Open Hardware Creators
in Academia Fellowship

Enabling Practices:

Creating and Advocating for Open Source Hardware in Academia

Introduction

OSHWA began with the concept of amplifying open hardware in academia at the 2020 Open Hardware Summit within four audiences of academia: researchers and professors, students, TTOs, and granting organizations. Throughout 2020, OSHWA crafted a baseline survey completed by the higher education open hardware community. The survey data was compiled and summarized in 2022 by S Wu. In 2022, with the generous support of the Alfred P. Sloan Foundation, OSHWA launched the Open Hardware Creators in Academia (OHCA) Fellowship. Throughout this process from the survey to our reflections of our fellows at the end of the program, we have been listening to topics regarding red tape or stoppers to open hardware in academia, success metrics and impact indicators, necessary skills and unlearnerings, and a host of conversations comparing the creation of open hardware in various university settings. Ultimately we believe these things will drive a shift in mindset of key stakeholders.

The Open Hardware Creators in Academia Fellowship was designed to celebrate open hardware throughout higher education. The Fellowship invited participants to create content to assist other academics in their open hardware journey. This award amplifies the importance of time spent creating information in the academic community that will further the movement as a whole. The fellowship also valued the work of advocating for or creating open hardware and partnered fellows with mentors, industry, and other institutions as a team effort to collaborate, build upon, and expand the work of open hardware being discussed under the academic umbrella.

The one year fellowship provided $50,000 or $100,000 grants to individuals who are leading the way as open source hardware expands into academia. The program supported the fellows as they gave a glimpse into their path of open hardware creators and advocates. Documentation is key to open source hardware, and these fellowships supported the development of how to successfully make open source hardware work across a broad spectrum of academic environments and departments as meta-documentation.

The Open Hardware Creators in Academia Fellowship is designed to:

1. Recognize existing leaders
2. Give those leaders tools to expand their work
3. Encourage the leaders' institutions to recognize and value their work
4. Identify and accelerate the development and dissemination of information about developing open hardware within the context of universities
5. Leverage diversity, equity, inclusion, and justice initiatives to broaden the community of open hardware practitioners at universities
6. Pair leaders with industry mentors to share knowledge

During our fellow meetings, we recognized that in effort to drive broader adoption and greater impact of open hardware in academia, we need to broadly and intentionally amplify the benefits and potential impact of open hardware. We can decrease resistance, increase motivation, and increase the resourcing that drives both creation and adoption of open hardware in academia.

Universities have the mission of educating their communities, but often intellectual property is behind paywalls, hardware is patented, and sharing broadly for the good of humanity has been forgotten. By working with academics who have successfully accomplished open hardware projects in their institutions come the Open Hardware Creators in Academia (OHCA) Fellows. The fellows are one of a kind champions fighting for the good of open source, sharing their work for all, proving paths forward for open hardware in academia. Others can learn from these open hardware leaders in the field, paving the way for a new culture of creation and sharing. Fellows have figured out how to guide open hardware development through a process that is not designed to support that approach. This grant was created to understand how fellows navigated open hardware in academia, how others could follow, and how OSHWA can make it easier for other academics who want to work towards similar ends.

Cohort Participants

Our 2022-2023 cohort of fellows and mentors included nine fellows: AnnMarie Thomas, Carlotta Berry, Dahl Winters, Jonathan Balkind, Kevin Eliceiri, Manu Prakash, Miriam Langer, S Wu, and Zsuzsa Marka, and seven mentors: Brandon Stafford, César Garcia Saez, Chris Chronopoulos, Elizabeth Hendrex, Huaishu Peng, Jinger Zeng, and Joshua Pearce. This documentation is a write up of the 2022-2023 cohort's collective thoughts and writings, facilitated by Lecia Ductan, Alicia Seidle and Allen Gunn. This does not insinuate that all of the participants or their organizations endorse all of the parts of the document.

Four of the nine (44%) fellows and two mentors are BIPOC individuals. Five of the nine (55%) fellows and two mentors are women, and one fellow identified as non-binary. One fellow is neurodiverse. While OSHWA selected from American Universities for participation, 3 fellows have international backgrounds, and roughly half of our mentors have international backgrounds. University types spanned a large range from top tier research universities to small teaching universities. We included a Hispanic-serving university, a religious university alongside a top ten university. Departments spanned from arts to astrophysics. The higher ed institution we had hoped to incorporate but lacked applicants for was a community college.

Forming Enabling Practices

While creating these documents through the lens of shared 'Best Practices', the cohort quickly recognized that their University structures, even limited to an American cohort, were so vastly different, that one set of best practices would not suffice. Some academics owned their research and others did not, some had a form of Tech Transfer Office and others did not, many spanned the landscape of positions one could hold at a University. Some had their Dean's support in open hardware and others did not. Depending on these differences, "best practices" varied drastically. Some enabling practices may not be a one-size fits all solution, but our fellows and the universities they navigate represent a broad spectrum of American universities. We shifted the terminology to enabling practices to encompass more types of universities, where "best" would imply that one university type would be prioritized with which practices work in that system.

The main take away from these sessions collectively was that there is a difference between the creation of open hardware and the advocacy for open hardware to have a place in academia. These roles took different skill sets to move forward, different verbiage, and worked toward different outputs. These conversations were merely a starting point. There is much discussion over time needed to truly force change.

Cohort sessions included:

1. An inventory of Red Tape / Stoppers of open hardware in academia
2. Principles needed to create thriving open source hardware in academia
3. An inventory of skills and competencies needed to succeed when creating open hardware in academia and an exploration of the assumptions we need to challenge as we pursue open hardware goals.
4. Influential personas of power for Adoption of Open Hardware & Creation of Open Hardware
5. Success Factors for OSH in Academia for the Creation and Advocacy of OH in academia

This cohort's introductory meeting was to figure out the common issues with creating open hardware in academia and potential solutions to them, while honoring the fact that this is the first cohort, and our focus was on baby steps to move open hardware forward in academic institutions as a whole, not as specific hardware projects. Our first question posed was 'Where is the red tape within creating open hardware in Universities?' We then created lists of skills and learnings necessary to navigate open hardware in academia. We circled back to a principles conversation, which may or may not be reflective outside this cohort. Finally, we came up with the following personas who may find some of our enabling practices useful: Dean or admins at the University who make decisions about tenure and keep tabs on what research gets funded; Faculty who act as advocates to create road maps into the open hardware space; Practitioners and Researchers who are trying to create open source hardware in academia; and tertiary groups who are users of open hardware but do not create it themselves, and funders with the ability to build open hardware requirements into grants.

Throughout our cohort meetings we discussed the following broad topics that enformed our enabling practices, and further work to be done, including the following points:

- Mapping common issues encountered in creating open hardware in academia, and characterizing and contextualizing the unique aspects
- Exploring and characterizing potential solutions in academia to identified challenges and needs
- Capturing common processes and enabling practices for creating open hardware in academia
- Prototyping a plan for strategically documenting practices for open hardware in the academic context
- Working to situate open hardware leadership within career advancement contexts, in particular defining meaningful metrics for tenure

- Working with your Tech Transfer Office / IP hurdles or constraints
- Building Meaningful Metrics for tenure, for example, what are the specific awards (e.g. NSF Career Awards) / media pieces that would be meaningful
- Reflecting on why open hardware is a relatively rare approach within academia (although it is growing exponentially based on Google Scholar citations- following a similar trend to open source software with approximately 15 year delay).
- Determining Who do we need to empower, what would empower them, how do we need to empower them to create or advocate for open hardware
- Helping OHCA Fellows recognize that successfully producing open hardware within academia is a skill set that is distinct from producing the hardware itself

Principles of the 2022-2023 Cohort

Summary: In academia, right now valuing individual contributions is the norm; rather than valuing open hardware communities, where the value is more about the collaborative contributions. There are enough academics doing open hardware with no clear structure within their institution, which points to the current system of value not working. One conversation that came up continually throughout our cohort meetings was, systematically who is the academic system working for / not working for?

This cohort meeting was no different as participants were asked to list values and beliefs that inform and guide our actions:

- We have a responsibility for stewardship to involve students as they are the future of open science in academia.
- We create equitable, reciprocity and inclusive cultures in our project teams.
- A community supported model will lead to making all projects better, more useful and more robust.
- Value is created by the community/collective and not always the individuals.
- We welcome input from multiple disciplines, positions or levels of seniority.
- Engagement with the community allows others to access the OSH tools through good documentation.
- Good documentation is needed to ensure reproducibility because it allows others to build upon earlier work; documentation is community care.
- Networking can help creators get answers and resolutions to obstacles.
- We share our work because openness and reproducibility enable technical diversity.
- We share our work because reproducibility is a core value in open hardware as it enables the longevity and improvement of a project.

The following words were stated with frequency during our values and beliefs discussion: Open, accessible, communication, networking, reproducibility, who, stewardship, documentation, learning, structures, build, institution, norms, community, sharing, cross-disciplinary, Who, supporting, engagement , understanding, tools, information, population, Reciprocity, education, teaching, involved, adoptions, enabling, empowering, and WHO.

The Good, the Bad, and the Tangible Solutions

Summary: Open Hardware in academia has advantages for many reasons, including the nature of its sharability and portability. However, there are several stoppers at play, which differer based on university type, role and funding mechanisms, such that the group agreed the university as an industry needs a paradigm shift in its thinking of open hardware. Two tangible solutions that benefited the most people in our cohort were outreach and education about open hardware to universities and the need to create a metrics guide for measuring contributions in open source for academics.

What's Great about Open Hardware in Academia

The group started by listing what's great about open hardware in academia. That list included the following. Sharing that is intrinsic both to attitudes and source files as well as the open hardware community itself. The learning and teaching opportunities which are available when open sharing is in place means that learning and teaching can be broader than the University walls. Open hardware gives the space for us, including diverse populations, to create. Academic outreach is easier because of the low barrier to entry common among open hardware projects. Undergraduates involvement and their contributions to OSHW can feel ownership, empowerment, learn from, and make meaningful contributions to open hardware while receiving credit for their work, both in course credit and in attribution as credit.

Open Source Hardware itself was affiliated with low cost benefits for tight lab budgets, modularity, and faster development than closed source counterparts. When creating derivative open hardware projects, it was reported to be more productive because the project infrastructure already exists. More hands and

heads to work on a project or problem is more efficient for time, beneficial for problem solving, and more effective for including multiple audiences. The open hardware, through its documentation, can live on after a group of creators moves on from that hardware or research or has exited that University because of its public documentation. And finally, open hardware broadens the base of activities and industries interacting with it because it can be replicated or ported to new fields the original creator did not intend to work in.

What's NOT Great about Open Hardware in Academia

The problem statement we started with was: What is the Red Tape / Stoppers of open hardware in academia? The group began listing problems through the lens of what's not great about open hardware in academia. Open Hardware can be seen as a toy and not "real" research by administrators and colleagues. Open hardware contributions don't count toward tenure so there's the traditional incentive structure does not apply (unless it is published in a peer-reviewed open hardware journal). Making open hardware in academic systems which are not aligned to support open source in general. Navigating administration (TTOs/ Deans) can be tricky, partially because open hardware is a new concept and lengthy to explain to administrators and funders. Open hardware isn't always called open hardware and therefore can be hard to find.

Documentation takes time in itself and takes resources, and funding documentation is not usually a part of grants. It was also reported that for many, finding funding for open hardware itself was difficult. Although one fellow had funding from the National Science Foundation, enforcing the entire project be open source. Due to funding structures, sometimes academics publish papers with open hardware, with the best intentions of documenting and publishing the source, but once the paper is published, the author gets busy or and does not release the source. Related to the funding issues, maintaining the documentation after the paper or product is done was also reported as a problem.

What are Tangible Solutions to these Problems?

The solutions are listed in order of reported importance. The first two solutions were identified as the biggest problems by the most people, although for small teaching colleges, we honored that metrics were not nearly the problem set for those individuals compared to those at research universities. We separated into two breakout groups for an outreach/education brainstorming session and a metrics brainstorming session.

1. Outreach/Education about open hardware to Universities. Outreach could include ambassadors to Universities, Publishing Societies, and Funders: APS, IEEE, Elsavier, Nature, NSF, NIH, etc, where open source presentations could be useful. Education could look like OSHW presentations for plenary sessions. Slides created by OSHWA can help with lecture prep time and successful implementation of messaging.
2. Create a metrics guide for measuring contributions in open source. Publish your open hardware in open facing journals: Journal of Open Hardware, HardwareX, PLOS One, Designs, or introduce open hardware to specialty journals. Traditionally important metrics to capture for academics are publications and citations.
3. Standardize a commitment for open hardware in universities. Use language that reflects back on a university's mission to encompass open hardware.
4. Build paths to Industrial liaison offices. Create a program for open hardware Industry Alliances or Partners who are willing to work with TTOs to put open stipulations on the research they fund.
5. Legal frameworks or guides for protecting open hardware developers however, it was noted this concept has a limited scope and limited research concept.
6. Build Open Source paths in TTOs in a generic way to easily implement across many styles of TTO offices. It was noted not all universities had TTO or equivalent offices.
7. Create short descriptors/Boilerplate language to use collectively when mentioning open source hardware. For example, "...Open source hardware, an intellectual property alternative focused on sharing, ..."

Outreach / Education for Open Hardware Focused Academics

This group further defined tangible solutions that would advance an open source hardware mindset and be useful in their experiences for Outreach/ Education about open hardware to Universities. Some ideas OSHWA was able to create during the cycle of this grant, or already had. One fellow commented that doing the below list will push open hardware forward in academia by proving respect for open hardware, which will lead to more people producing open hardware in the academic setting.

Idea	Output
Create Slides about open hardware basics for academics	Slide deck
Need Open Hardware Presentation as video	Video (available on YouTube)
Need Video for certifying hardware	Video (available on YouTube)
Pathways to students for the Summit	Website
One sheet flier that describes what open hardware is and how to do it	Flier (from industry partner; can be modified to reference university missions)
Tab or specific site for edu (on-ramping platform)	OHCA website
Workshops about open source hardware	Tutorial
Flier on individual's "Open Source Hardware Journey"	Video Series
Need boilerplate language for writing about open hardware in general or to write into grants	See Boilerplate section
Tool kit / digital media kit for different audiences, faculty, administration and student societies	—
Make people who are already sharing hardware documentation openly understand open hardware is what they are already what they are doing	—
Stories or testimonials from industry partners directed at Universities to help persuade the value of open hardware	—
Flier debunking myths / risk factors about open hardware	—
Empower ambassadors at universities, publishing societies, and funders	—

Metrics Guide for Open Hardware Focused Academics

Current academia metrics are how we define clout, they tend to fall into two groups: 1) publications and citations and 2) levels of prestige for journals/ conferences. The goal should be to frame open hardware according to those metrics (DOI, citations, publications). One beneficial solution to push open hardware forward in academia is to Create a metrics guide for measuring contributions in open source. The checklist for this guide are as follows:

- ☐ Publish your open hardware in open facing journals: JOH, HardwareX, PLOS One, Designs, or introduce open hardware to specialty journals.
- ☐ Utilize Zenodo or the Open Science Framework, open data platforms, because anything you put up there gets a DOI (Digital Object Identifier). While it not traditional publication venue, your work still is citable (DOI = citable, a feature of a work to count)
- ☐ Utilize open data - put down a paragraph that must be included in acknowledgments similar to standard citation/acknowledgment text: “this research was done using [X open source hardware project]”
- ☐ Put thought into the citation so that it gets more attention
- ☐ GitHub has a help page on referencing and citing content
- ☐ Create DOIs within your OSHWA certification. There are OSHWA certified projects using DOI urls as project reference plus the OSHWA platform itself supports citations, for example: https://certification.oshwa.org/be000008.html. However, the current citation field should not be used for this, according to the API Citation field should contain: “If the project incorporates or builds upon other open projects that are not currently certified by OSHWA, this field can be used to cite those projects.” Reference: https://certificationapi.oshwa.org/documentation#tag/Project/paths/~1api~1projects/post
- ☐ Produce something analogous to links for patents or patent pending citations in papers for OSHWA certified hardware.
- ☐ Label your open hardware grants as open hardware on faculty CV’s with mount of grants awarded and include funds for Research Experiences for Undergraduates.

To strengthen the metrics guide, and push open hardware forward in academia, the following approaches could be explored. The group noticed there aren't many hardware projects on GitHub, and posed whether different git best practices would be better? Would GitHub put DOI's on repos? OSHWA could work to be an ambassador to existing open-source authorities, like GitHub, to put their weight behind academic metrics and get DOI's on repos. We could be leveraging platforms like Grimoirelab (https://chaoss.github.io/grimoirelab/), a platform to gather metrics about software communities, for hardware.

Ways to push the OSHWA Certification forward to assist with academic metrics: OHSWA needs to clear up the citation field in the API to include certified and non-certified projects; The certification could auto-generate formal DOI citations; A tracking mechanism is needed for OSHWA certified projects being cited in academia; a standardized template for open hardware project citation, for example "interested in citing? [do this, follow this link, copy this ref]"; A certification might need a multi-field option, for example the ability to select 'education', 'healthcare', and '3D printing'. Fields could be expanded to include lesson plans or curriculum in the education aspect.

Enabling Practices: Skills Inventory

Summary: The cohort listed a skills inventory based on the following prompt: Imagine you are making an inventory of all the "open" and "open-relevant" skills needed to successfully imagine, initiate, implement, sustain and scale an open hardware project in an academic context? The list was extrapolated into categories of skills to imagine, initiate, implement, sustain and scale an open hardware project in an academic context.

Phase 1: IMAGINE an open source development project idea in academia

At the earliest conceptual stage, consider how your OSH project would be received in academia: advocate for it from the beginning:

- Advocate for the concept of Open Hardware in your institution
- Link the open hardware goals to traditional academic goals (i.e write a paper, aligning with department goals, etc)

Include academic educational and research aspects at the earliest stage: including contributors, users and students. These include:

- Audience researvch / thinking creatively about additional use cases and users
- Connection to a community of users who are willing to help you develop an ecosystem, understand the community and strive for community buy-in

Think broadly: brainstorm on additional use cases, participants. Conceptualize while keeping open-source aspects in focus:

- Structuring your project to make it easy for others to contribute, understand the balance between hierarchical and flat organizations
- Understanding different role types which can be transferred from open source software ("Maintainer", "core contributor", "community manager", etc) which might be critical for open hardware

Phase 2: INITIATE

Evaluate existing resources (PEOPLE, SPACE and TOOLS, FUNDING), and the need for new resources. Apply for funding if needed.

People

- Engaging students to distribute workload/research plus proper mentoring, follow-up
- Interdisciplinary collaboration builders

Space and tools

- Fabrication or lab space / test environment (this includes testers/ need feedback, prototyping), toolset
- What can be done in-house, what needs to be outsourced?

Securing funds - approaches differ for high-risk versus standard OSH projects

- Getting sponsorship from relevant stakeholders in your university/area
- Money (grant writing, beyond skills), team (depends on scale of project)
- Obtain funding for creating open hardware by coupling to grants that need new functionality (e.g. not available commercially or too expensive)

Phase 3: IMPLEMENT

General skills needed:

- Project management
- Understand practical limitations both in time and in resources
- Documenting meta aspects of the project for reviewable design, development, and sustainable maintenance
- Communication skills, e.g. not speaking in acronyms to be inclusive
- A clear plan for dissemination for response/feedback
- Documenting for different audiences (academics, students, final users)

OSH-related skills:

- Familiarity with open source building blocks, e.g. Arduino, Design Software (kiCad) – avoid behind the paywall, but verify sustainability of elements you rely on
- Familiarity with open source documentation interfaces (eg git)
- Workflow - having foresight to know which components of doing open hardware work need to be documented at a given stage in order to avoid dependency related problems
- Publish the designs in open hardware journals like HardwareX and JOH and then publish using the free and open source hardware (FOSH) in more conventional journals – for every project

Phase 4: SUSTAIN

Imagine problems that may arise for new/outside users, be open to suggestions/ideas from others:

- Good communicator to diverse audiences
- Having a zeal for documentation, maintaining documentation
- Provide troubleshooting documentation or feedback to users
- Understanding where UX is best as diagrams, explanatory notes, and heavy text for ease of recreation or derivatives.
- Willingness to work in the open (sharing unpolished steps, etc)
- Having a good sense of what matters most to the given audience, and always give polite feedback

Phase 5: SCALE

Support inclusion of additional technical elements, additional use-cases, and cost saving possibilities (if exist):

- Avoid using materials or parts you cannot obtain readily in quantity if you plan to scale
- Technology translator, ensuring many communities can understand your project
- Giving the possibility for others to better the original design (git reviews, merges)

Route to commercialization; evaluate open source aspects of intellectual property issues:

- Evaluate intellectual property licenses and where they can be used, both in source and geographical boundaries
- Knowing who to consult in case of licensing or applying standards - who's the tech transfer office equivalent for open source hardware?
- Have partners for commercialization / Finding partners to scale out/up
- Decide what, if any, plan you will do for order fulfillment /shipping if you are planning to sell or distribute your hardware directly

The skills inventory when broken down by specific use cases (All hardware, open hardware, and open hardware in academia) were organized into the following themes around a skills inventory: Community and Governance matter because of WHO is creating open hardware; Collaboration and Sharing is the PROCESS for contributions to open hardware; Documentation and Reproducibility is HOW to achieve the OUTCOMES of open hardware; Business and Funding to IMPLEMENT, SUSTAIN, and SCALE.

The cohort noticed three groupings that could be extrapolated based on whether the skill was applicable to All Hardware, Open Source Hardware, or specific to Building Open Hardware In Academia.

All hardware - skills needed:

- **Community and Governance:** A clear plan for dissemination for response/ feedback
- **Community and Governance:** communication skills - e.g. not speaking in acronyms
- **Collaboration and Sharing:** Have partners for commercialization / Finding partners to scale out/up
- **Collaboration and Sharing:** Audience research / thinking creatively about additional use cases and users
- **Documentation and Reproducibility:** Fabrication or lab space / test environment (this includes testers / need feedback, prototyping), toolset
- **Documentation and Reproducibility:** provide troubleshooting documentation or feedback to users
- **Business:** project management
- **Business:** Decide what, if any, plan you will do for order fulfillment /shipping if you are planning to sell or distribute your hardware directly
- **Business:** money (grant writing, beyond skills), and team (depends on scale of project)

Open Source Hardware - skills needed:

- **Community and Governance:** Good communicator to diverse audiences
- **Community and Governance:** Willingness to work in the open (sharing unpolished steps, etc) and willingness to give grace to those unpolished steps
- **Community and Governance:** Connection to a community of users who are willing to help you develop an ecosystem
- **Community and Governance:** Understanding different role types which can be transferred from open source software (“Maintainer”, “core contributor”, “community manager”, etc) which might be critical to the longevity of an open hardware project
- **Collaboration and Sharing:** Technology translator, ensuring many communities can understand your project
- **Documentation and Reproducibility:** Intellectual property, licenses, and understanding how they work in the real world

- **Documentation and Reproducibility:** Documenting meta aspects of the project for sustainable maintenance
- **Documentation and Reproducibility:** Structuring your project to make it easy for others to contribute
- **Documentation and Reproducibility:** familiarity with open source documentation interfaces (eg git)
- **Documentation and Reproducibility:** familiarity with open source building blocks, e.g. Arduino, Design Software (kiCad)
- **Documentation and Reproducibility:** having a zeal for documentation, maintaining documentation
- **Documentation and Reproducibility:** giving the possibility for others to better the original design (git reviews, merges, the license itself)
- **Documentation and Reproducibility:** workflow - having foresight to know which components of doing open hardware work need to be documented
- **Documentation and Reproducibility:** Understanding where UX is best as diagrams, explanatory notes, and heavy text for ease of recreation or derivatives.
- **Documentation and Reproducibility:** Enthusiasm for documentation

Skills highly specific to building open hardware in academia:

- **Community and Governance:** Interdisciplinary collaboration builders, e.g. not siloing your hardware project
- **Community and Governance:** Engaging students to distribute workload or research plus proper mentoring and follow-up
- **Community and Governance:** Documenting for different audiences (academics, students, final users)
- **Documentation and Reproducibility:** Knowing who to consult in case of licensing or applying standards - who's the tech transfer office equivalent for open source hardware?
- **Documentation and Reproducibility:** Publish the designs in open hardware journals like *HardwareX* and *JOH* and then publish using the free and open source hardware (FOSH) in more conventional journals – for every project

- **Funding/Business:** Obtain funding for creating open hardware by coupling to grants that need new functionality (e.g. not available commercially or too expensive)
- **Funding/Business:** Getting sponsorship from relevant stakeholders in your university/area
- **Mapping:** Able to link the open hardware goals to traditional academic goals (i.e write a paper, aligning with department goals, etc)
- **Advocacy:** Advocating for the concept of Open Hardware in your institution

The following Visualizations were organized by S Wu.

FIGURE 1. BODIES OF WORK

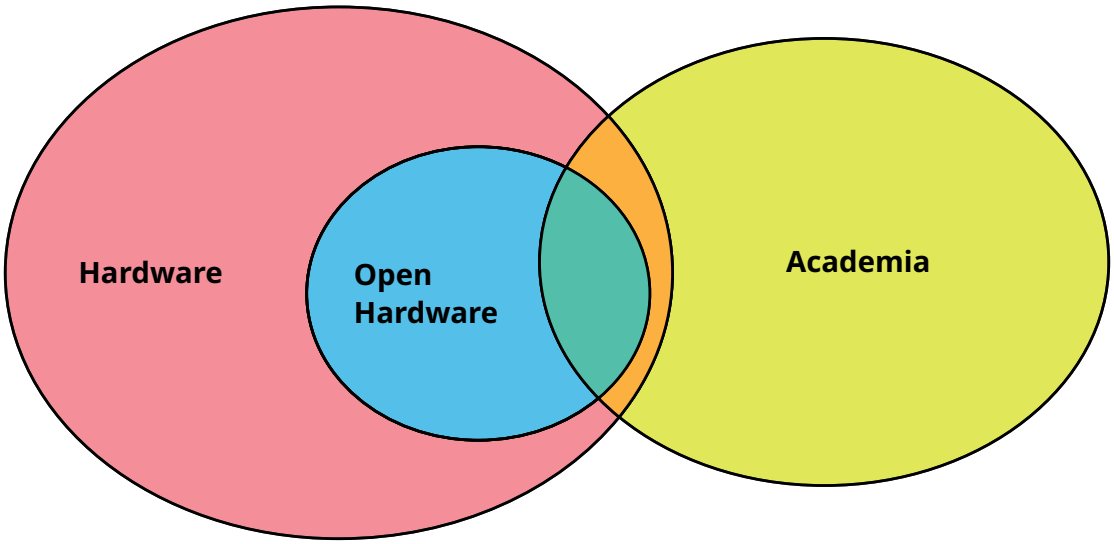
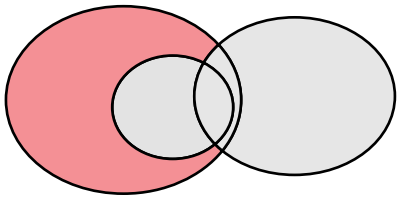


FIGURE 2A. AFFINITY DIAGRAMMING OF SKILLS REQUIRED IN HARDWARE



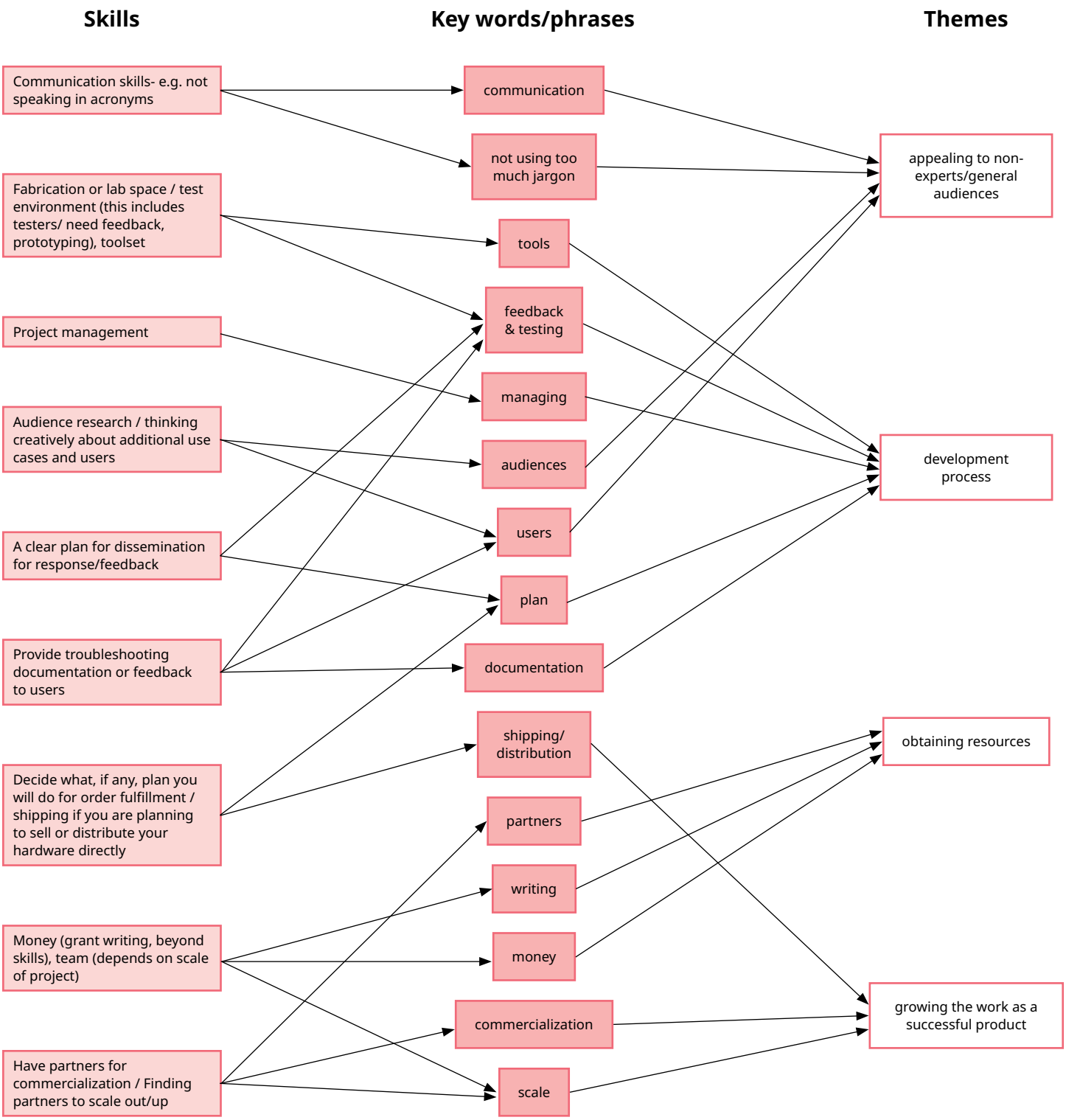
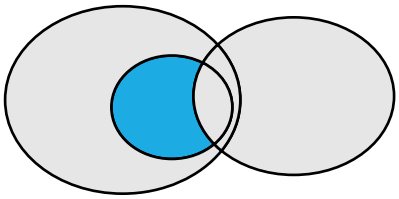


FIGURE 2B. AFFINITY DIAGRAMMING OF SKILLS REQUIRED IN OPEN HARDWARE



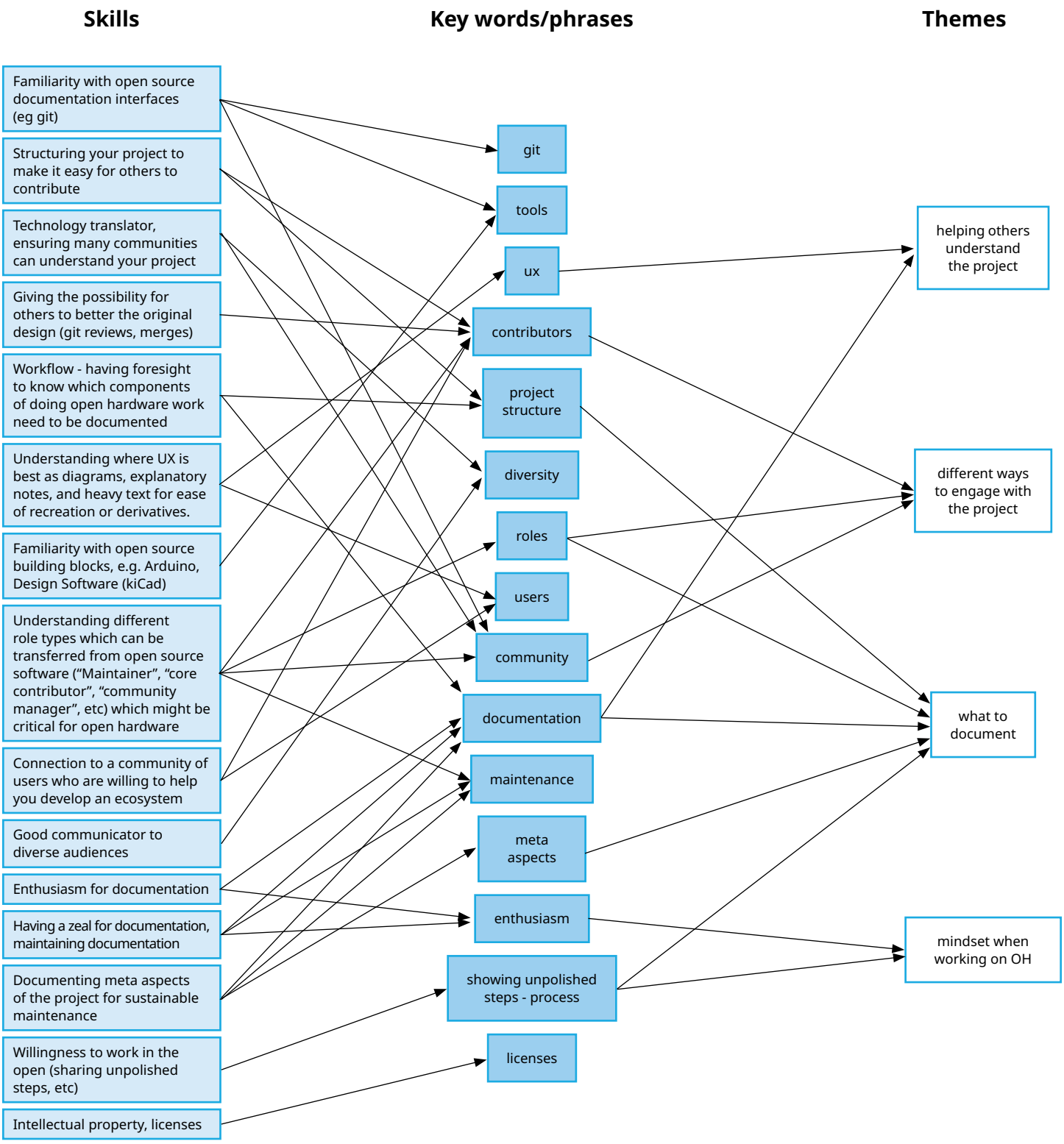
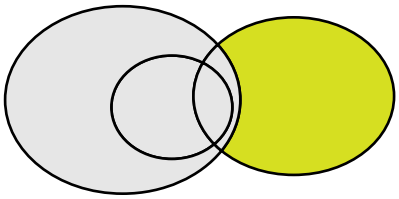


FIGURE 2C. AFFINITY DIAGRAMMING OF SKILLS REQUIRED IN ACADEMIA



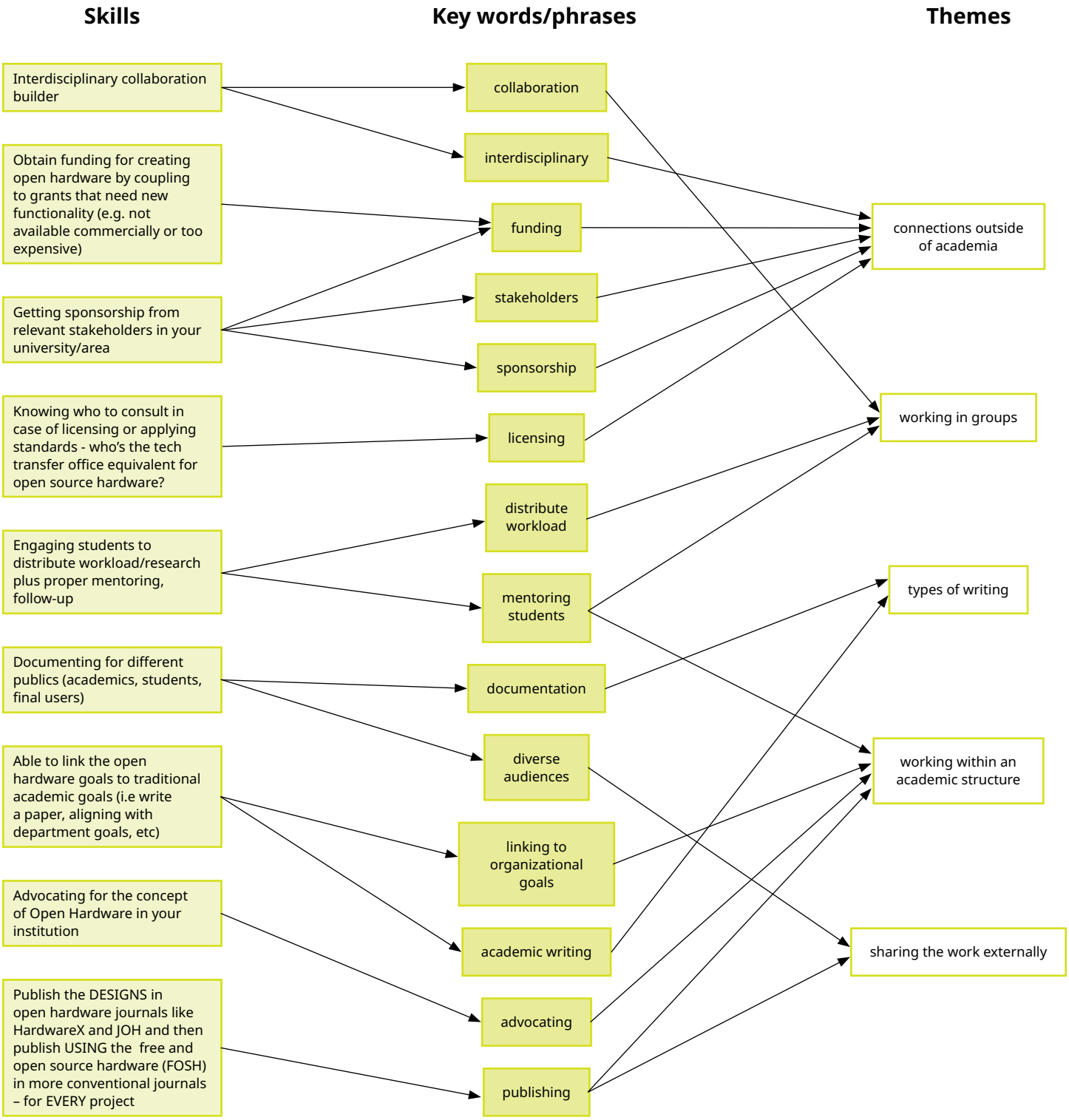
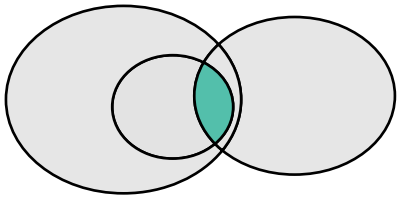
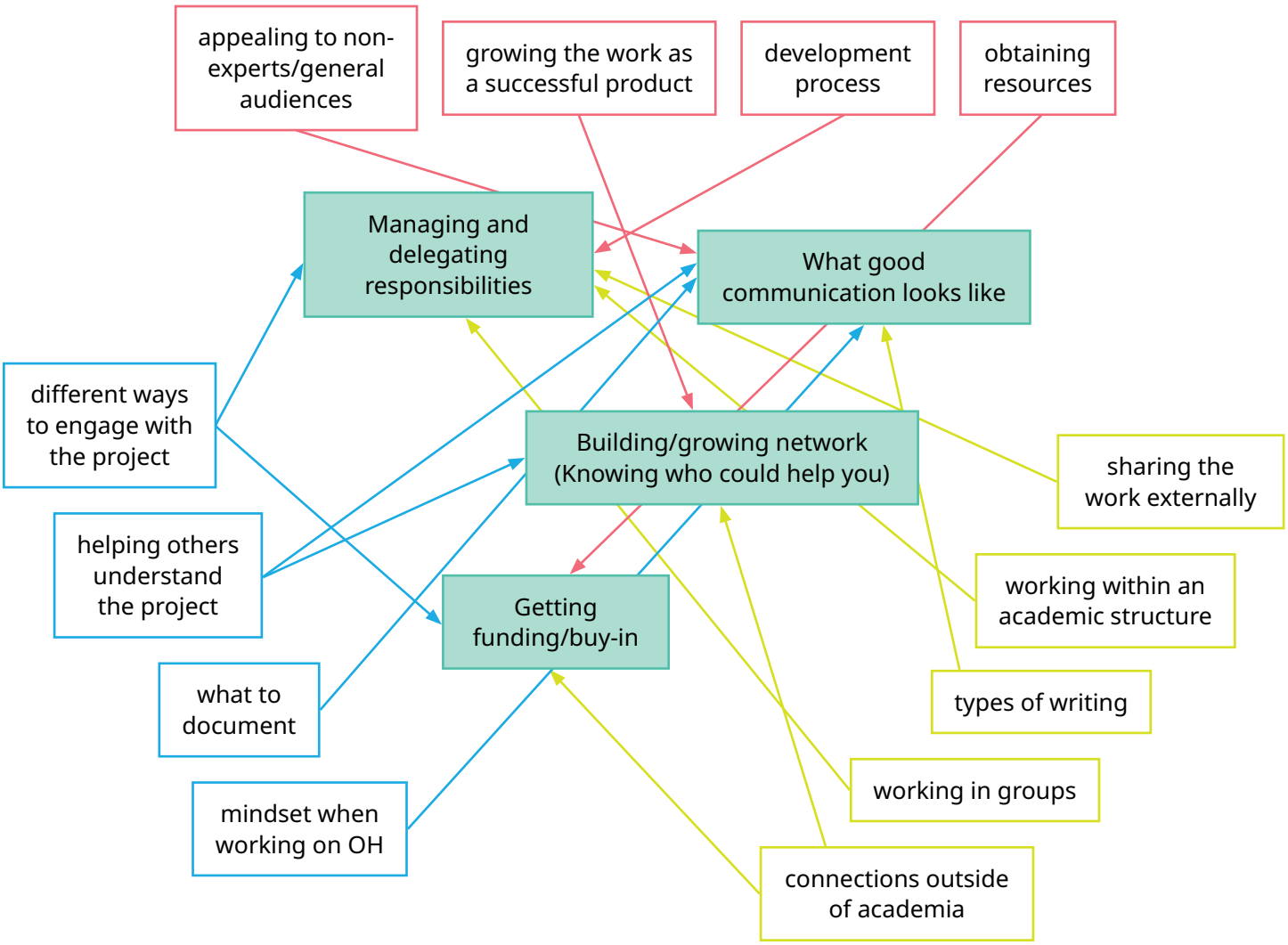


FIGURE 2D. AFFINITY DIAGRAMMING OF SKILL THEMES REQUIRED ACROSS ALL BODIES OF WORK





Exploring Assumptions

Summary: The cohort listed a skills inventory based on the following prompt: What are the assumptions, norms and limits we need to challenge or completely unlearn as we pursue open hardware goals in academic contexts? What do we need to stop doing, enabling or allowing, or do very differently? The following themes were broken up around these lists: Assumptions about WHO does open hardware or who does/doesn't "belong"; Assumptions about how the PROCESS of open hardware happens in academia; Assumptions about the OUTCOMES and what they are supposed to be for. Let's[1] unlearn.

Unlearnings Checklist

These groupings were extrapolated based on whether the unlearning was about institutions, collaboration and sharing, ownership and control, and documentation.

Unlearning about institutions:

- ☐ The university expects that you're going to patent something & make millions for them. It doesn't mean there aren't commercial opportunities when thinking through "ownership" in a different way, or through a different lens of the university's mission.
- ☐ Let's unlearn staying under the radar because opening it may cause scrutiny, but that mindset keeps from connecting with other departments who can use it
- ☐ Let's unlearn that funders will scrutinize open hardware projects.
- ☐ Let's unlearn that open hardware projects need to be big to be useful. Not all open hardware projects in academia aim to take over the world and that's okay.

---

1 In Theater, there's a game called Yes Let's that capitalized on collaboration and honoring other's ideas: https://www.dramatoolkit.co.uk/drama-games/item/improvisation/yes-lets

- ☐ Let's unlearn siloing and territorialism in the academic environment, cite projects with admiration.
- ☐ Stop believing it is ok to privatize publicly funded research through intellectual property.
- ☐ We need to make clear there are ways for open hardware activity to be compatible with traditional academic metrics, for example, getting tenure.
- ☐ Let's unlearn the norm that the usefulness of an open hardware project to current publications is critical for determining the level of support or attention it should receive. A project may be critical to publications later, or perhaps its usefulness might be greater in a different department within the university. Or maybe in another university altogether. That's why sharing and broad communication about open source hardware work is important.
- ☐ Let's unlearn an open hardware project is worthless if you don't use it to produce a paper/thesis
- ☐ Everybody loves open hardware! There is something special about open hardware projects in academia compared to regular non-open hardware projects. It shows bravery to publish unfinished work, compassion to allow others to build upon, and courage to do something new. Let's be proud of that work.
- ☐ Let's unlearn that all open hardware coming from academia comes from universities, versus other research institutes or labs like CERN, or nontraditional environments spaces like hacker spaces.

Unlearning ownership and control:

- ☐ Let's unlearn that you have the right to prevent others from doing something because you had an idea.
- ☐ Let's unlearn that you are the best one who can do the task at hand - people you work with are collaborators
- ☐ Adopting not just open designs, but the open tools that make them truly useful and accessible
- ☐ Stop assuming that open hardware is anti-commercial. Open hardware generates businesses and income.
- ☐ Let's unlearn the engrained traditional role of patents in society.

- ☐ Let's honor the difficult feelings of traditional clout in closed hardware: If your dad | PhD advisor | obnoxious aunt who used to work in tech in 1981 thinks you're giving away all your secrets, it can be hard to break free.
- ☐ Let's unlearn that open hardware applies to one domain i.e. Open source hardware is particularly well suited to electronics.
- ☐ Let's unlearn who can do open hardware i.e. You don't have to be an engineer to develop open hardware project, and students/faculty can develop open hardware outside of STEM.

Unlearning about collaboration and sharing:

- ☐ Let's unlearn that copying is bad.
- ☐ Let's unlearn that we need perfection before sharing or waiting until the end of the project to share; let's learn empathy for projects that aren't complete
- ☐ Let's unlearn siloing our data and experimental processes - not just the hardware itself, to enable reproducibility.
- ☐ Think deeply about the value our projects give and how they can co-exist with "competitors". Bring more value than the sum of the parts by working together through open hardware.
- ☐ We need to remember that open hardware often has audiences beyond the original target. We need to remind the community that open hardware impact is bi-directional, it benefits the developer in addition to the adopter.

Unlearning about documentation:

- ☐ Let's unlearn that documentation is something you do *later* or *once*
- ☐ Let's unlearn that documentation (outside of what goes into a publication) isn't as valuable a contribution
- ☐ Good documentation is enough for projects to succeed, perfection is the enemy of done.

Influential personas of power for Adoption of Open Hardware & Creation of Open Hardware

Summary: The cohort began teasing out the difference between adoption of open hardware and creation of open hardware, recognizing that both were important mechanisms of institutional change. The cohort was split into two groups, rating personas of power as High, Medium, or Low through the lens of either adoption or creation. The cohort also recognized within groups were subgroups that deviated slightly from each other, i.e. Faculty vs. junior or senior faculty.

Adoption of Open Hardware

Adoption of open hardware was defined as adopting open hardware to be used or bought in the academic system, but not created by a student, faculty, or researcher.

Stakeholder Persona	Influence/power in Adoption (High/Medium/Low)
Faculty/ Faculty PIs	High
Funding partners	High
VP finance	High
Colleagues	Medium
Dean/Chairs/Vice Presidents	Medium
Dept head	Medium

The cohort then broke down each persona into their high impact motivations and most achievable outputs per persona.

Senior faculty (e.g. Tenured faculty) would be motivated to adopt open hardware by:

- Being able to use OSHW as research/teaching tools at lower cost than closed equipment
- Sharing resources across departments
- Doing work that gets tenure, promotion, retention

External Funding Partners (e.g. NSF) would be motivated to adopt open hardware because open hardware:

- Increases innovation velocity
- Increases ROI
- Increases impact
- Increases access for lower-resourced research institutes

High-level administrators (e.g. Vice Provost for Research) would be motivated to adopt open hardware by:

- Being able to save on costs associated with research or teaching programs by using OSHW in labs and as teaching tools
- Bragging rights for being innovative
- Being able to save on costs that the use of particular OSHW can reduce (i.e. electric bills at the university)

The cohort recorded 1-2 tangible ways open hardware could be adopted by each persona that would be most important to their experience.

Stakeholder Persona	Tactic
Faculty/ Faculty PIs	Adopt open source hardware in teaching lab curriculum
Funding partners	Write in OSH as budget lines or explicit activities in proposals Create new funding lines to support just OH projects
VP finance	Present a cost/benefit analysis of adopting open hardware/proprietary hardware for one or more key projects

Creation of Open Hardware

Creation of open hardware was defined as creating the open hardware itself as research, educational materials, or lab equipment.

Stakeholder Persona	Influence/power in Adoption (High/Medium/Low)
Vice Provost for Research	High
Tenured faculty	High
Myself and my family	High
External Funding Program Officer	High
Head of sponsored research/development office	Medium
Engineering dean	Medium
Pre-tenure faculty	Medium
Graduate Student	Medium
Machine shop staff / Lab staff / Core facility directors	Medium
Postdoctoral scholar	Medium

The cohort then broke down each persona into their high impact motivations and most achievable outputs per persona.

High-level administrators (e.g. Vice Provost for Research) would be motivated to allow creation of open hardware by:

- Increased visibility of research at the institution including press attention
- Help with recruiting
- Cross fertilize within university, promote multidisciplinary application of hardware, and more funding opportunities by connecting to other disciplines

Senior faculty (e.g. Tenured faculty) would be motivated to create open hardware because it:

- Gives more citations if open source hardware adopted (and has a DOI)
- Leads to new collaboration

Myself and My family are motivated by creating open hardware:

- Whether open hardware matters to me, especially for those who own their own intellectual property at a university
- Whether open hardware matters to a researcher's family values

External Funding Partners (e.g. NSF) would be motivated to fund the creation of open hardware because it:

- Advances "broader impact" goals as a metric
- Creates outreach opportunity, especially in DEI
- Integrates open hardware in the open science ecosystem, and level to open software and open data

The cohort recorded 1-2 tangible ways open hardware could be adopted by each persona that would be most important to their experience.

Stakeholder Persona	Tactic
Vice Provost for Research	Educate persona about ways in which other universities are involved in creating open hardware and how that might be leveraged for funding/attention/prestige/rankings Create a list of top funded research universities and show the strategic advantage and savings they could achieve if they were to create open source versions of the equipment that they use.
Tenured faculty	Train faculty on career-advancing opportunities related to open hardware (funding opportunities, publishing opportunities, etc.) Provide mentorship/training for faculty that want to do this open hardware work but don't know how to start.
Myself and my family	Understand my own agency within an institution Understand my own intrinsic motivation and principles
External Funding Program Officer	OSHWA to lobby for open hardware development in universities funding to reach goals Provide data on what other foundations/orgs are supporting open hardware creation work.

Identified Resources for Adoption and Creation of Open Hardware

The following list is resources identified as valuable to fellow's open hardware objectives for adoption of open hardware:

- Documentation of successes at other comparable institutions, for example, an editable list hosted by OSHWA.
- Clear talking points for sharing open hardware with university boards.
- Talking points for lobbying for public funds at the state level.
- Examples of how open hardware has been successfully applied by communities within that course topic (i.e. sustainability/medical/mechanical engineering).
- Share bill of materials or costs for starting up a research lab compared to the more traditional pathway.
- Illustrations of how faculty at universities with lower resources can engage in teaching, service and research by going the open hardware route.
- Demonstrate that using open hardware can help with external dossier reviewers.
- Document that the broader impacts reach a more diverse and larger audience with a higher chance of impact through implementation.
- By not having information being proprietary or hidden behind paywalls the access helps to quickly improve research output and innovation of research artifacts.
- Point out that OSHW is a great way to get community support for high-impact research and development projects. There is nothing better than having support from a community that helped to make and validate research products before they are published and/or later commercialized.

The following list is resources identified as valuable to fellow's open hardware objectives for creation of open hardware:

- Mobilizing faculty who are already doing open hardware to discuss open hardware at department meetings.
- Build list of articles in the New York Times or prominent journals that mention open hardware and universities positively.
- Request For Proposals that specifically target open source hardware.
- Suggestions for language in Request For Proposals that include open hardware.
- Funding to cover publishing costs in open hardware journals.
- Social media presence that highlights university research in open hardware.
- Guidelines for open source hardware documentation.

Success Factors for Open Hardware in Academia

Summary: The cohort was asked to envision that we have achieved dramatically broader adoption and creation of open hardware in academia. What would be indicators of that impact? What is anything we could measure, observe or otherwise point to that would demonstrate or affirm this broader penetration. What changes would be observable? The group came up with multiple ways to categorize their success factors lists. One way being Funding, Utilization or Impact of Creating Open Hardware, Cultural Paradigm Shifts, and Adoption.

Funding

- Increased funding/grant opportunities for open hardware projects.
- Funding for open hardware programs or projects, either from federal or private sources.
- Cost savings would be something easily measured - if the cost of lab equipment and renewing lab equipment is presently of concern, finding open hardware alternatives would be helpful to show and report savings to foster wider use of OSHW to continue seeing these benefits.

Utilization/General Impact of Creating Open Hardware

- Number of new OSHW projects/papers that are based on existing open hardware projects (either as building blocks or prototypes).
- Paper publications in high-visibility journals with citations.
- Advancement of academic position for people working on open hardware, for example we would see undergrads being exposed to open hardware become Grad students working on open hardware; Postdocs who research open hardware become Faculty who create and advocate for open hardware.

Cultural Paradigm Shifts

- There would be more observed freedom in student-faculty interactions due to less concern about intellectual property, usefulness to current/future research goals, and concerns over too much spending because open hardware would be more widely used and demonstrating how research can be done more fluidly and openly without being hindered by cost concerns.
- Increased recognition of open hardware projects/research including validity and appreciation.
- Open hardware language becoming more vernacular in academic discussion including in journals and at conferences.

Adoption

- Open hardware becoming the default way to publish academic work that built something, in the same way open source is becoming standard/required for research software.
- Number of academic open hardware projects created/maintained would be relative to the total number of papers published.
- Success indicators could be we bring XX new faculty into open hardware research.
- Success indicators could be XX faculty use OSHW in their teaching and curriculum.
- Number of grants and journal publications highlighting open hardware would increase.
- Number of spinoff companies from universities led by students pursuing open hardware products/support/development would increase.

A second way to categorize the groups success factors was Standards Related, Grant Related, Teaching Related, Intellectual Property, and Career Advance / Publications.

Standard Related Grant Related Teaching Related

Intellectual Property Career Advance / Publications

- Specific grants would appear for open hardware projects in academia.
- Open source hardware is integrated into teaching labs.
- Open hardware is the new default for new courses going forward.
- The most popular papers in several fields are based on open hardware.
- Patents and open hardware rank equally to the advance in the academic careers of researchers.
- OSHW related journals would have significantly increased impact factors and would be the standard for publishing hardware.
- Universities keeping track of open source projects, as part of an 'innovation index'.
- Using closed hardware is discouraged as it prevents full replicability / transparency.
- There are many-many-many open-source-hardware projects that have a long list of contributors and gazillion updated versions running through many years of updates (parts, new use cases) as witnessed on the project's page.
- Most projects would be created in the open source way, by default. It would be a requirement from agencies, international collaborations.
- Open source hardware would be truly integrated in the open source ecosystem. For example, when using open data everyone would be aware (and could find easily) what are the specifics of the open hardware that collected the open data and we would have open software to analyze the data.
- Impact frameworks would start to incorporate open source software and hardware.

- New metrics get developed by outreach offices to incorporate the open source hardware outreach as a default.
- Measurable DEI goals would have an increased reach of hardware development projects in diverse communities.
- Using OSHW would be a normalized choice, not an exceptional or noteworthy one.
- Papers/publications would use the language of open hardware without having to explain what it is.
- The ecosystem of users/support/discipline crossover and sharing of hardware would become a standard event, rather than an exception.
- University is keeping track of open source hardware projects through their tech transfer offices.

Finally, as another way of visualizing this information categorically, a suggestion was made that we could visually categorize/map indicators of impact, for example, education / equality / industry / etc, similar to the below example from IRIS+ and the Global Impact Investing Network:

Program Summary

The big goal of the Open Hardware Creators in Academia was to drive broader adoption and greater impact of open hardware in academia through the lenses of the fellows, honoring the differences and similarities of each individual's experience with creating open hardware in their own institutions. By broadly and intentionally amplifying the benefits and potential impact of open hardware, we can decrease resistance, increase motivation and correspondingly increase resourcing that drives both creation and adoption of open hardware in academia, and diversifies the open source creative population.

Our community delivery plan of this work includes a dedicated website of the OHCA fellow's work, their collective work products, and a series of resources designed to help move open hardware forward in academic adoption and creation: https://ohca.oshwa.org/. Delivery of our fellow's work has come from a multipronged approach for amplification in different avenues: papers, conferences, journals, social media, websites, blog posts, YouTube videos, Hackster.io, or Instructables.

Our fellows worked to identify, contextualize, and educate key influential stakeholders in the academic context regarding benefits and mandates for open hardware, in order to inspire and motivate them to support and drive broader adoption and creation. Our fellows and mentors have built the foundation of this program, which OSHWA plans to grow with future cohorts.

Open Source Hardware in Academia FAQ

How do you convince higher-ups that you can have a successful career with open source hardware?

Negotiate from a position of strength. Point to the success of free and open source software. Talk about the significant industrial support. Show new business models. Talk about more reads and more citations. Point to this program for bringing in money. Point to more uptake in the community.

How can open source hardware help you as a faculty member?

When you are building your lab, using open source hardware will save you money, stretching your startup package further. Then, every time you would normally submit a paper, write two (1 normal and 1 open source hardware). This will boost your productivity and pull in more citations.

How do you balance the maintenance of open source hardware projects with academic responsibilities?

In the project documentation, describe the level of support/maintenance that is being offered with the project. If significant support or maintenance is needed, you may need to hire a research assistant to do the work. Grants can help with this.

Can I certify a project before it is publicly launched, like in a Journal?

Yes. You will need to provide links to the final documentation that you will make available at launch. OSHWA will then review your project and, if appropriate, grant you provisional certification. Once your project is live OSHWA will review the publicly available documentation in order to ensure that it matches the requirements. If the publicly available documentation matches the documentation used during the application process, the provisional certification will become formal certification. Email certification@oshwa.org for details.

Where should I publish my results?

Publish in open-access journals, if possible.

These include:

- Journal of Open Hardware: Platinum Open Access, no article processing charge (APC)
- PLOS ONE: Gold Open Access, APC=$1,931 USD
- HardwareX: Gold Open Access, APC=$500 USD
- Designs: Gold Open Access, APC=1400 CHF
- Nature Methods: Open Access if you pay an open access fee

Your university may be able to pay open access fees, especially if you have a grant supporting your project. You can also get APC waivers and often special issues waive the APC fee.

How can I involve my students in designing open source hardware?

Some of your current hardware might require expensive proprietary software solutions. By using open source software alternatives, for example, using KiCAD for PCB layout software, students will be able to use it both at school and at home, allowing them to contribute without any constraints.

How can I engage with a company that offers proprietary hardware to open up their ecosystem for research/open source hardware solutions?

Offer evidence that open source hardware can help them broaden their audience, reach new audiences and learn from a community of innovators. Show them the collection of compelling case studies available at the OSHWA site.

How can I make my work more visible outside academia to grow a larger community around the project?

Focus on the first steps that other people can take to use your projects. Provide a learning path to engage them, providing clear instructions that include text and images.

Offer this introductory content on the channels that your potential users might be using at the moment, like Facebook, TikTok, or posters around the city. When you get new users, verify what they use to learn about your project.

Boilerplate Blurbs and Talking Points for Open Hardware in Academia

Defined

From the Open Source Hardware Communal Definition: Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design.

The Open Source Hardware Association (OSHWA) aims to foster technological knowledge and encourage research that is accessible, collaborative and respects user freedom. OSHWA's primary activities include hosting the annual Open Hardware Summit and maintaining the Open Source Hardware certification, which allows the community to quickly identify and represent hardware that complies with the community definition of open source hardware.

OSHWA Certification provides an easy and straightforward way for producers to indicate that their products meet a uniform and well-defined standard for open-source compliance. The Certified Projects Directory makes it easy to find certified open source hardware and to search by type of hardware, license, and country of origin.

Open Source Hardware is an option in the landscape of intellectual property.

Benefits

Some benefits of open source hardware include to talk to Deans, Tech Transfer Offices and funders about includes the following:

- Open Source Hardware can produce a citation of your work through certification.
- The open hardware project could include a license for attribution to both the creator at the university if someone uses your source, which creates visibility marketing for the university.
- Open hardware builds community knowledge and is a feel good feature that is marketable, especially when taking public tax dollars for research.
- Patents are expensive for a university to acquire, and even more expensive to enforce. Focusing on solving a problem through open hardware is a more efficient use of resources and researcher time, rather than spending time on patent descriptions and drawings.
- A successful open hardware project creates an active community that focuses around a project or product. This can introduce prospective students, industry partners, or peer to peer collaborations to your university.
- Open source hardware allows for replicable lab equipment, hardware design, and testing jigs, which creates more reproducible science.
- Using open hardware can save a university money, many open hardware products are cheaper than closed counterparts.
- Public disclosure protects the right to practice and prevents others from patenting the same art, as it acts as clearly disclosed and published prior art.
- Open hardware benefits for students includes the creation of a public portfolio which publicly demonstrates their work that future employers can easily see and evaluate.
- Successful Open Hardware protects against project abandonment and can live on by community involvement even when students or researchers leave.
- It is easier to evaluate the security, safety, reliability, and limits of hardware devices when the source is publicly available.
- In the words of the CERN knowledge transfer group: “Our mandate is to maximise the impact of CERN technologies on society, we have a toolbox to achieve impact and open source is one of those tools.” They further state: “Identifying opportunities to collaborate with industry for the development and commercialisation of OSHW is another key part of our process to maximise impact on society.”

Broader Impacts

Broader impacts for grants might include some of the following:

- Open Hardware builds something more sustainable and reusable for the earth's resources because people are able to repair and repurpose hardware whose designs are publicly available and free to modify. People are able to use decentralized manufacturing that reduce carbon footprints, whether or not they created the project.
- Open source projects/products allows for derivatives. Those derivatives build upon the original source and can be modified or used in fields the original creator knows nothing about, countries where the original creator doesn't speak the language, and with functions the original creator never thought of.
- Successful Open Hardware protects against project abandonment and can live on by community involvement even when students or researchers leave.

Helpful Links

This list includes helpful documents to advance advocacy of open hardware in academia:

- Policy Briefs for Tech Transfer Offices, Sustainable development, and Funding: https://openhardware.science/policy-briefs/
- Policy for Science Funders and University Managers: https://osh-policy.org/
- Quantifying the Value of Open Source Hardware Development: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3331131
- Economic savings of scientific open hardware: https://linkinghub.elsevier.com/retrieve/pii/S2468067220300481
- ROI on open hardware scientific development: https://www.researchgate.net/publication/281361072_Return_on_investment_for_open_source_scientific_hardware_development
- Value of Open Source: https://joinup.ec.europa.eu/collection/open-source-observatory-osor/news/first-results-study-impact-open-source
- CERN's goals, services and activities, including the Open Hardware Repository: https://openscience.cern/hardware

Suggestions?

Do you have something to add? Email info@oshwa.org If included in this document, your written response in the email will be public domain. Individual hardware projects will not be added.