

REVIEW

Gathering for Open Science Hardware 2016

Shannon Dosemagen*, Max Liboiron† and Jenny Molloy‡

Without hardware, there is no science. Instruments, reagents, computers, and other equipment are essential for producing systematic knowledge. Yet, current supply chains limit access and impede creativity and customization through high mark-ups and proprietary designs, compounded by proprietary hardware licenses and patents. Open Science Hardware (OSH) addresses part of this problem by sharing designs, instructions for building, and protocols. Expanding the reach of OSH within academic research, NGO initiatives, citizen science, and education has potential to increase access to experimental tools and facilitate their customization and reuse. We organized with others the “Gathering for Open Science Hardware” (GOSH) in 2016 to address what we see as the primary barrier to OSH: early adopters are disparate and separated by geographical and disciplinary borders which limit interaction, exchange and community building. This inaugural gathering brought together 50 of the most active developers, users, and thinkers in the OSH movement, complemented by expertise from diverse backgrounds, to seed a global community. This article provides a review of the activities and debates we conducted at GOSH 2016.

Keywords: open science hardware

Introduction

What is the Gathering for Open Science Hardware (GOSH)?

Without hardware, there is no science. Instruments, reagents, computers, and other equipment are essential for producing systematic knowledge. Yet, current supply chains limit access and impede creativity and customization through high mark-ups and proprietary designs, compounded by proprietary hardware licenses and patents. Open Science Hardware (OSH) addresses part of this problem by sharing designs, instructions for building, and protocols. Expanding the reach of OSH within academic research, NGO initiatives, citizen science, and education has potential to increase access to experimental tools and facilitate their customization and reuse. A growing number of people and organizations around the world are developing and using OSH (e.g. Baden et al., 2015; Pearce, 2014), but a coherent, self-organizing international community has yet to emerge that can drive the required social change within institutions: effecting change through laws, policies and common practice that would make open science with open hardware the norm.

We, with others, organized GOSH 2016 to address what we see as the primary barrier to OSH: early adopters are disparate and separated by geographical and disciplinary borders which limit interaction, exchange and community

building. This inaugural gathering brought together 50 of the most active developers, users, and thinkers in the OSH movement, complemented by expertise from diverse backgrounds, to seed a global community. Now in its second year with a gathering in Santiago, Chile in 2017, GOSH fosters a community to overcome these difficulties, based on commonalities in approach and a need for similar standards, best practices and enabling technologies. Many developers of open hardware for science are highly active Internet citizens and already share designs and information online, often under permissive licenses. Others are new to the movement, but lack colleagues who can introduce them to various platforms, licenses, and other resources. GOSH aims to foster a self-organized community invested in OSH that spans a diverse range of disciplines, geographies, and motivations.

Growing Towards GOSH 2016

Discovery and innovation have long been built upon scientific hardware, but despite considerable advances in technology, many scientific endeavors are being held back by lack of access to hardware for even routine experiments. This limits the ability of groups to engage in the scientific process, especially groups outside of well-funded research institutions. Even for those with the resources to purchase equipment, customization to address local experimental setups remains challenging, expensive, and in many cases, impossible. This, among other compounding factors, can restrict creative expression in experimental design and restrain scientific progress and basic research, particularly for scientists in non-profits, community

* Public Lab, US

† Civic Laboratory for Environmental Action Research, CA

‡ University of Cambridge, GB

Corresponding author: Shannon Dosemagen
(shannon@publiclab.org)

groups, low-income countries and regions, and disaster zones (e.g. AOSTI 2014, Gibbs 1995). At a more pragmatic level, if scientists can easily reproduce and alter their research hardware, they will not be left stranded by non-functioning equipment, a commercial vendor going out of business, or other unanticipated changes to their routines and resources.

GOSH intersects with a strong, dispersed movement towards open access to scientific knowledge (e.g. Suber, 2012; Joseph, 2013), data (e.g. Boulton, 2016; Pampel and Dallmeier-Tiessen, 2014), software (e.g. Eglén, et al. 2016; Hey, 2015) and open participation in the scientific process (e.g. Delfanti, 2016; Franzoni and Sauermaun, 2014). Proponents of open science overlap with OSH advocates and users because the idea of sharing instrumentation designs that allow others to replicate experiments complements their vision for more reproducible and transparent research. These are the shoulders we stand on, and we propose that including hardware alongside these movements can mitigate some of the problems described above.

Movements building on movements is common: the Open Source Hardware Definition¹ (2010) builds on the Free Software Definition, and subsequent derivations, and the Open Source Hardware Association² (OSHWA) has been established to manage the definition, promote best practices and organize an annual Open Hardware Summit covering aspects from licensing to education to manufacturing and business models to certification schemes.³ Open Hardware Licenses have proliferated and several comparative projects have characterized the legal options for sharing open hardware (reviewed in Katz 2012), although many developers continue to use licenses designed for software or general copyrighted content such as copyleft⁴ and Creative Commons.⁵ The CERN Open Hardware License⁶ seeks to address the needs of hardware sharing in a scientific context.

GOSH exists to build on these open hardware advances and the progress of the open science movement to address the unique needs of science hardware that are not always represented in our sibling movements, such as validation, calibration, and reproducible protocols. We aimed to represent many existing initiatives at GOSH 2016 in Geneva, Switzerland.

GOSH 2016: the Gathering

The GOSH! Grounding Open Source Hardware summit in 2009 was the birthplace of the Open Source Hardware And Design Alliance,⁷ who first explored certification and registration of open hardware designs. The Gathering for Open Science Hardware was independently named but we were pleased to continue the legacy and invite organizers of that original meeting. GOSH 2016 came together in early 2015 through a group of individuals, including two of the authors, representing organizations and projects that focused on a diverse spread of topics related to OSH. The organizing committee came from University of Geneva, Public Lab, University of Cambridge, Hackteria, Gaudi Labs, PhotosynQ and Arable (at the time Pulsepod.io). We collaborated on

creating a space for a community to start to grow around the intersections of science, laboratory work, DIYbiology, citizen science, and community science where they met with OSH.

We brought together 50 participants in early March 2016 over the course of four days at the European Center for Nuclear Research (CERN) IdeaSquare in Geneva, Switzerland. The table below offers a sample of the communities and community members we drew upon for the gathering and the full list of participants can be found at: <http://openhardware.science/2016participants/>.

Area	Community	Invitee
Biology and microscopy	DIYBio community	Gaudi Labs, OpenLabTools
Environmental Monitoring	DIY sensing & citizen science	SafeCast, Public Lab, CLEAR
Education	Open Education	Backyard Brains, TRoND Africa
Making	DIY Makers, Fab Labs	Arduino

The core theme of the first three days of GOSH were developed with a focus on participants moving from grand challenges (day one), to enabling solutions (day two), and finally to sharing what we know (day three). Day four featured a workshop on crowdfunding science as a form of financial support for OSH projects.

Combining unconference with programming was intended to provide space for people to create sessions together, to work on technical components of projects and to hear from people working across the spectrum of OSH projects.

The main topics that emerged from the spontaneous unconferences sessions clustered around several core issues:

Civic, citizen, and community science

Issue: OSH enables communities and non-accredited scientists to engage in research so communities can assess and address community research objectives. However, these communities are often overlooked in the creation of OSH, and partnerships between accredited and unaccredited researchers and their respective institutions are not common.

Our concerns: ensuring goals are shared between citizens and accredited scientists; increasing emphasis on the process as well as the end product; how to best address power differentials between parties.

Design

Issue: Proprietary and/or hard-to-use design software is often cited as a reason to reimplement open projects from scratch, rather than use an existing design. Private and proprietary design also prevents people getting involved with open hardware in the first place.

Concerns: How do we make design files (e.g. CAD files) open and editable, leaving room for different preferences, needs and platforms?

Diversity

Issue: Technology design and scientific and technical cultures often exclude women, people of colour, Indigenous peoples, elders, children, people with disabilities, LGBTQ+ community members, people in rural areas, and people in low GDP countries, among others. Yet, accessibility and inclusion are hallmark values of OSH. This includes diverse ways of creating knowledge.

Concerns: Our community suffers from the same lack of diversity, even though access to and control of scientific technology for diverse modes of inquiry and use is part of our goal. This needs to be addressed at future GOSH events. At the same time, how do we ensure the OSH movement is aware of and open to various forms of knowledge?

Documentation

Issue: Most projects advertised as “open” are not well documented. Documentation describes the target group, modular architecture, functionality, testing and handling of the product, including its source files and assembly instructions for re-creation or modification. Clear and thorough documentation is imperative to OSH as one of our goals is that others can build, use, and modify our hardware.

Concerns: Standards of documentation should be created and promoted by GOSH. Much can be gained from sharing OSH in an appropriate way, including clarity about the requirements of a project in terms of skills, tools, and resources and the target group for the documentation.

Education and training

Issue: Many OSH tools require training or workshops so tools are built and/or used effectively, and to encourage newcomers to the practice of OSH.

Concerns: Spaces for training on OSH development must be created not only in existent community spaces for technological and scientific exploration, but within university settings, so as to create a culture of public service and openness to the community.

Government + Institutions

Issue: We often have to work with or within government, academic, industrial, and other institutions that can restrict or support open and free hardware development for science.

Concerns: Partnering with institutions with different intellectual property (IP) practices can restrict open hardware development and sharing; best practices and guiding principles for institutional relationships would aid the movement.

Manufacturing

Issue: Obtaining OSH often involves a significant investment of time and/or access to expensive equipment. From the developer’s perspective, manufacturing is one of the biggest obstacles to scaling up a project and enabling more people to use it.

Concerns: While start-up companies can – and have – been founded to make specific open hardware available to those without facilities or time (e.g. Seeed Studio, Adafruit), many others do not have the resources to do so.

Metrics for impact

Issue: How do we tell if our overall movement, our individual projects, and our individual technologies are useful and impacting society more broadly? Audiences for these metrics include: universities, funding agencies, users, designers/builders, our peers, policy makers, media, and community groups.

Concerns: Some impacts are hard to trace (especially social and cultural change); other impacts are easier to measure but difficult to integrate into the metrics used in our various institutions and particularly universities.

Scale

Issue: Open hardware projects have a variety of successful outcomes – from a well documented project that anyone can build (e.g. RepRap 3D printers), to a large company selling devices which have open designs but are rarely built by anyone but the company (e.g. Adafruit). Each requires a different strategy to scale.

Concerns: This matrix of outcomes and motivations can make thinking about how to scale OSH a daunting task. How do we account for these differences, but still move towards the goal of making OSH ubiquitous and widely available?

Sustainability

Issue: Creators of open hardware have a wide range of motivations: from increased income to personal enjoyment. However, OSH creators face a unique set of opportunities (e.g. viral adoption of open designs) and pitfalls (e.g. misalignment with the objectives of their university tech transfer departments) which require different strategies to create a sustainable project.

Concerns: How can the OSH community collectively develop strategies for a broad range projects and motivations?

Validation and calibration

Issue: Many OSH tools measure things and must be precise and/or accurate in those measurements.

Concerns: When someone makes an OSH tool, how do they know it works?; How do we make sure our tools are measuring the same things in the same ways?

Some collaborative efforts towards the end of GOSH 2016 began to address some of these issues, such as two major outputs described in the next section, the GOSH manifesto and roadmap. Additional activities post-GOSH 2016 have included the first regional GOSH workshop in Brazil during October 2016, presentations and workshops on GOSH at venues such as MozFest and Border Sessions, articles referencing GOSH in *Nature*,⁸ *The Guardian*,⁹ *Labtimes*¹⁰ and *Makery*¹¹ and collaboration around this journal, *The Journal of Open Hardware*, whose editorial board includes thirteen participants present at GOSH 2016.

GOSH Manifesto

Despite the different countries, types of technology, employers (or lack thereof), and career goals of those assembled, conversations at GOSH 2016 were consistently

united by the underlying values of participants. For many of us, technical innovations and practices are an extension of our values, not an end in themselves. In response, two GOSH participants, second author Max Liboiron (Civic Laboratory for Environmental Action Research) and Greg Austic (PhotosynQ), began collecting and articulating key values expressed in various workshops, focus groups, and in formal and informal conversations. This became the GOSH Manifesto.

While facilitated by two people, the process of the GOSH Manifesto followed the ethos of GOSH. It started with a survey of GOSH participants about the core values of their practices. We then drafted a Manifesto that followed survey submissions as closely as possible, then opened up the process for collective editing to all GOSH 2016 participants via an online platform and virtual meetings. Twelve participants offered substantive edits, and dozens more weighed in. Participants came to consensus on points of difference. Consensus is not a process of totally even unanimity, but an agreement to move forward given uneven, if final, support. Given the diversity within GOSH, this unevenness is central to the manifesto as a reflection of the larger movement. The final result is a statement of nine guiding principles for GOSH, each with a series of sub-principles. The main principles are:

- GOSH is accessible
- GOSH makes science better
- GOSH is ethical
- GOSH changes the culture of science
- GOSH democratizes science
- GOSH has no high priests
- GOSH empowers people
- GOSH has no black boxes
- GOSH is impactful tools
- GOSH allows multiple futures for science

The full manifesto can be found at <http://openhardware.science/gosh-manifesto/>. The manifesto has over 200 signatures, well over the 50 initial attendees at GOSH 2016, and GOSH members have translated the text into Spanish, French, Portuguese, and Chinese. The process of collectively creating the manifesto, the people who labored to translate it, the countries of origin and affiliation of signatories, and the content of the manifesto itself is what sets GOSH apart from other technical or scientific gatherings: we are a diverse social movement more than the sum of our tech.

GOSH Roadmap

Using the GOSH Manifesto as the basis for the future vision of the community, we are creating a roadmap prior to GOSH 2017 that lays out the potential impacts of OSH and details the actions our community and other stakeholders can take to move the field forward. GOSH community members that are attempting to advocate for OSH approaches within their institutions and at higher levels require evidence and resources to emphasize aspects of importance to research administrators and policy makers, such as improved knowledge transfer, increased participation in science, international exchange,

and accelerated innovation. This evidence is starting to emerge through mechanisms like the CERN survey on Open Hardware as a knowledge transfer mechanism (manuscript in preparation).

Direct promotion and implementation of the roadmap will be key to getting OSH on agendas at an international level and we will publish it and present it at events where key decision makers on science technology and innovation policy are gathered focused on events where other aspects of Open Science are dominant but OSH is underrepresented.

GOSH 2017

GOSH 2017 will reconvene members of the OSHcommunity for a second four-day workshop in March 2017 at the Anacleto Angelini Innovation Centre, Pontificia Universidad Católica de Chile. Based on feedback from 2016, this will have a greater focus on unconference sessions and making activities. The location aims to represent the global nature of OSH, as well as the diversity of approaches outside of practitioners in research-intensive academic settings. The venue in Santiago will enable GOSH to accommodate a larger group of 75–100, again composed of the active thought leaders, developers, researchers, and community conveners of OSH. In response to issues of internal diversity mentioned above, GOSH 2017 has increased representation from outside of Europe and the U.S. and from women compared to the 2016 meeting, while maintaining the spread of organizations in academia, industry, community, and independent groups that proved valuable in 2016. One of the attractive features of Santiago is the opportunity to connect to an active local maker and open hardware community^{12,13} and help facilitate community building for OSH in Latin America, where there are already ongoing efforts in OSH complemented by strong free and open source software and open access movements (Alperín et al., 2008; Alperin and Fischmann, 2015; Costa and Leite, 2016).

While GOSH 2016 focused on mapping common points of interest and bringing the community together, in 2017 we will focus on how to progress as a community and implement the roadmap, seeking reflection and feedback to add inevitable missing pieces and prioritize actions. As the final principle of the GOSH manifesto states, GOSH allows multiple futures for science. Using the roadmap, we intend to: change the norms within established, institutional science so researchers openly share knowledge and technology; so research can happen in or out of the academy, in or out of the lab, in or out of commercial spaces; and so enable science to happen in places it would not usually happen. Such are the changes that a robust GOSH community will foster, and is already doing so in many cases.

Notes

¹ <https://perma.cc/F4UN-787X>.

² <https://perma.cc/JZD3-LV74>.

³ <https://perma.cc/5BB6-97ML>.

⁴ <https://perma.cc/U3F2-W9W6>.

⁵ <https://perma.cc/Z8B5-EPZ6>.

⁶ <https://perma.cc/LLB7-A2MM>.

- ⁷ <https://perma.cc/PEX8-SXXJ>.
⁸ <https://perma.cc/GF7W-ULWH>.
⁹ <https://perma.cc/XAJ7-QJTN>.
¹⁰ <https://perma.cc/N7KQ-QQE7>.
¹¹ <https://perma.cc/24UR-AYSS>.
¹² <http://makezine.com/2012/12/07/the-maker-movement-in-latin-america-an-interview-with-tiburcio-de-la-carcova/>.
¹³ <http://fablat.org/>, <https://twitter.com/fablatam>.

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Competing Interests

JM and ML are members of the editorial board for the Journal of Open Hardware, which is on a voluntary basis. JM, ML and SD are all organisers of GOSH and SD is Executive Director of Public Lab.

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