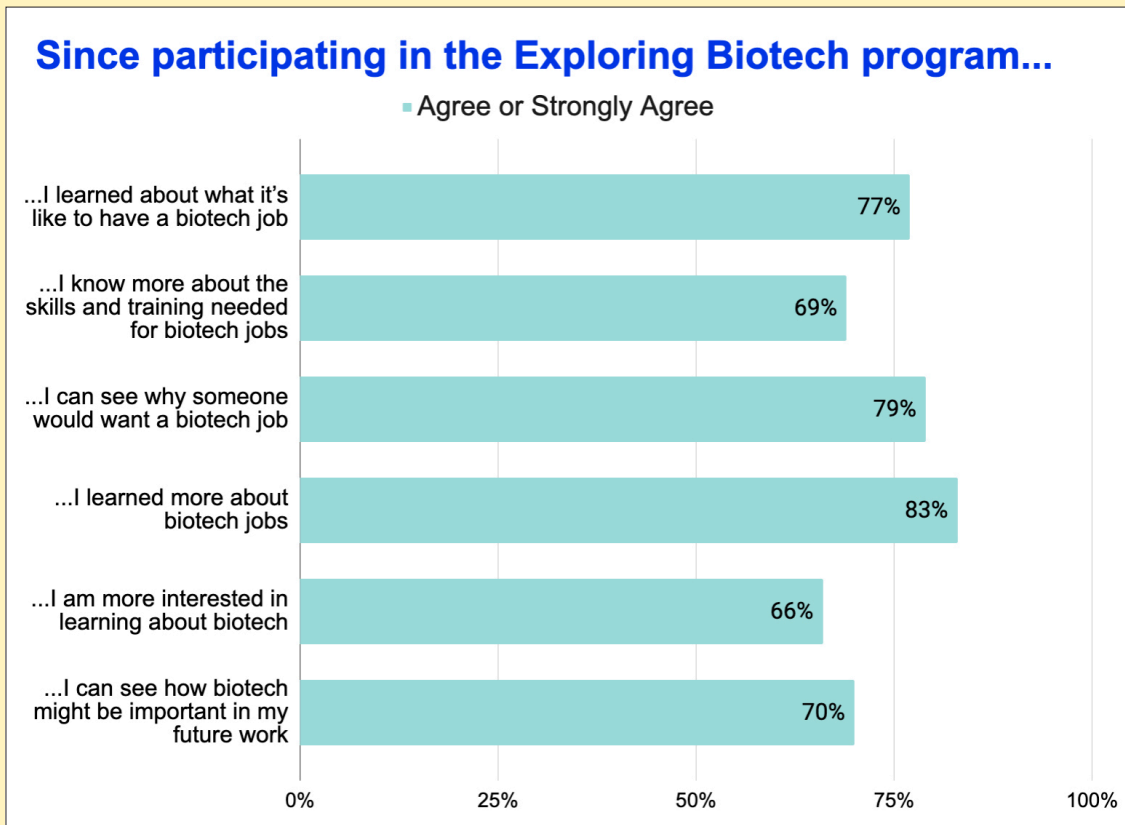
Note: The scale of the graph has been adjusted from 1–4 to 2.3–3.3 for ease of interpretation. The vertical bars in each of the columns show the 95% confidence interval.

We found that the program increased student engagement with biotech in a meaningful way. We compared students' retrospective pre-test and post-test scores for Biotech Fascination, Values, and Competency Beliefs to assess whether any changes occurred from before the program to after. The results shown in the graph above indicate that the mean post-test scores are statistically significantly higher than the mean retrospective pre-test scores for Biotech Fascination (mean diff=.28, $n=814$), Values (mean diff=.35, $n=793$), and Competency Beliefs (mean diff=.27, $n=786$).

In educational intervention studies, effect sizes above 0.2 are considered large and meaningful (Kraft, 2020). A series of paired samples t-tests revealed large effects for all three outcomes: Fascination ($d=0.55$, $t(813)=15.65$, $p<0.01$), Values ($d=0.70$, $t(792)=19.62$, $p<0.01$), and Competency Beliefs ($d=0.62$, $t(785)=17.47$, $p<0.01$), with the largest effect for Values (where "d" refers to Cohen's d effect size). Given the large sample size and diverse student populations within the Berkeley and San Leandro Unified School Districts (California Department of Education, 2023), the large effect size is particularly promising as it suggests that the program could be scaled to other diverse populations and achieve similar impacts.

AWARENESS OF BIOTECH CAREERS

We surveyed students and teachers about their changes in awareness of biotech careers. Student results are shown in the graph below.



Teachers:

- 100% know more about local biotech careers.
- 93% learned what a day in the life of a biotech professional looks like, the skills and training needed for a biotech job, and motivations for going into biotech.

IMPACT ON TEACHING

Teachers reported that they were more likely to teach about biotech again after participating in the program. In fact, 80% of teachers felt confident in their abilities to integrate biotech lessons into their curriculum compared with 31% before the program. When asked how knowing more about local biotech careers might impact their teaching in the future, teachers shared (anonymously) the following answers:

- *It definitely helps me inspire students to go into the field, even if their main interest isn't "science."*
- *It gives me a "why" to tell students. Why we are learning about it, why it's important, and why it is important to look into the future in biotech for our worlds.*
- *It would help me understand the science workforce I'm preparing students for. I think it would be great if more local biotech companies organized field trips or visited classrooms as guest speakers.*

FUTURE NEEDS

When asked about challenges to implementing biotech in the future, teachers identified barriers including:

- more guidance on how to integrate biotech into curricula that don't explicitly include it.
- a need for more support in teaching abstract ideas of biotech to younger students.
- materials, lesson plans, and funding for field trips due to limited budgets.

Concluding Remarks

This Exploring Biotechnology program was made possible through the support of Bayer Fund, which enabled us to develop the instructional resources and subsidize transportation costs to offer this program free of charge to schools. Continued financial support will be critical to enable us to continue to meet our goals around broadening engagement with science by offering this experience to all students, regardless of their school's financial resources. We also hope to provide ongoing support to teachers who were engaged through this program, as well as to revise and adapt program resources to share with schools around the country.

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THE CENTER FOR TRANSFORMING SCIENCE & SOCIETY

The Center for Transforming Science & Society at The Lawrence promotes meaningful connections between cutting-edge science and the lived experiences of youth, families, and educators through interactive exhibits, hands-on curriculum, and engaging workshops and events. By designing and researching these culturally responsive experiences, we support youth as they build their science understanding and drive positive change in their communities.

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CREDITS

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