BioFabLab: Workshop:

Tapping the *Maker Movement* to Engage Life Science Students with Creativity, Innovation, and Research

A proposal to the Engaged Practices Innovation Grant Program October 1, 2015

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Abstract

Creativity, innovation, 'tinkering', and the ability to collaborate across STEM disciplines (science, technology, engineering, mathematics), are skills increasingly critical to the modern working biologist, and to STEM careers in general. Here we describe a collaboration between the biology faculty, CAS Dean's Office, and the *makerspace* Burlington Generator, which will investigate the application of tools of the *maker movement* to undergraduate biology education, and ultimately to other STEM disciplines, at UVM. Recently, the grass-roots maker movement has provided a framework for democratizing technology, and bringing new tools to a broad cross section of the public, while fostering an atmosphere of community and collaboration. The ultimate goal of our project, BioFabLab, is to increase engagement and retention of STEM students by combining the high-impact practice of undergraduate research with novel, hands-on maker approaches to create a uniquely engaging first year experience for potential STEM majors. Phase one, described here, is BioFabLab: Workshop, a three-credit, one-semester course in which small teams of undergraduate students address a real research question by the design, construction, and clear demonstration of a novel experimental apparatus. An aim of BioFabLab: Workshop will be to develop and refine curricular approaches that will be applied to an expanded first year experience course for fall 2016, which is the subject of a

forthcoming NSF proposal for incorporating and investigating the effects of maker-related approaches on engagement and retention in STEM education.

Introduction and Background

Nobel laureate Sydney Brenner is noted for saying "Progress in science depends on new techniques, new discoveries, and new ideas, probably in that order."

Indeed, a major part of doing science is coming up with new ways to interrogate the world around us. At this moment in the life sciences, where the "omics" revolution has brought about a deluge of molecular data, this is particularly true. A recent report from a NSF sponsored workshop on the future of organismal biology strongly emphasized the need for development of new technologies to study the complex interplay between organisms and their environments in order to make biological 'sense' of omics data!. One way to tackle this challenge, while preparing students for an increasingly interdisciplinary STEM workforce², is to emphasize the hands-on, innovative side of research.

The success of the maker movement in engaging a broad cross section of the population, from high-tech hobbyists to amateur inventors to artists, with powerful new technologies has attracted the focus of education researchers and agencies such as the NSF, who aim to exploit that success to improve the effectiveness and attractiveness of formal STEM education³. We see the maker setting as a unique place to teach our students relevant and underemphasized skills in a way that employs multiple high-impact educational practices that have been demonstrated to increase student engagement and retention^{4,5}.

Project Description

BioFabLab: Workshop takes a student-centered, project-based approach⁶⁻⁹. Two teams of four students each will design, construct, and describe novel experimental apparatuses to address real research questions. These questions will derive from current research being conducted by labs in the biology department, and be chosen on the basis of achievability, accessibility of the biological principles involved, and dependence on a range of design challenges – from construction to computer control. Several candidate research questions have been identified. (For an example of the kind of project envisioned, see Appendix I, an extended abstract describing recent work by Dr. Mead and students to quantify fruit fly behavior.) Students will work directly with the investigator whose research their apparatus will support. The final project will be a working prototype, accompanied by a demonstration video in the format of the Journal of Visualized Experimentation (<u>www.jove.com</u>) and a detailed written

experimental protocol. Final video demonstrations will be presented at the student research conference in late April. Independent work on team projects at Burlington Generator (www.generatorvt.com) will be accompanied by seminar-style discussions, as well as practical instruction in basic hands-on techniques (Figure).

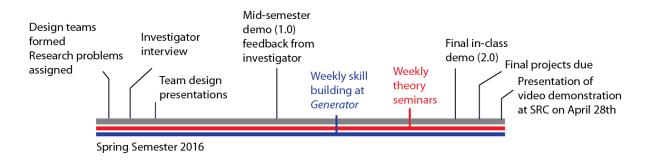


Figure. Timeline of BioFabLab: Workshop course

Educators. Our approach will exploit the expertise of the three collaborating groups. Eugene Korsunskiy, Senior Coordinator of Design Initiatives in the College of Arts and Sciences teaches "Design Thinking and the Art of Innovation," and will guide students in elements of the collaborative design process such as 'brainstorming', 'prototyping', and 'storytelling'. Principal instructor Dr. Andrew Mead is a post-doctoral researcher and lecturer in biology and has designed multiple apparatuses to interrogate muscle function in diverse species from fruit flies to bats. He will lead seminars in topics relevant to gathering data from biological systems, such as signal processing and instrumentation control.

The highly trained staff of Burlington Generator will provide instruction and safety certification for the hands-on skills of *making*, including rapid prototyping, microelectronics, and fabrication.

High-impact practices. By design, *BioFabLab* leverages multiple high-impact educational practices, in addition to undergraduate research, in order to maximize student engagement^{4,9}. To be successful, student groups will have to collaborate with the investigator and with members of the Burlington maker community, who may possess skills and insight applicable to their projects. This community-based learning is an important element of the course and has, itself been demonstrated to enhance student engagement¹⁰. Writing and clear communication are heavily emphasized in *BioFabLab*: *Workshop* in the materials that will accompany the apparatuses. Finally, we envision *BioFabLab* in its ultimate form as an interdisciplinary, *first year* experience⁴.

Learning outcomes. Students will gain i) basic literacy in core technologies and approaches, ii) essential concepts of measurement in biology, iii) approaches for effective collaboration in design, and iv) clear communication of results.

Discussion

As educators and researchers, we have come to realize that however well we do the job of communicating the *facts* of biology and the practice of the scientific method, a crucial component of the problem solving tool kit is missing unless we prepare students to think creatively, and to understand the essential role of design, innovation and tinkering in the progress of scientific discovery.

The ultimate goal of the greater *BioFabLab* project is to build evidence that *making* is an effective strategy for attracting, engaging and retaining STEM students, and for improving learning of fundamental concepts of the scientific process. To build on the pilot course described here, we plan to implement, test, and validate a larger course for undecided first time first year (FTFY) students. In that expanded study, which is the subject of a grant being submitted concurrently to the NSF, we aim to evaluate, through qualitative and quantitative means, the potential benefits of learning in the maker context relevant to attraction, retention, and continuing performance of life science students. *BioFabLab: Workshop* will provide a platform for curriculum development and for strengthening and developing the collaboration between the biology department, CAS Dean's Office, and Burlington Generator.

Assessment Plan

The small size of *BioFabLab: Workshop* limits any quantitative assessment of efficacy in either attraction/retention, or learning efficacy. However, its size and seminar format will confer flexibility and foster student feedback. Therefore the assessment of the course will take the form of an assessment of the process. Course instructors will hold regular meetings throughout the semester. With input from students, we will prepare a report on what we learned, on successes and failures, and what we plan to do differently in the larger, fall 2016 *BioFabLab* course. This, together with final project materials, will be submitted as part of our final report on the project.

References:

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- 2. Van Noorden R. Interdisciplinary research by the numbers. *Nature*. 2015;525:306-307.
- 3. Halverson, Erica Rosenfeld, and Kimberly Sheridan. "The maker movement in education." *Harvard Educational Review* 84.4 (2014): 495-504.
- 4. Kuh GD, O'Donnell K and Reed S. Ensuring quality and taking high-impact practices to scale. *Washington, DC: Association of American Colleges and Universities*. 2013.
- 5. Woodin T, Carter VC and Fletcher L. Vision and change in biology undergraduate education, a call for action--initial responses. *CBE life sciences education*. 2010;9:71-3.
- 6. Bédard D, Lison C, Dalle D, Côté D and Boutin N. Problem-based and Project-based Learning in Engineering and Medicine: Determinants of Students' Engagement and Persistance. *Interdisciplinary Journal of Problem-Based Learning*. 2012;6.
- 7. Gyori B. Mentorship Modes: Strategies for Influencing Interactive Learners. *Interdisciplinary Journal of Problem-Based Learning*. 2012;7.
- 8. Schaffer S *et al.* 2012. Self-efficacy for cross-disciplinary learning in project-based teams. *Journal of Engineering Education*, 101: 82-94.
- 9. Colley K. 2008. Project-based science instruction: A primer. *The Science Teacher*, 75(8): 23-28.
- 10. Bringle RG dand Hatcher JA. Campus–community partnerships: The terms of engagement. *Journal of Social Issues*. 2002;58:503-516.

Budget, Justification, and Cost Sharing Plan for BioFabLab: Workshop

EPI Shared (CAS/OVPR)

A. Salaries, Wages (Senior Personnel) \$0

\$5,250*

The College of arts and sciences (CAS) will cover instructional salary for Dr. Andrew Mead, the instructor of record in the amount of \$5,250. *CAS will also assume the full salary of Eugene Korsunskiy, who will provide course-planning support and teach 3 seminar sessions. (See attached letter of support.)

B. Burlington Generator

\$2,500

\$2,000

Students will have general membership access to Burlington Generator (BG) space and equipment for the duration of the semester. The Office of the Vice President for Research (OVPR) will cover membership in the amount of \$2000 through an agreement with BG. (See attached letter of support.) In addition, BG will provide basic instruction and safety certification for 8 students and 2 instructors in five key areas: i) Rapid prototyping, ii) microelectronics, iii) woodworking, iv) cold, and v) hot metal working (\$2000). Students who require more in-depth instruction in any of these areas will have access to a common pool of 20 hours of additional instruction (\$500).

C. Materials \$7,500 \$0

This covers the anticipated cost of all materials necessary for the construction of main course projects. Since all potential projects involve a computer programing and instrumentation control component, \$2,000 is set aside for a dedicated laptop computer capable of running Matlab software, and communicating with external devices. An additional \$1,000 is set aside for AV equipment to record demonstrations and final projects.

EPI grant share: \$10,000

CAS/OVPR share: \$7,250*

Total cost: \$17,250*

Appendix I

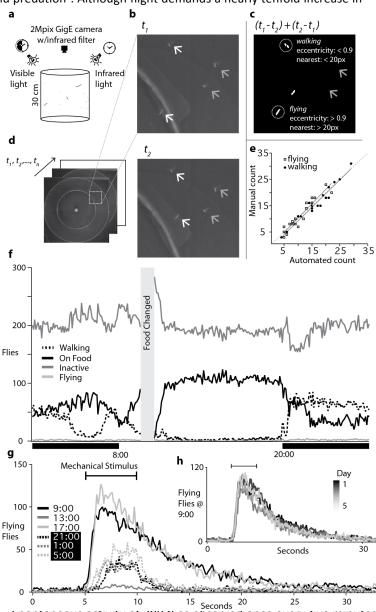
ExerFlyzer: A High-Throughput System For Inducing and Quantifying Flight Behavior in *Drosophila*Over Extended Time Periods.

Andrew F. Mead, Ravi Nagori, Jim O. Vigoreaux *Univesity of Vermont, afmead@uvm.edu*

Every living organism possesses homeostatic mechanisms to cope with unaligned temporal patterns of energy availability and energy expenditure imposed by its living environment. In the wild, *Drosophila melanogaster* is observed to fly kilometers/day in search of food, and to use flight to avoid predation¹. Although flight demands a nearly tenfold increase in

body-wide metabolic rate², no analog to this physiologically challenging behavior exists in the laboratory as standard housing conditions obviate the need for and severely restrict flight. Recently Drosophila has emerged as an important model for the study of age-related diseases, such as diabetes and heart disease, associated with high calorie diet and minimal physical activity. While dietary restriction has been demonstrated to affect fly physiology, especially with age⁴, little is understood of the effect of the sedentary lifestyle imposed by the laboratory environment, or of the effect of flight on wellconserved homeostatic mechanisms that to lose function with age. To address this, we have developed the ExerFlyzer - an environmental chamber and imaging system that uses an array of vibration motors as a mild mechanical stimulus to induce flight, while continuously quantifying specific locomotory behaviors in large cohorts (100s) of flies over timescales of seconds to weeks. With code developed in Matlab, the ExerFlyzer identifies flies in motion between sequential images, using velocity to differentiate between flying and walking. Infrared illumination allows for 24-hour observation. A multi-day study of 300 wild type (Oregon R) flies shows a consistent pattern of spontaneous activity, as well as a robust and repeatable response to flight stimulation that is highly time-of-day dependent (Figure). In addition to establishing flight exercise as an independent variable for the study of homeostasis mechanisms, the ExerFlyzer holds potential as a platform for observing the effect of genetic manipulations, interventions, and the circadian clock on Drosophila behavior.

¹Coyne JA et al, 1981 *Am. Nat.* 119:589–95 ²Lehmann, FO et al, *J Exp Biol*, 2000. 203 Pt 10: p. 1613-24. ³Demontis, F et al, *Dis Model Mech*, 2013. **6**(6): p. 1339-52. ⁴Partridge, L et al *Mech Ageing Dev*, 2005. 126(9): p. 938-50.



Spontaneous activity of 300 flies observed once every five minutes for 24 hours. (g) Flight response of 300 flies to five seconds of mechanical stimulation (mild chamber vibration) at different times of day. (h) Repeated stimulations over five days in the same group shows no long-term desensitization.



September 25, 2015

Brian Reed, Associate Provost for Curricular Affairs University of Vermont

Dear Provost Reed,

I am writing in support of the proposal BioFabLab: Workshop, being submitted to the Engaged Practices Innovation (EPI) grant program by Andrew Mead of the Department of Biology, and Eugene Korsunskiy of the CAS Dean's Office and the Department of Psychological Science.

This project takes an innovative approach to increasing student engagement and fosters collaboration with a vibrant and growing segment of the Burlington innovation/maker community. I believe it will be a valuable contribution to our development of the first-year experience. In partial satisfaction of the grant's cost-sharing requirement, the College of Arts and Sciences will cover instructional salary for Dr. Mead, the instructor of record for the proposed three credit-hour course, in the amount of \$5250. Eugene Korsunskiy will be involved in course development and will lead three seminar sessions during the semester. His time will also be covered by the College of Arts and Sciences.

Sincerely,

William Kalls

Interim Dean, College of Arts and Sciences



September 29, 2015

Brian Reed, Associate Provost for Curricular Affairs University of Vermont Burlington, Vermont 05401

Dear Provost Reed.

I'm writing to express my enthusiasm for the prospect of deepening Generator's relationship with the University of Vermont by developing a collaboration with UVM Biology. From what I can assess in Dr Mead's proposal, there is real potential for tremendous mutual benefit. I anticipate many fruitful relationships to arise between UVM students and researchers, and members of the Burlington maker community if we get this pilot effort right. The course planned for the coming spring will provide important learning opportunities for both sides as we build toward larger projects down the road.

Under the terms of our collaboration, detailed in the budget portion of the grant proposal, Generator will provide membership to students and instructors for the duration of the spring semester. This membership provides access to our workshops (hot and cold metal work, rapid prototyping, microelectronics, and woodworking) and certification courses in which well-trained and experienced members provide basic instruction and safety certification in our workshops. As need arises, students will be welcome and encouraged to seek out more in-depth training in any area in addition to specific tools.

My expectation and enthusiasm for this effort arises from real benefits that will happen outside formal training – while at Generator, students will have the chance to interact on a daily basis with an incredibly diverse and skilled community of makers, and in doing so both contribute to the knowledge base of our community, and learn from it. It will be exciting to observe the spontaneous collaborations that emerge as a result of proximity and the rubbing together of adjacent knowledge and skills.

Many thanks for your support, Provost Reed. I look forward to meeting at some point and hope to share the results of our joint efforts.

Sincerely,

Lars Hasselblad Torres



Richard A. Galbraith, MD, PhD Vice President for Research

September 28, 2015

Dr. David Rosowsky, Provost University of Vermont 348 Waterman Building 85 So. Prospect Street Burlington, VT 05405

Dear Dr. Rosowsky:

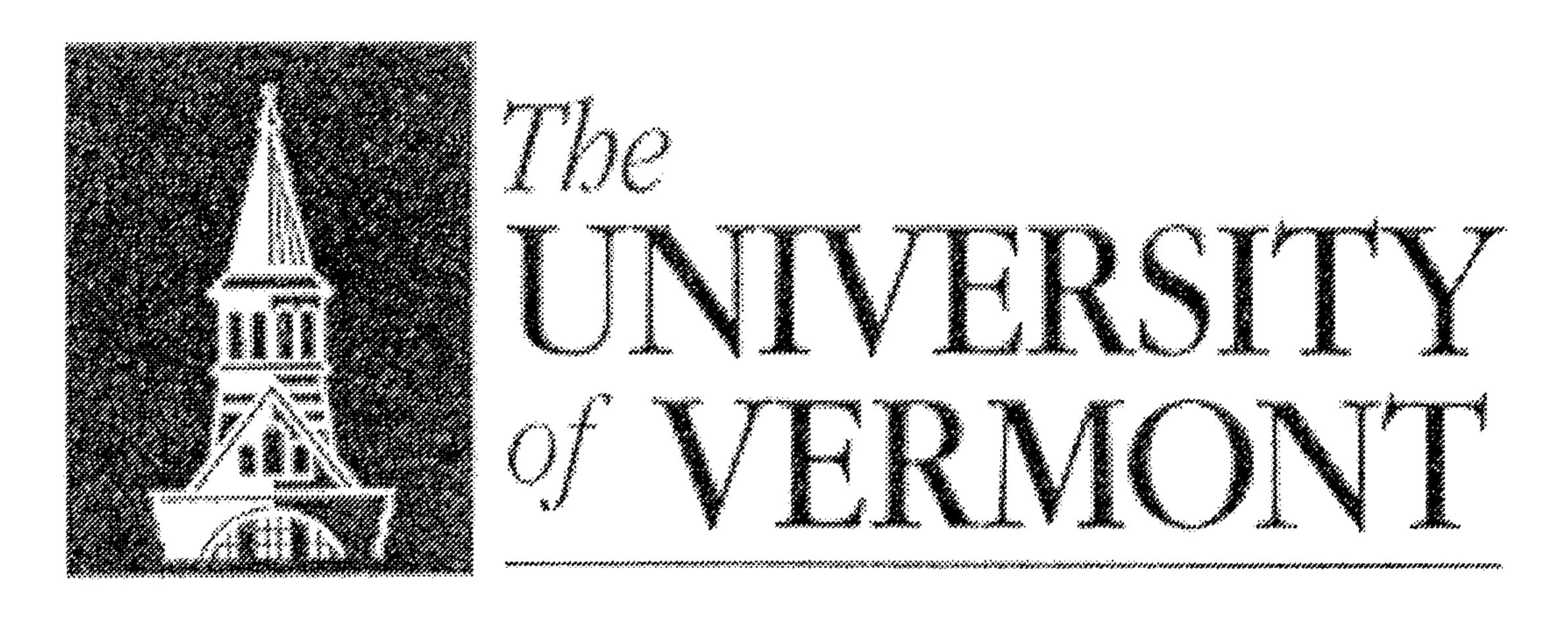
I am writing to support the collaboration between the College of Arts and Sciences and Burlington Generator described in the BioFabLab: Workshop Proposal to the Engaged Practices Innovation Grant Program. OVPR has developed a close relationship with Burlington Generator and this project represents exactly the kind of collaboration this office hopes to encourage.

To satisfy cost-share requirements of the grant, OVPR will contribute support in the form of membership access to Burlington Generator for all students and instructor staff in the amount of Two Thousand Dollars (\$2,000).

Sincerely,

Richard A. Galbraith Vice President for Research

Attached: BioFabLab Workshop Abstract



Department of Biology, Marsh Life Sciences Bldg., Burlington, VT 05405 Phone: (802) 656 2962, Fax: (802) 656-2914, email: scahan@uvm.edu

September 28, 2015

Dr. David Rosowski
University of Vermont Provost
85 South Prospect Street
348 Waterman Building
Burlington, VT 05405-0160

Dear Provost Rosowski,

I am writing to express my enthusiastic support to the Engaged Practices Innovation grant program proposal being submitted by Dr. Andrew Mead of the Department of Biology and Eugene Korsunskiy of the Dean's office. Both the pilot course, detailed in the EPI proposal, and the subsequent First Year Experience course that it will support, align well with the department's overall vision of developing a stimulating, high impact curriculum for early undergraduates. The concept will be particularly valuable for engaging with students undecided in their choice of major; by presenting science as a creative, interactive process, these students may feel empowered to embark on a path toward a STEM career.

I am in full support of dedicating three credit hours of Dr. Mead's effort to teaching this course in the spring of 2016. The Department of Biology faculty have embraced the project and their supportive role in making it work. They have generously offered use of research laboratory space for work on student projects, and their assistance in identifying undergraduate students to participate in this exciting course.

Sincerely,

Sara Helms Cahan Interim Chair

Department of Biology