The Biophysicist

Dismantling Silos: Academia, Industry, and a Science Museum Working Together

Thomas Zimmerman[1,2,3,*], Kristina Yu[1,4], Dana Carrison-Stone[1,4], Jonathan Erwin[1,4], Joyce Ma[1,4], Zachary Hui He[1,3], Simone Bianco[5], Raymond Esquerra[1,3], Sara Capponi[1,2]

[1]Center For Cellular Construction, San Francisco, CA, USA
[2]IBM Research-Almaden, San Jose, CA, USA
[3]San Francisco State University, San Francisco, CA, USA
[4]The Exploratorium, San Francisco, CA, USA
[5]Altos Labs, Redwood City, CA, USA

ABSTRACT A partnership between four universities, an industrial research lab, and a public science museum, created as a National Science Foundation Science and Technology Center, offers diverse collaboration and learning opportunities in cellular engineering. Each institution plays a vital role: universities advance science education, industry develops and commercializes technologies based on basic research, and science museums educate and engage the public. However, differences in the culture, values, and focus of these institutions create collaboration challenges. Three workshops highlight how consistent funding, intellectual property agreements, shared facilities, and long-term collaborations can harness the strengths of each institution to promote rapid prototyping, confront global problems, and encourage commercial applications from research.

KEY WORDS prototyping; patents; bromoform; collaboration

I. INTRODUCTION

The Center for Cellular Construction (CCC) is a National Science Foundation Science and Technology Center comprising four San Francisco Bay area universities, an industrial research lab, and a nonprofit science museum. The Center's vision is inherently multidisciplinary: "to design and build cells and tissue with specific three-dimensional structures" (1). Each institution plays a crucial role: universities expand science foundations, industry develops and commercializes technologies based on basic research, and science museums engage and educate the public. The CCC showcases the synergistic benefits of multidisciplinary collaboration among academia, industry, and a science museum while also uncovering the challenges of bringing members of these institutions together.

Academic institutions are traditionally organized into separate departments, each with its own staff, funding, and culture (2). However, interdisciplinary science is vital for addressing complex challenges such as climate change and public health. The CCC works to dismantle these silos with consistent funding, intellectual property agreements, shared facilities, and long-term collaborations. These

"*" corresponding author

Received: 31 January 2024
Accepted: 8 August 2024
Published: 4 September 2024

issues and challenges are explored by examining three recent CCC workshops.

A. Rapid Idea Generation Workshop (the Exploratorium)

In February 2023, the Exploratorium hosted the first Rapid Idea Generation (RIG) workshop, bringing together 15 CCC members from the University of California San Francisco (UCSF), the University of California Berkeley, San Francisco State University (SFSU), and IBM Research with five Exploratorium staff and three Exploratorium facilitators to address a design challenge (Fig 1, left panel). The agenda was to brainstorm and prototype museum experiences for real-time interaction with living microscopic specimens. The RIG aimed to re-establish in-person connections, build confidence in rapid prototyping, encourage science outreach, and generate ideas for engaging exhibits.

Before the event, CCC participants visited the Exploratorium to familiarize themselves with its exhibits and observe public engagement. The RIG workshop day lasted 8 h and included a lunch break. Participants started Round 1 with the marshmallow challenge, a team-building exercise (see Supplemental Material). Guided by Exploratorium staff, the small teams, comprising participants from diverse backgrounds, brainstormed by using coarse materials to create low-fidelity prototypes and then presented their ideas for group feedback.

In Round 2, teams were shuffled to enhance prototypes with diverse perspectives. Feedback from participants and Exploratorium staff supported idea development throughout the day. Facilitators selected two themes—interacting with cells via sound and touch. Participants returned to the biology laboratory for feasibility experiments and further prototyping. These activities created new opportunities for public programming and exhibit development at the Exploratorium.

B. Bromoform Production in Seaweed Workshop (Climate Foundation, IBM Research, SFSU, UCSF, University of California Berkeley)

Ruminants (e.g., cattle and sheep) produce methane gas during digestion, accounting for ∼6% of global human-caused greenhouse gas emissions (3). Seaweeds produce natural compounds, including bromoform, which reduce methane emissions in ruminants when used as a feed supplement (4). The synthesis and retention of high bromoform levels in seaweeds are not well understood, but peroxisomes appear to be involved in these processes (5). In July 2022, the CCC's summer course project explored seaweed peroxisomes by using locally collected seaweeds (Fig 1, right panel).

Meeting twice a week for 2 h each, 9 participants gathered at the SFSU campus to identify local seaweeds with high bromoform retention by studying their peroxisomes. Participants conducted field trips to collect seaweeds and visited cultivation facilities at California State University's Moss Landing Marine Laboratories. They designed experiments, collected and analyzed data, and presented their findings through oral and poster presentations. The workshop developed an effective method to detect seaweed peroxisomes and analyze their morphology and behavior (see Supplemental Material). The method was applied to peroxisomes in *Asparagopsis* and local seaweeds under different growth conditions such as temperature, light, and salinity.

C. Intellectual Property Workshop (IBM Research, UCSF)

At our 2023 summer retreat, 20 faculty and 44 students attended a 1-h intellectual property (IP) workshop led by four CCC IP experts, who have experience creating several startups and have dozens of issued patents. The objective was for each participant to write an invention disclosure (i.e., a document used internally

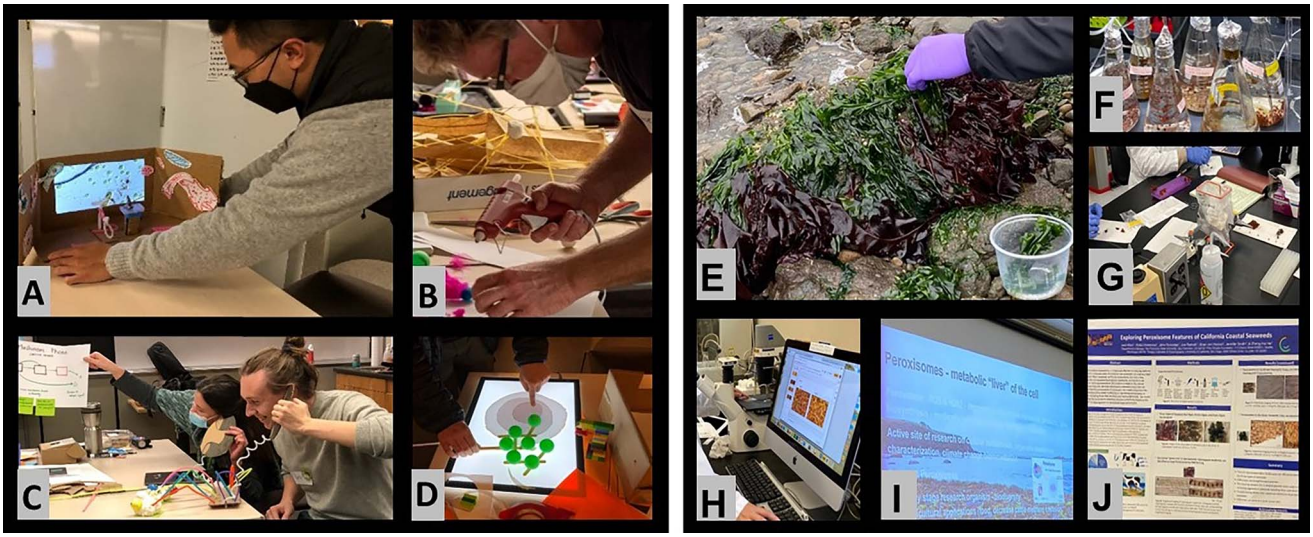

Fig 1. (Left panel) Rapid Idea Generation (RIG) workshop. (A) Mockup of the cell cycle concept in which visitors use a bicycle to control a microscope, experiencing viscous and contact forces at a cellular scale. (B) Preparing a first-round exhibit mockup with available items. (C) A Cellular Construction Center graduate student and Exploratorium exhibit developer present their concept. (D) Presenting a second-round idea to the group. (Right panel) Seaweed workshop activities. (E) Seaweed sampling site on the California Bay Area coast. (F) Seaweed samples are cultured in the lab. (G and H) Trainees perform histochemistry and microscopy experiments with collected seaweed samples. (I and J) Trainees give oral and poster presentations at local and national research symposiums.

to evaluate the merits of an invention to determine whether a patent application is appropriate; see Supplemental Material). After an overview of the invention process, the experts assisted participants in identifying elements of their research suitable for invention disclosure. Later, two experts gave a joint talk on their experiences in biotech startups, illustrating the ways in which laboratory discoveries can evolve into companies and products, which are all supported by IP protection.

II. DISCUSSION

The RIG workshop encouraged students and professionals to think outside the box, stimulate creative thinking, and engage in unusual and novel solutions. Rapid prototyping taught skills to quickly test numerous ideas and accept that failure is a natural step toward innovation. Involving participants from diverse backgrounds, skill sets, and cultures enriched the designs, perspectives, and approaches, creating a broader solution set.

Having explored the idea and design space, the process now moves to the development stage, where the specific demands of a successful interactive museum exhibit must be met. These include building a robust exhibit to demonstrate the basic science and phenomena, providing a positive user experience that engages visitors and promotes inquiry, and addressing practical considerations such as durability under heavy use, maintainability, and safety.

The IP workshop introduced many CCC members to the value of patents in commercial endeavors and the process of attaining a patent. Requiring each participant to complete an invention disclosure based on their work provided a concrete means to teach participants to view their work from a commercial perspective. Real-world stories from researchers who brought laboratory work to the marketplace demonstrated the value of patents in protecting work and building businesses. The workshop and similar efforts throughout the CCC have increased our number of invention disclosures.

Discussions among IP experts and CCC members revealed strong cultural differences between academia and industry. Openness is fundamental

in scientific research, promoting the sharing of methods and results through publication. Students are accustomed to freely downloading music, code, videos, and papers. Professors typically focus on publishing to support tenure, grant applications, and credibility (6–8), with some preferring to keep their research in the public domain (9). Additionally, attaining a patent is expensive, so universities typically pursue the process only if a licensee shows interest and invests in the research. To reduce investment risks, universities often use low-cost, 1-year provisional patent applications to solicit outside interest (10).

In contrast, industry values secrecy for a competitive edge, which leads to patent systems protecting inventors and their investors. With a 20-year lifespan, inventions are often patented before market proof. At its inception, the CCC established prenegotiated IP agreements to facilitate open discussion and collaboration, bridging the cultural gap between academia and industry. This inclusive atmosphere encourages cross-discipline brainstorming and inventions, highlighting the need for IP and entrepreneurial education and support for students and professors.

The Bromoform Production in Seaweed workshop encouraged students to step out of the laboratory and engage with the environment, taking actions to devise creative solutions to address global issues. Leveraging their collective abilities in biology and chemistry combined with access to the Moss Landing Marine Laboratories, participants fostered a space to share skills and problem-solving approaches. Their collaborative effort resulted in an effective method to detect seaweed peroxisomes (i.e., cell structures vital for producing bromoforms), which reduce methane production in ruminant animals.

SUPPLEMENTAL MATERIAL

Supplemental files for this article are available at https://doi.org/10.35459/tbp.2024.000269.

AUTHOR CONTRIBUTIONS

SC and TZ conceived and designed the paper. TZ collected and processed data from CCC institutions. Sections authors are as follows: Introduction (TZ, SC, RE), RIG (JE, JM, KY, DC-S), IBM Intellectual Workshop (TZ, SC), Bromoform Production in Seaweed (ZHH), Discussion and editing (TZ, SC, RE), and guidance and support (SC, SB).

ACKNOWLEDGMENTS

This material is based on work supported by the National Science Foundation (DBI-1548297). Disclaimer: Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors thank the CCC members for their valuable contributions and special thanks to Debra Singer, CCC Managing Director, for her pivotal support and assistance. The authors affirm no conflicts of interest.

REFERENCES

1. Center for Cellular Construction. Cellular engineering. Accessed 22 August 2024. https://centerforcellularconstruction.org/.
2. Amoo, M. E., J. Bringardner, J. Chen, E. J. Coyle, J. Finnegan, C. J. Kim, P. D. Koman, M. Z. Lagoudas, D. C. Llewellyn, L. Logan, J. Sonnenberg-Klein, N. M. Trent, S. M. Strachan, and B. C. Ward. 2020. Breaking down the silos: innovations for multidisciplinary programs. ASEE Virtual Annual Conference. https://monolith.asee.org/public/conferences/172/papers/30136/download.
3. Beauchemin, K. A., E. M. Ungerfeld, R. J. Eckard, and M. Wang. 2020. Review: fifty years of research on rumen methanogenesis: lessons learned and future challenges for mitigation. *Animal*. 14:s2–s16, https://doi. org/10.1017/S1751731119003100.
4. Glasson, C. R. K., R. D. Kinley, R. de Nys, N. King, S. L. Adams, M. A. Packer, J. Svenson, C. T. Eason, and M. Magnusson. 2022. Benefits and risks of including the bromoform containing seaweed *Asparagopsis* in feed for the reduction of methane production from ruminants. *Algal Res* 64.102673. https://doi.org/10.1016/j.algal.2022.102673.
5. Marquez, R., J. Ramahi, and Z. He. 2024. Characterization of peroxisomes in red seaweed Asparagopsis taxiformis. *J Bio Chem* 300:106799. https://doi.org/10.1016/j.jbc.2024.106799.
6. Foster, J. G., A. Rzhetsky, and J. A. Evans. 2015. Tradition and innovation in scientists' research strategies. *Am Sociological Rev* 80:875–908. https://doi.org/10.1177/0003122415601618.
7. Rawat, S., and S. Meena. 2014. Publish or perish: where are we heading? *J Res Med Sci* 19:87–89.
8. Niles, M. T., L. A. Schimanski, E. C. McKiernan, and J. P. Alperin. 2020. Why we publish where we do: faculty publishing values and their relationship to review, promotion and tenure expectations. *PLoS* 15: e0228914. https://doi.org/10.1371/journal.pone.0228914.
9. Nag, D., A. Gupta, and A. Turo. 2020. The evolution of university technology transfer: by the numbers. Accessed 22 August 2024. https://ipwatchdog.com/2020/04/07/evolution-university-technology-transfer/id=120451/.
10. Deerfield Institute Report. 2019. Key insights into technology transfer offices: white paper. Accessed 22 August 2024 https://deerfield.com/publications/deerfield-institute-report-key-insights-into-technology-transfer-offices.