

# Biohacking Food: A Case Study of Science Inquiry and Design Reflections about a Synthetic Biology High School Workshop

Justice T. Walker, Mia S. Shaw, Yasmin B. Kafai, Debora Lui, University of Pennsylvania  
[justicew@upenn.edu](mailto:justicew@upenn.edu), [mshaw12@gse.upenn.edu](mailto:mshaw12@gse.upenn.edu), [kafai@upenn.edu](mailto:kafai@upenn.edu), [dlui@upenn.edu](mailto:dlui@upenn.edu)

**Abstract:** In synthetic biology scientists genetically modify—or biohack—cells in order to repurpose their function or products. While synthetic biology is gaining societal relevance, few opportunities exist for K-12 students to have actual biodesign or biohacking experiences. We developed and implemented a workshop in which high school students genetically modified and repurposed yeast to produce and deliver vitamin A. Analyzing workshop observations and interviews of focus groups, we addressed the following research questions: (1) How did biodesign activities reflect science practices as characterized in national science standards? and (2) What did students have to say about their experiences with bio-design activities? We also discuss what we learned about facilitating and improving biodesign in K-12 classrooms.

## Introduction

The last decade has seen growth in synthetic biology, where organisms are genetically modified for growth into real-world applications (e.g., Cheng & Lu, 2012). This technology has made it possible to develop numerous products like: : Vanillin™, a synthetic alternative to vanilla grown using yeast by Evolva and Biosteel™, a fully biodegradable high-performance fiber used in Adidas sneakers. Given that synthetic biology has moved out of research labs and into our day-to-day lives, there is an urgent need to introduce the field and its associated issues into K-12 education (NRC 201). Most existing research in K-12 life science education has concentrated on students' understanding of and attitudes toward biotechnology (Dawson, 2007). However, hands-on experiences with synthetic biology are lacking in these K-12 settings, even though they are widely available in community biolabs and universities laboratories (Loparev et al., 2016). In this study, we designed and implemented a synthetic biology-based workshop called BioCakes. We identified which science practices (as described in Next Generation Science Standards, or NGSS, 2012) were realized (or not) in order to explore synthetic biology's potential for learning in contemporary science curriculum frameworks and also investigated students reflections on their experiences. The goal of our research is to develop a better understanding of how design in biology may contribute to science inquiry (and vice versa).

## Context and Methods

Our BioCakes workshop took place at a science center in a northeastern U.S. city, with nine students from a partnering high school (6 White, 2 Asian, 1 Black; 5 Females, 3 Males, and 1 They). The workshop spanned seven two-hour sessions and activities were divided into three phases: fabrication, application, and imagination. The fabrication and application phase involved wet lab procedures needed to genetically modify yeast cells to produce vitamin A and bake an enriched cake. Teams of 2-3 students used a prototype of the biomakerlab, a low cost and portable wetlab machine (Kafai et al., 2017). The imagination phase involved developing an hypothetical application of synthetic biology in a real-world context and required research on existing methods for delivering a medicine, vaccine or vitamin. Students were then asked to create a 2-4 minute video 'pitch' of their idea.

We examined video data from two case study groups and two debriefing focus groups. We developed codes based on the existing NGSS framework applied by two coders in order to establish 100% consensus. Codes were applied only in instances when science practice behaviors were unprompted. In the focus groups, we asked students about their perspectives and experiences of synthetic biology, struggles during the workshop, and processes they used to develop their final pitches. We analyzed transcriptions of student responses for instances when there was consensus around particular ideas (i.e., perspectives about participating in this BioCakes workshop).

## Findings

We identified four of eight NGSS practices at work during through the workshop including: (1) asking questions and defining problems (41%); (2) analyzing and interpreting data (18%) and (3) engaging in arguments from evidence (18%); and (4) obtaining, evaluating and communicating information (23%). Here, we describe one example of

engaging in argument from evidence practice because, by nature, it requires engagement with the other three practices. When developing their video pitches, students Mel engaged in a discussion about whether a synthetic-biology based vaccine could be delivered through skin pores using a facial mask. Another participant, Daniel, critiqued Mel's idea using his prior scientific knowledge as he asserted:

Daniel: The reason that a shot works so well is that it's injecting right into your bloodstream.

Mel: You're literally trying to replace a vaccination with a vaccination.

Daniel: No no, I'm not trying to. I'm just saying that's why the vaccination works. The problem with the pores, it's a good idea, but the problem with the pores is that the pores don't lead into the bloodstream. So it would be harder...for that vaccination to get around the body as quickly.

By comparing a facial mask to a shot, students demonstrated how they could evaluate competing design solutions based on existing knowledge and limitations (NRC, 2012). Iteration of design ideas therefore emerged as students constructed explanations for rationales when developing their imaginary synthetic biology-based delivery systems.

Focus group responses provided insights into student experiences. They described their efforts coming up with iterations of their imaginative designs. Jesse explained his reaction to being assigned the vitamin deficiency as the issue to address with an imagined genetically-modified organism (GMO): "I thought that the [assignment] would limit the possibilities for us but [we] came up with a lot of ideas I feel." In fact, members of Jesse's group went through four iterations before finally deciding on using a yogurt to deliver vaccines, which was completely different than their original focus (i.e., vitamins delivered by lozenges). While the procedural hands-on portion of the activity did not yield opportunity to iterate upon ideas, students' responses illustrated how the imagination activity not only supported personal expression but also iteration and revision—hallmarks of making and inquiry-driven learning.

## Discussion

Our project took a first stab at illustrating what biodesign activities could look like in a class-like K-12 STEM setting and how students engaged with various science practices in the process. While students do engage with some of the science and engineering practices articulated in the NGSS science standards when participating in biodesign, they were also many other practices that we did not see in our analysis of workshop interactions. The success of the imagination activity was an unexpected outcome, since this was where we observed many science practices. Future research should consider how biodesign activities could enhance student design competencies, which have been shown to be an instrumental part of learning and making.

## References

- Cheng A. A. & Lu, T. K. (2012). Synthetic Biology: An Emerging Engineering Discipline. *Annual Review of Biomedical Engineering*, 16(14), 158-178.
- Dawson, V. (2007). An Exploration of High School (12–17 Year Old) Students' Understandings of, and Attitudes Towards Biotechnology Processes. *Research in Science Education*, 37(1), 59-73.
- Kafai, Y., Telhan, O., Hogan, K., Lui, D., Anderson, E., Walker, J. T., & Hanna, S. (2017, June). Growing Designs with biomakerlab in High School Classrooms. In Proceedings of the 2017 Conference on Interaction Design and Children (pp. 503-508). New York, NY: ACM.
- Loparev, A., Westendorf, L., Flemings, M., Cho, J., Littrell, R., Scholze, A., & Shaer, O. (2017). BacPack: Exploring the Role of Tangibles in a Museum Exhibit for Bio-Design. In Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction TEI'17 (pp. 111-120). Yokohama, Japan.
- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.
- Palmer, M., Kuldell, N., & Sittenfeld, D. (2016, May). Building with Biology. *O'Reilly BioCoder*, 41. Retrieved from: <https://www.oreilly.com/ideas/building-with-biology>

## Acknowledgments

This work was supported by a grant (#1623018) from the National Science Foundation to Yasmin Kafai and Orkan Telhan. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors

and do not necessarily reflect the views of the National Science Foundation or the University of Pennsylvania. The authors wish to thank Karen M. Hogan, Aurora MacRae-Crerar and Keith Lewy for their help with developing and supporting workshop activities.