The UAlberta geekStarter Science Hardware Hackerspace

Abstract

The evolution of technology has entered an exciting phase where great opportunities for hands-on enrichment of undergraduate science education are exploding onto the scene. It has become feasible to provide undergraduate access to a much broader range of hands-on possibilities than ever before. This TLEF proposal requests funding for undergraduate research assistantships to accelerate the development of a new, experiential-learner-focused Science Hardware Hackerspace (also known as "the Shack"). The top priorities of the Shack are the promotion of hands-on hardware skills, experiential learning in interdisciplinary science, and the facilitation of creative activities and fostering of an entrepreneurial spirit. The undergraduate experience will be enriched through student exposure to real-world problem solving, construction and deployment of new instruments, and opportunities for students both to learn from and to mentor their peers. The Shack will lead directly to substantial curricular enhancement, particularly in years 2 – 4 of numerous Science programs.

Keywords: Experiential learning, hands-on skills, experimental science, interdisciplinary community, course enrichment, entrepreneurial culture

Description

"He will find that a taste for amateur carpentry and making things with his own hands unites him with the world of science." – Harold Wright, 1933 [1]

Project-based, hands-on learning has long been recognized as the most effective means of extending undergraduate science education beyond the fixed boundaries of course curricula [1-4]. The effectiveness of a project-lab derives from enabling students to follow their own enthusiasms, in a more 'real-world' encounter with subject matter.

Historically, the resources required to support such opportunities for the undergrad population-at-large have limited major project lab initiatives to very selective, smaller schools. The new, widespread availability of advanced instrumentation in low-cost commodity and do-it-yourself form has changed the resourcing equation. Many people don't yet realize that the smartphone in their pocket already packs a powerful science lab.

The "new industrial revolution" [5] is knocking on the doors of research labs and making high-end functionality available at dramatically lower cost. A recent challenge to build an atomic force microscope, one of the key tools of nanotechnology, for $500 in five days ran as a contest between students in the UK and China [6]. An even more recent report describes an apparatus built with LEGO to illustrate the new Système International (SI) definition of mass and to measure Planck's constant *h*, the quantum parameter introduced in the 20th century to repair a breakdown of 19th century descriptions of nature [7].

At the same time, a small and shrinking proportion of our undergraduate population has any

opportunity to design or build components of scientific apparatus [8], despite the fact that skills gained through such projects are highly complementary to classroom learning, and often more transferrable to other contexts.

These observations come together in this request for TLEF support of the development of a "do-it-yourself makerspace" for science hardware, which we call "the Shack". The Shack will create a collaborative community of practice organized around hands-on science. Students will move between individual and teamwork seamlessly within a mentored environment, to both learn and practice new skills. Through the synthesis of their curricular knowledge from the classroom, their basic psychomotor and application skills in the lab, and the guidance and mentoring in the student-directed "Shack" environment, students will improve their critical thinking and problem solving skills in an interdisciplinary milieu.

We are applying simultaneously to TLEF, the AITF geekStarter program, and to the CFI partnership program with Canada Research Chairs (see Fig. 1), to bring the Shack fully to fruition in a format that leverages the CCIS building. We will hire 18 – 20 undergraduate research assistants in total over the course of three summers: four in 2015, seven in 2016, and seven or more in 2017. The 2015 team will include students from at least three Science departments, and this will ramp up to representation from all seven departments in the summer of 2017. TLEF support will accelerate the development of the Shack and transform it into a sustainable, interdisciplinary student-focused space.

The TLEF Shack Team will become role models, establishing benchmarks for what can be achieved, and leave a legacy of information and procedures that will help sustain the Shack long into the future. The students will work on their own Shack projects and on all aspects of development of the facility, including animation of workshops, and mentoring in general.

The Shack will seamlessly serve several complementary interests of the UAlberta community, through contributions to: experiential learning and course enrichment; research experience and outcomes; and the entrepreneurial mindset and culture. These complementary goals are reflected in our proposed budget through co-funding, from partner organizations interested in all of the outcomes but in unequal measure.

This complementary arrangement is illustrated schematically in the Venn diagram, Fig. 1, and is reflected in the construction of the proposed budget. There is a remarkable resonance of the skills-development, training, outreach and entrepreneurial goals of the Shack with the Province's geekStarter program. A paired application is under consideration by geekStarter (submitted 06 Jan. 2015, decision expected late Feb. 2015). Similarly, the research outcome and training goals of the Shack will be co-supported through the CRC program, and with equipment infrastructure by the CFI John R. Evans Leader's Fund - Partnerships [9]. All of this is additionally supported by cash commitments from the Faculty of Science and by in-kind contributions in the form of technical support already being received from the Department of Physics and from NINT. A modest foundation of electronic and mechanical components, tools, and physical space has been established already, through support from the Department of Physics and geekStarter, nucleated by an event for high school students.

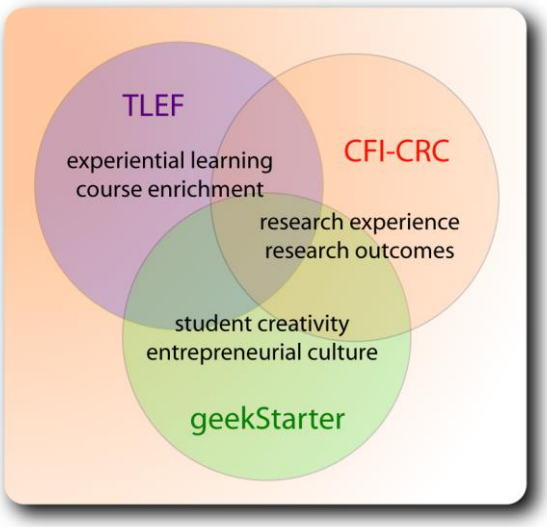

Fig. 1. A representation of the scope and overlap of Shack contributions to our community of scholars. The complementary functions of the Shack will in turn be supported by complementary funding.

Sustainability

Over a longer term, a growing proportion of Shack activity will be supported by researcher grants and by funding sourced by the students themselves. The "statement of interest" forms submitted to geekStarter by students and advisors seeking support are great templates for Shack proposals, and will require very little modification. In start-up Shack activities already in progress, faculty members present students with specific hardware challenges of relevance to research and/or teaching activities, and help provide the resources needed for workable solutions. These "programmed" activities lend focus to initial skills-development [10].

The proportion of Shack projects defined by students will grow with time. Advanced projects will require a short proposal. Help will be available in the form of periodic proposal boot camps. In addition to technical requirements, the proposal checklist will address safety concerns, intentions to open-source or protect IP; possible crowdfunding; and ethical concerns. UAlberta already has much of the non-hardware hackerspace functionality covered by eHUB, U of A's in-house entrepreneurial accelerator. eHUB has confirmed the value of the Shack as a complement to their effort and willingness to work together [11].

The Shack operating model will draw from parallels with how the UAlberta nanoFAB has been managed successfully for the past 15 years. The keys are a multi-talented and energetic coordinator, assisted by an ad-hoc committee of interested faculty. The Shack will be an 'open-access user facility', operated within the Faculty of Science for the benefit of all interested UAlberta students. The proposed coordinator is Ross Lockwood. Dr. Lockwood was instrumental in the development of the Shack idea in 2014, even providing inspiration during his mission in the simulated-Mars habitat on Mauna Loa from April to July [12].

Workshops highlighting the equipment in the Shack will be run semi-regularly, with very low barriers to entry, ensuring that students from all backgrounds have access to the tools and knowledge necessary to make their ideas a reality. Workshops will be run by the Shack coordinator, but also arranged through specialists within the Faculty and the community-at-large. For example, electronics and soldering may be taught in collaboration with the Department of Physics' Electronics Shop. Student mentorship will also play an important role, with student "experts" teaching their peers about the correct methods for certain tool use. Part-time student supervisory positions will keep the shop open evenings and weekends – to ensure that what people are doing is safe (additional safety training, no working alone outside regular hours). These could be internship, community service learning, and volunteer positions.

Hands-on projects will be supplemented by lectures for and by students, and seminars on problem solving techniques. Innovative efforts in science communication [13] and design [14] will be pursued in partnership with the Faculty of Arts. There will be a Shack Speaker Series sponsored by geekStarter, featuring distinguished visitors who will give public talks. The Shack will run contests, and have hack-a-thons organized for it by Startup Edmonton and other partners.

A physical starting point for the Shack in CCIS consists of two rooms allocated by the Physics department in CCIS (Oct. 2014, access keypads already installed): L2-209, at a high traffic location near large undergraduate lecture theatres and the first-year physics labs, for routine access by all students; and L1-330 (in a less accessible spot, in the midst of our research labs) for equipment requiring more safety protocols and higher levels of training. The Faculty of Science will endeavour to allocate an inspiring, interdisciplinary space for the Shack by the end of the TLEF project. The communal space will complement departmental nodes developing now [15].

Student hands-on skills acquisition and enriched experience are the paramount objectives, but the advantages from a focus on creative utilization of sophisticated low-cost instrumentation extend well beyond the skills and experience gained by our students. There will be direct payoff in the evolution of course-based undergraduate laboratory offerings. In physics, this is a more promising avenue for updating labs than off-the-shelf commercial offerings, which do not feature the same performance-for-the-price nor agility in response to new ideas. Quantum optics and biophysics experiments will be developed for the third-year Phys 397 lab. More broadly, the Shack is in concert with the trend towards an expanded menu of research-based course offerings, capstone projects, and degree certificates.

Evaluation and Dissemination of Results

Success will initially be measured by student participation, with student attendance as the primary metric. It is expected that a core-group of students will develop around the Shack and its philosophies in general in very short order.

Project write-ups on the Shack's self-hosted MediaWiki will be mandatory, and students will be encouraged present their work on campus, and to invite collaboration locally and globally. The number of projects hosted, whether "in-progress", or "finished" will reflect the number of hours being spent in the Shack.

Outreach through social media is also critical for student engagement. The Twitter handle @ScienceHackers has been reserved, and a Facebook page Science Hackerspace has been created. Social media metrics from the Shack's website and blog, Facebook page, and Twitter account will be aggregated to document community involvement.

The ultimate indicators of success, interwoven with dissemination, will be the publication and commercialization of ideas that have been fostered within the Shack, and the adoption of Shack hardware in experimental science courses.

In addition to the science learned on a need-to-know basis by individual students as a result of specific projects, educational outcomes will derived from students' abilities to master skills native to the tools available in the Shack.

One method of measuring and disseminating these outcomes may be through the creative use of "badges" or "achievements". Students today will be immediately familiar with this

type of reward system, as it is ubiquitous in modern gaming, as well as the "gamification" of other activities such as fitness and health. Student profiles highlighting their skills will also serve to communicate those skills within the context of the Shack, allowing students to quickly find mentors to learn new skills.

Summary

> "It has always pained me that when an English teacher asks a student to write about 'my summer vacation', the result, however lame, is a more original product than anything done by most students in their science course." [3]

The next transformative phase in the evolution of science hardware is underway. The Faculty of Science has committed "to enrich a vibrant learning environment for the discovery, dissemination, and application of scientific knowledge through teaching and learning, research and creative activity, community involvement, and partnerships." This TLEF proposal, through the co-funding of 18 – 20 undergraduate assistantships and a multi-talented coordinator over three years, will realize a compelling opportunity for sustainable and cost-effective enrichment of the undergraduate experience.

The Shack, in its fully realized incarnation, will help dissolve barriers between disciplines from the ground up, and allow significant numbers of students annually to enjoy direct exposure to an interdisciplinary learning environment, acquiring hands-on skills near the frontier of instrumentation.

Currency with state-of-the-art technology will be maintained, informed by the latest research instruments and methods. This focus, and the Shack's intrinsic interdisciplinarity, will differentiate it from the complementary makerspaces that have inspired us [16]. Other universities are already active in this general space. UBC has something similar, within the context of its Engineering Physics program [17]. Waterloo has an operation related to some of what is being proposed here, with a "strong focus on synthetic biology and medical technologies" [18]. The Shack will fill an important niche within the UAlberta ecosystem.

References

1. Harold Wright, in "University Studies, Cambridge 1933" (H Wright, ed., 1933, p. viii). Wright refers to PMS Blackett's chapter, "The Craft of Experimental Physics", wherein Blackett notes "the experimental physicist is a Jack-of-All-Trades, a versatile but amateur craftsman. He must blow glass and turn metal, though he could not earn his living as a glass-blower nor ever be classed as a skilled mechanic; he must carpenter, photograph, wire electric circuits and be a master of gadgets of all kinds; he may find invaluable a training as an engineer and can profit always by utilising his gifts as a mathematician." (p. 67).

2. John King, "On Physics Project Laboratories", Am. J. Phys. **34** (1968), pp. 1058-1062.

3. "LabNet: Toward a Community of Practice", R. Ruopp *et al*., eds., (Erlbaum Associates, Hillsdale NJ, 1993). Within this volume, King summarizes student survey responses from a quarter-century of project labs at MIT, to document the efficacy of the concept (p. 281).

4. The late John G. King is also co-author with Paul Gluck of the new book, "Physics Project Lab" (Oxford UP, Nov. 2014), based on a half-century of project-based learning.

5. Chris Anderson, "Makers: The New Industrial Revolution" (Crown Business, 2012).

6. "Students build LEGO AFM", Microscopy and Analysis, (Wiley, Nov. 2013), p. 35.

7. LS Chao *et al*., "A LEGO Watt Balance", arxiv.org:1412.1699v1 (Dec. 2014).

8. Excellent training opportunities will always arise through one-on-one mentoring from faculty members or graduate students, but these positions are relatively rare. The minimum GPA for an NSERC undergrad summer research assistantship has been 3.9 in recent years.

9. Proposals submitted Oct. 10, 2014, decisions expected Apr. 2015. The CFI proposal is entitled "Microwaves for nanoscience: off-the-shelf and do-it-yourself". The tools requested for the Shack – multi-material 3D printer, benchtop lathe and mill, 'wetware' tools for bottom-up self-assembly nanofabrication – all now enjoy physical incarnations permitting very cost-effective and safe utilization by students.

10. Within Physics alone, in addition to many active, individual research groups, the Shack has natural resonances with the UofA Observatory, the Institute for Space Science, the Institute for Geophysical Research, and the Centre for Particle Physics.

11. eHUB letter of support from M Lounsbury, T Briggs, Q Rasi, Jan. 11, 2015.

12. Hawai'i Space Exploration Analog and Simulation, Mission 2 (http://hi-seas.org/?cat=64) (Ross also spearheaded the UAB Observatory's outreach program.)

13. For example, the teaching of improvisation as emphasized at the Alda Center for Communicating Science at Stony Brook (http://www.centerforcommunicatingscience.org).

14. For example, the renewed emphasis on drawing skills within the context of science, technology, engineering and math education, emerging at the Rhode Island School of Design and elsewhere (http://stemtosteam.org).

15. A new computer science Arduino makerspace has opened in Athabasca Hall, prompted by many of the same motivations as the Shack physics 'node'.

16. Locally including Edmonton New Technology Society, EPL Makerspace, JP school .

17. http://projectlab.engphys.ubc.ca

18. http://velocity.uwaterloo.ca/science/