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Open culture and innovation: integrating knowledge across boundaries

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Introduction: What is Open?

Introduction

What does open source mean for culture? For knowledge? As cultural production has come to be characterized by contribution as well as consumption and as alternative modes of intellectual property transfer challenge the 'dominant paradigm' that knowledge and information should be protected and monetized (Mansell, 2012), the logic of 'open sourcing' has extended into many cultural spheres (Tkacz, 2012). Knowledge commons like Wikipedia can demonstrate the value of knowledge produced collectively and openly made available for use – but still struggle with how to govern and maintain that knowledge. In this shifting context we need to better investigate how the people who evoke 'openness' imagine it to operate, and how different forms of cultural production – extending beyond software production -- engage with the possibilities of open source.

This article positions 'openness' as a value that intermediates between re-usable software code, institutional transparency, and expanded opportunities for participation in knowledge production cultures. By observing and analyzing the expansion of 'openness' from computer software to electronics hardware, we can develop a framework that identifies the tensions between socio-cultural visions of knowledge commons and the realities of governing those commons. This research focuses in particular on the knowledge related to electronics hardware and other material objects governed by open hardware[1] licenses. While the case study focuses on the contests of knowledge between scientific institutions and loose communities of practice formed over the internet, the insights are relevant to studies of culture and communication where value and knowledge are created as often through loose, emergent communities of practice as through monolithic institutions, and where the negotiations between these forms of cultural value – top down and bottom up – create new opportunities for cultural development and innovation. The insights in this article are valuable for anyone studying open source and peer production processes and the knowledge claims surrounding them: for example remix artists and file-sharing music fans

[1] It is worth noting the important difference between 'free software' which refers to software whose source code is held in commons and where any product using this source code must also be returned to commons, and 'open source' – a mode of commercial production that employs online repositories of software but does not maintain them in commons. Open hardware licenses vary but most are attempts to extend the principles of free software to other forms of knowledge.

renegotiating the value of music with the studio institutions, or citizen journalists and contributors to platforms like Global Voices engaging with legacy mass media.

Open Hardware

Open hardware is used by artists, amateurs, publicly-funded organizations including CERN, as well as being manufactured and sold as part of emerging "long tail" business models (Buechley and Mako Hill, 2011). Numerous proposals aim to make hardware standards, licenses, and patenting more 'open', put forward by various different communities of practice. In Lave and Wenger's (1991) terms, communities of practice are defined by common interests and constituted through knowledge sharing. In open hardware, different communities of practice have proposed different governance structures that make concrete a range of visions for open hardware. These range from licenses that employ free software terminology to position open hardware as a conceptual descendent of free software, to governance structures that simply rely on a set of community norms related to sharing.

This range of visions for open hardware is also inflected by varying perspectives on the extent to which institutions, rather than loose collections of peers carry the most influence in defining these 'open' relationships. Open hardware licenses are thus a site of negotiation about how to define and expand the open culture in relation to different forms of 'authority' over knowledge. These negotiations are part of broader struggles about how to deal with expectations that, as transmitting digital information becomes easier, ever-increasing varieties of knowledge should be openly shared.

Drawing from the science and technology studies (STS) perspective, and specifically Susan Leigh Star's (1989; 2010) boundary objects framework, arguments about how best to extend open hardware employ discussions of licensing to create and negotiate boundaries. This article presents the result of a three-year case study of the development of open hardware licenses. Based on interviews, thematic analysis of discussions on internet mailing lists and participant observation at open hardware conferences and other events, it analyses how proposals for licenses serve to demarcate boundaries between different interpretations of open hardware and hence, how negotiations over these boundaries illustrate the balance between different forms of knowledge and authority. These include the "constituted authority" of formal

institutions and the "adaptive authority" of loosely connected online groups (see Mansell, 2013). As participatory culture and contribution-based knowledge sharing practices expand, these forms of knowledge will have to be continually negotiated and balanced. An integration of constituted and adaptive authority is necessary for the creation of more open ways of conceiving of culture and innovation, and the case study in this article explores how this investigation might be undertaken.

Four factors within the contemporary communicative environment create greater complexity with respect to knowledge: a more extensive networking of both communications capacities and communicative practices that leads to changes in 1. Modes of access to knowledge; 2. Modes of distribution of knowledge, and 3. Modes of collaboration related to knowledge. These factors can increase the openness of these knowledge production environments, possibly creating a new framework for innovative cultural exchange. These practices are of course connected with the expansion of the internet, but the change is not only technological but also social. As Mansell and Steinmueller point out, "intermediation in both physical and electronic space is giving rise to many new patterns and modes of communication and information exchange. Some observers claim that these new developments contain the seeds for revolutionary changes in all aspects of social and economic life, including the processes of knowledge creation and application" (2002; p. 2). Forms of knowledge can be contested, but they can also be governed, for example through standards like licenses. Standards sometimes seem to be contested by entities that enact different relations to knowledge production.

For example, Mansell (2013) discusses the contending frameworks for citizen science, noting that the collaborations between professional scientists and untrained "citizen" scientists involve conflicts between the values and norms associated with the production of different forms of knowledge. While scientific institutions typically valorise constituted knowledge, curated and structured by the kinds of entities they recognize as meeting specific standards, another type of knowledge is increasingly pervasive as a result of the spread of digital networks that is created and circulated following adaptive or flexible, bottom-up forms of knowledge creation that draw largely on the activities of loosely coordinated groups. Mansell points out how crowdsourcing and new forms of digital curation, as well as practices involved in both

scientific and other forms of knowledge production yield new meeting points between these two forms of knowledge. Drawing on this insight I suggest that openness in culture and innovation depends on the ability to creatively integrate the practices associated with constituted and adaptive knowledge.

Furthermore, the integration of different knowledge practices is necessary, but not sufficient, for the development of open culture and innovation beyond the production of software or other digital goods. Such openness becomes visible at boundaries where different communities of practice interpret the same object in different ways. This article focuses on how open hardware licenses perform this boundary work, examining how debates about the license facilitate negotiation of the different forms of authority present in open hardware ecosystems. Empirical data derived from interviews and analysis of open hardware mailing lists buttresses the notion that the willingness to encompass various forms of knowledge is a central characteristic of openness. The final section of the article assesses how open hardware licenses might promote this openness as they become more infrastructural.

Expanding open source practices

Open hardware licenses join a set of other normative and cultural practices that develop the collaborative aspects of knowledge production and seek to enrich this through the expansion of commons-based peer production (Benkler, 2006). These include rising participation in "sharing economies" (John, 2013), the expansion of freely available information through efforts aimed at reforming control of intellectual property (Lessig, 2006) increased participation in collaborative spaces for design and creation work, including FabLabs and hackerspaces (Hermann and Buching, 2013; Hunsinger, 2011). These cultural practices integrate forms of adaptive authority that valorise keeping knowledge in commons and managing its distribution through peer production. Although these cultural practices are expanding, they continue to conflict with existing forms of constituted authority that valorise the control of knowledge and information.

As Mansell (2012) argues, this contestation in forms of authority is part of the paradoxical interplay between dominant and alternative views of contemporary ICT environments. These dominant and alternative views take different perspectives on

how knowledge should be distributed – either through strong protection of intellectual property or through the expansion of a commons-based peer production model. Mansell writes, "Proponents of these two imaginaries are pitted against each other in policy and regulatory debates; one group advocating reliance on the emergent properties of a complex system underpinned by intellectual property (IP) rights, the other reliance on the emergent properties of a complex system underpinned by the generative activities of communities of online participants" (2012, p. 178).

This contest between forms of knowledge is expanding, along with the sites where the paradoxes Mansell identifies are produced. The expansion of hackerspaces and fablabs where people share physical space, materials and knowledge about design and production are evidence that commons based peer production processes are now employed for more than the production of digital goods. Hackerspaces provide opportunities for creative exchange that may challenge traditional forms of knowledge production like the training that happens in jobs and at school (Hunsinger, 2011). They also provide places to experiment with and share ideas and practices related to technology, and influence broader cultures of innovation (Lindtner, 2013). Thus, hackerspaces, and their cultures of tinkering are fun and extend the kinds of social organization that valorise contributions to the knowledge commons. They are part of a broader set of practices in which knowledge is valorised through adaptive authority rather than only through constituted authority.

As these practices expand they begin to be codified; within open source communities of practice participants have tried to create licenses and governing practices that create the dynamics of information sharing associated with open-source software production (Powell, 2012). In attempting to valorise commons based peer production, these licenses also valorise adaptive authority, since they must be created and adopted by the community of practice who uses them. But this does not mean that constituted authority disappears – this emerging dynamic of innovation results from the relationships that develop between the two forms of knowledge. Developing ways to integrate constituted and adaptive authority is essential to developing a new culture and innovation ecology that considers how knowledge can be produced for public good. The development of open hardware licenses demonstrates how this integration can happen through the interpretation of licenses as 'boundary objects'. After

discussing how boundary objects can be useful to understanding the power of the constituted/adaptive authority dialectic, this article analyzes the case of open hardware, examining in particular the way that notions of authority are balanced and integrated by communities of practice developing an open hardware license.

Social Worlds and Boundary Objects

In the STS tradition, there is particular interest in the way that communities of practice interpret technologies. These bounded, self-organizing entities share common values or social imaginaries – shared perspectives that define a group (Taylor, 2004; Mansell, 2012). "Interpretive flexibility" (Bijker, 1995) of a technology can refer how different social imaginaries contest or oppose interpretations of new technologies. One way to observe how this flexibility works is in relation to a "boundary object": a "sort of arrangement that allows different groups to work together without consensus . . .. These common objects form the boundaries between groups through flexibility and shared structure—they are the stuff of action" (Star, 2010 p. 602). These objects develop organically in situations where groups have overlapping information and work requirements, and are characterized by the language that people use to describe their work with respect to an object.

Boundary objects do not have to be physical objects but instead may be organizing principles. For instance, Star and Greisemer (1989) observed how repositories of documents stored in a library provided ways for amateurs and professionals to work together on the same collections, even though they had radically different ideas about what was appropriate scientific knowledge. The library, with its repositories structured into a catalogue, provided the ability for amateurs to pursue one kind of practice and the professionals another. In the contemporary world, various technical and social changes have intensified these simultaneous amateur/professional knowledge production practices, which are still at work in a number of cultural spaces. Boundary objects are frameworks for organization and understanding situated between groups of practitioners that do not necessarily adhere to the same norms and values, nor work in the same way.

Star (2010) discusses how sometimes boundary objects are 'ill-structured' in these relationships because of the differing perspectives on how to use them. When

participants in social worlds with a strong shared identity work on them, they become "well structured". Groups that operate without consensus move back and forth, however, between less and more structured interpretations. When these processes scale up, boundary objects may become part of the infrastructure and standards in the form of commonly held values, norms and practices then emerge. As Star (2010) notes, this characteristic of boundary objects has not been studied extensively, and the process of open hardware license development provides an opportunity to do so – and to model how this kind of negotiation might be relevant in other areas of culture and innovation that have been transformed by networked and collaborative knowledge production.

Under these circumstances, a more complex knowledge ecosystem has emerged where ideas circulate across networks as well as in relation to established institutions (Mansell, 2012; Cohen, 2012). This combination of different modes of circulation is a more extensive version of the knowledge environment that Star has discussed in her work. In this situation, multiple boundaries are likely to be present. Star's distinction between "well-structured" and "ill-structured" boundary interpretations is likely to be too limited. Instead, we need to develop the boundary-object concept so that it can account for a spectrum or continuum of complex knowledge relationships, some involving well-structured or firm interpretations and others, more flexible interpretations. The notion of a continuum, in contrast to the well/ill structured distinction, offers two potential advantages: first, it departs from a presumption that "better" outcomes are associated with well structured interpretations. Second, it provides a foundation for analysis of knowledge production contexts where there is empirical evidence that greater "openness" is occurring and is valued by certain participants in the relevant communities of practice, while being contested by others in similar or adjacent communities.

The "boundary object" that I am considering here is the idea of a license for open hardware. This is not a single object but a claim about how to organize knowledge. Both representatives of institutional bodies and those who gain their authority through their participation in peer produced projects can make such claims. To see how the negotiation of these claims unfolded in practice, I observed how open hardware advocates discussed why and how to license their work, and how they in developing a

license of value to them. The proposal for this license emerged from CERN, the European Organization for Nuclear Research. CERN is well known for its investigations in particle physics, but also has a strong policy of knowledge exchange. In 2011 a researcher in the Beams Section proposed creating a license for sharing the design specifications of the electronics that the section commissioned or created, in order to inspire future use of these designs and to provide other electronics creators with a similar way to share their designs. In partnership with the Knowledge Exchange Section at CERN, the researcher proposed an open hardware license known as the CERN OHL. The team recruited participants at open hardware community events and created a mailing list with dozens of enthusiastic participants who discussed the notion of open hardware as well as commenting on specific aspects of the license. As such, the project provides a space for debate between institutional knowledge and authority and the emergent authority of online communities of practice.

Methods for Studying Boundary Objects

This article draws from participant observation of the process of defining open hardware, including attendance physical meetings of open source hardware advocates, including the Open Hardware Conferences in 2010 and 2011, the Open Knowledge Foundation conferences of 2009, 2011 and 2012, and participation through membership on three relevant mailing lists. Field notes and documentation collected through this process are relevant to this argument, which also draws from thematic analysis of 480 messages sent on the CERN OHL mailing list from January 2012 to June 2014. This material has been analysed and categorized in order to identify key controversies and boundaries that emerge in the interpretation of open hardware licenses. Methodologically, this form of "participant comprehension" (Collins, 1984) holds the promise of robust research results and enhances accountability.

The CERN OHL – on the boundary of constituted and adaptive knowledge

Javier Serrano, a Beams Department researcher and free culture advocate, launched the CERN OHL. Serrano positioned the license as a means for the lab to create a virtuous cycle of open innovation by requiring its suppliers to provide open designs

for the products provided to the lab. These interventions linked open hardware development with the rhythms of formal institutional research, including the requirement to demonstrate the use of public funds and the monopsonistic power that a large institution can exert over its suppliers. Since 2012, the CERN license development has been crowd-sourced over a mailing list involving open hardware advocates, providing a record of the counterpoint between the institutional and the adaptive. For example, licensing can be seen as an appeal to constituted authority through reference to the legitimacy of CERN as a scientific institute. Equally, the development of the CERN OHL as an open source project was intended to gain the legitimacy of the distributed community of open hardware practitioners. This is particularly important because if CERN were to be able to argue for open hardware licensing as a means of fulfilling their mandate for sharing scientific knowledge, designs for hardware that they released would need to be subject to a license that was actually in use (or at least accepted as legitimate) by the distributed community of practice who use open hardware. Thus, the legitimacy of the CERN OHL stems from its ability to integrate these two forms of knowledge production.

CERN developed a hardware license with the aims of supporting collaboration and knowledge sharing, employing the structures and practices of open source software development. In the initial public description of the project, Serrano stated that "For us, the drive towards open hardware was largely motivated by well meaning envy of our colleagues who develop Linux device-drivers," (quoted in Giampietro, 2011). However, at the same time, the CERN initiative was positioned in terms of knowledge exchange and the organization's interest in promoting open science. The open source collaborative design processes that were used to create the lab's Linux-based device drivers drew on a worldwide community of software developers who shared expertise, and improved CERN's software.

Serrano's section hoped to reproduce this same type of peer produced oversight of products for the electronics they were designing: "I was inspired by my colleagues, the software behind the section I lead . . . my big inspiration was not other people, but [free] software". (Interview with author, 17 Sept 2013). Serrano began by creating an Open Hardware Repository where designs for electronics and other physical objects could be stored, allowing designers to collaborate through the sharing of their

knowledge about how to produce hardware from designs. In the Open Hardware Repository manifesto, Serrano writes, "The Open Hardware Repository is a place on the web for electronics designers to collaborate on open hardware designs, much in the philosophy of the free software movement" (OHR Manifesto, 2010). Reference to the free software project was meant to increase the legitimacy of the OHL project among the community of practice. This approach was also oriented towards gaining more legitimacy among the commercial sector while allowing the outcomes of CERN research to be broadly distributed. Serrano remembers:

> We were not happy with the way we were collaborating with companies . . . we became conscious that we had budgets [] and we had the right to request from the vendors whatever we wanted . . . The [Knowledge Transfer] Group got involved, and of the first things they wanted to solve, first of all was this, a legal framework in which [we could collaborate externally] (Interview with author, Sept 17 2013).

As a publicly funded scientific body, CERN had the constituted authority necessary to support the development of a framework for sharing knowledge, but it also had in Serrano and colleagues, enthusiastic participants in communities of distributed knowledge practices. So although the CERN OHL makes a claim for the role of research institutions in defining how to license the products of innovation, its legitimacy depends on the involvement of a distributed community of practice. This legitimation via adaptive authority required a concerted engagement with a community of practice.

Contesting licenses by definition

Serrano and CERN's project engaged with a distributed community of practice that was trying to define open source hardware with respect to existing intellectual property frameworks, but also with respect to existing contribution practices.
The original open hardware license and an inspiration for the CERN license was the TAPR Open Hardware License developed by John Ackermann, a legal expert and ham radio operator, and named for the Tucson Amateur Packet Radio (TAPR) club. In a law review article, Ackermann described how hardware intellectual property should be made available to distributed collective action in the same way as free

software: “At its most fundamental, the goal of licenses like the GPL[2] is to foster a community where those who benefit from the work of others in turn contribute their improvements to that community. A similar movement, inspired by many of the same concerns that drove those software developers, has taken shape among people involved in electronic hardware design efforts on a collaborative basis: the idea of Open Source Hardware.” (Ackermann, 2009 p. 184). The TAPR does not prevent patenting of open hardware designs, it also specifies that “those who benefit from an OHL design may not bring lawsuits claiming that design infringes their patents or other intellectual property” (Tucson Amateur Packet Radio Corp, 2014). The license thus releases patent rights to a predecessor, creating an expanding patent-free zone. This license served as the basis of the CERN OHL, but Serrano wanted to expand the approach into a form that would include the provisioning process within his section as well as the production of open hardware more broadly across the community of practice.

Over the next several years a growing group including entrepreneurs developing electronics prototyping kits, digital rights advocates, legal scholars and development advocates developed different open hardware licenses and distribution mechanisms (see Powell 2012) but also attempted to develop a shared definition for open hardware. Given that different participants had different views on the necessity of protecting individual intellectual property (and the means to do it), this definition had to have the legitimacy of networked community of practice.

A board of experts was solicited from participants at Open Hardware Summits and the resulting organization; the Open Source Hardware Association (OSHWA) devised an open hardware definition[3] that was discussed online by the community. The process of establishing the definition was collaborative and collective, but the resulting document reveals the tensions around delineating what is and is not open hardware,

[2] The GPL, or GNU Public License, is a free software license that guarantees to software users the freedoms to use, study, share (copy), and modify the software. These freedoms are secured by the specification in the license that any software that contains code licensed under the GPL is also subject to the license.
[3] The definition can be found at http://freedomdefined.org/OSHW

and how much work a license can do to achieve this, particularly in conversation with other knowledge frameworks:

> In promoting Open Hardware, it is important to make it clear to designers the extent to which their licenses actually can control their designs. Under U.S. law, and law in many other places, copyright does not apply to electronic designs. Patents do. The result is that an Open Hardware license can in general be used to restrict the *plans* but *not* the manufactured devices or even restatements of the same design that are not textual copies of the original. The applicable section of copyright law is 17.102(b), which says: *In no case does copyright protection for an original work of authorship extend to any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described, explained, illustrated, or embodied in such work.* (emphasis added) (Open Hardware Definition, 2010)

The definition defines a boundary between protection of intellectual property and distributed peer production. The negotiation of this boundary is important in defining the work and the legitimacy of open hardware actors. The definitions of open hardware developed by the community reflect differences in ideas about how firmly or flexibly the ideas about open hardware licenses should be interpreted. Concretely, this means that open hardware licenses make different interpretations of how to engage with existing intellectual property frameworks. The contention evident in the definition highlights how dialectic tensions between protection of IP and its release into commons percolate within open hardware communities of practice.

These tensions emerge in part from a contention about what open hardware is supposed to be, and how this can be defined with reference to a license. For Serrano and the CERN project, the social act of sharing is best encouraged through specific language and definition: "by default, public domain is all rights reserved … so you need a licence to say you want to share, and you need a licence to say you want to share [under] copyleft. If you don't to use a licence, that means you're not interested in sharing, because the default is not sharing. (Interview with author, September 16

2013)." The development of the CERN OHL was in part intended to create another potential set of defaults.

Other advocates question the focus on licensing as a means of definition. Michael Weinberg, a legal advocate involved in open hardware and manufacturing, expresses a commonly held view that creating greater expectations around licensing could have the perverse effect of limiting sharing of knowledge that is not already licensed. He argued that:

> One of the things that I worry about is, in the attempt to find a legal hook for the license, people start, kind of, like, stretching existing IP . . . So, you know, you think about a piece of hardware, and unpack that piece of hardware, and you say, okay, well, you know, in a state of nature, it's not really protected by IP, but then you start saying, well, we need to find a way to get this open source hardware license to apply to it, so maybe we'll kind of start pushing the boundaries of copyrightability, or we'll think of some other, kind of, legal theory that allows it to have some level of intellectual property protection . . . so we can attach this open source hardware license. (Interview with author, Sept 16 2013)

For Weinberg, defining open hardware too firmly with relation to its legal frameworks could have the unintended consequence of restricting intellectual property rather than opening it up to distributed peer production. Thus, the dialectic between constraining and opening intellectual property starts to intersect with the related tension between the value of constituted and adaptive knowledge about open hardware. We can see the same kinds of tensions playing out across cultural industries struggling with balancing emergent, adaptive knowledge with knowledge valued by existing institutions.

Intersecting Tensions: Interpreting licenses on a boundary

On these kinds of boundaries, firm or 'well-structured' ways of thinking about how to 'do' open hardware by licensing it coexist with looser or more 'ill-structured' ideas about the role of licenses. The following table lists the ways that the values and norms of constituted and adaptive authority intersect with well or poorly structured ideas about what open hardware licenses do. The table below summarizes the intersection of more or less firm or flexible interpretations of the role of licenses in defining ways to share knowledge about electronics hardware.

Table 1

Authority	**More flexible adoption of "licensing"**	**More fixed adoption of "licensing**
Constituted	- Various open hardware associations and bodies including Open Source Hardware Association and others i.e. Open Hardware and Design Alliance, Open Source Hardware Society - Support general principles of 'openness' and/or definitions rather than see it as defined by licenses	- CERN, World Intellectual Property Organization (WIPO) - Institutional practice of distributed peer production guaranteed by licenses for both software and hardware - Patent reforms by WIPO redefine intellectual property through details of patent protection
Adaptive	- Various online repositories for open designs without explicit licensing requirements – sharing practices regulated by community norms: i.e. Thingiverse for descriptions, bills of material and printing plans, OpenCores repository for open source hardware integrated circuits	- Online repositories specifying use of a particular license for inclusion (i.e. OSHWA and CERN repositories); entrepreneurial propagation of "open hardware" through labeling and promotion of particular licenses on products

This table illustrates that there is a continuum of relatively firm or relatively flexible interpretations of "open hardware licensing. There is no necessarily strong association between a well-structured interpretation of "open hardware" and a social world's reliance on constituted authority. While some sites of constituted authority have relatively firm interpretations of licensing which proceed from their interest in maintaining existing modes of managing intellectual property including patent

libraries, there are also constituted authorities that have a more flexible approach to licensing of open hardware, including the various open hardware associations.

Adaptive authority can also coexist with a fixed interpretation of open hardware: some 'knowledge commons' repositories specify the use of a particular open hardware license and, in some ways, labeling of open hardware occupies a similar space where open hardware can be interpreted as that which is labeled as such. Of course, there are some very flexible interpretation of open hardware that align with adaptive authority, particularly repositories like Thingiverse, where the 'openness' comes from the sharing of individual documentation in almost any form.

The next section draws on empirical evidence of the debate over the most recent version of CERN's open hardware license as a way of illustrating the negotiation between constituted and adaptive knowledge, and assessing the value of the integration between firm and flexible interpretations of hardware that is one result of that negotiation.

The CERN OHL – a boundary-transcending process?

In 2012 CERN was preparing to release a new version of the license, and used a public mailing list to solicit discussion from a distributed group of hardware hackers, entrepreneurs, legal experts and others. This discussion, which included over 400 mailing list messages that I coded using CAT: the Coding Analysis Toolkit, demonstrates how negotiations about how to define open hardware with respect to licenses (that is, boundary negotiations) also act as ways of balancing different forms of authority. These balancing acts are significant in a cultural landscape characterized by uneasy balances between different forms of knowledge and authority.

Appeals to Constituted Authority

The mailing list solicited participation in developing a new version of the license. As part of the discussion postings frequently referred to the significance of CERN as an institution, and linked the legitimacy of the license, the legitimacy of the institution and the legitimacy of open hardware. But this always came balanced with an acknowledgement of the process by which adaptive authority developed within the community.

For example, in one posting, a developer asked if CERN were interested in having their license be on the list of licenses used within the Thingiverse repository. Serrano replied that this was beyond the aspiration of CERN, but the original poster then put the request this way: "From previous emails from this list, I have learned it is not good to mix hardware and software licenses. So really, I cannot use CERN OHL and upload to Thingiverse because of this. I don't expect for you to put the license on the list, I was just hoping you could use your muscle to request it be available." (Pulkrabek, 20/04/2012). The author of this message positions his question within the frame of the knowledge he's gained through participation on the list. But at the same time he attributes to CERN some extra 'muscle' that he doesn't have in his own dealings with Thingiverse. CERN's intervention is important both because of the institution's profile and because of the license being developed.

The converse of this position comes when the adaptive authority of the mailing list group is folded back into the constituted authority of CERN. The legal representative from CERN, Myriam Ayass, wrote this post just after the launch of the new license version:

> "Hi Everyone, this new draft is slightly overdue, but I hope the end result integrates most of the comments and discussions that we saw and received on the previous draft. And here is the link where you can find the current draft: http://www.ohwr.org/documents/144
>
> The main changes you will find are in section 3.3 in an attempt to solve concerns around the copyleft/conditionality issue (thanks Andrew!). It now reads so that a Licensee knows, at the time of modifying Documentation, which conditions to comply with, and is able to comply with them at that time.
>
> We have also removed the clause requesting a Licensee to (attempt to) send the modifications he makes to the original Licensor and other people interested. This was discussed at length in the context of the previous draft, and felt that it might be too onerous or controversial.
> Other changes are relatively minor.
> I look forward to hearing your comments!" (Ayass, 12/06/2012)

These examples illustrate the negotiation between constituted and adaptive knowledge, and the way that their tension valorizes firm or flexible interpretations of open hardware. Constituted authority remains powerful enough that sometimes CERN

itself is described as an entity responsible for defining and managing the future of open hardware – even though the CERN OHL project was instituted as a way to integrate into the community of practice. For example, this posting proposes employing the CERN relationship to transform hardware even further into a 'free culture' phenomenon:

> Hi all.
>
> I've the feeling it could be a great moment to try to study the building of a FSF cousin, focused on "free hardware" ...Do you know where we (or other people) could discuss about this ? Do you think CERN could be a place where could be "homed" (meaning, adress of
> headquarter) this "Free Hardware Foundation" ? As CERN has gain a great experience in OHL, that could be natural, no ?"(Anon, 24/08/2012)

Appeals to constituted authority were thus not straightforwardly valorizations of a firm interpretation of licenses but rather acknowledgements of the value of institutions like CERN to the otherwise distributed knowledge production. Further, any reference to the authority of CERN's license writers remained rooted in the legitimacy of the community of practice.

Appeals to adaptive authority

The processes of adaptive authority developed through the mailing list negotiations were sometimes leveraged to create firm interpretations of the importance of licenses for defining open hardware. In the excerpt below, a legal expert acknowledges the importance of the discursive space on the mailing list. He employs a firm interpretation of open hardware licensing, arguing that the license sets the conditions for a legal understanding of open hardware, but more importantly for a practical one.

> Thanks for the interesting discussion, Myriam, Carlo and Erik
>
> I agree with Carlo's analysis, but it might be worth explaining why I was concerned about the original language.
>
> Generally speaking, to manufacture something, you don't need a license, (as Myriam said), although as Carlo correctly says, there are counterexamples to this.
>
> I think everyone agrees, therefore, that if you license a hardware design, and it happens to be covered by one of these IPRs [intellectual property rights] and you own or control them, (applicable design right, patent, etc), then you also need to grant a license to those IPRs.

> In the world of software, the assumption is that you will need a license to copy. That is usually correct, because all software except the most trivial will be subject to copyright, the duration of copyright is moronically long, and no software has been written which has yet fallen out of copyright . . .. So it's ok to have software licenses that contain the assumption that copying the software does, indeed, need a license. (Katz, 24/08/2012)

In this posting, the author acknowledges the importance of the adaptive process, while insisting on a firm interpretation of a license and an understanding of open hardware that derives from software.

Edge Cases

A large proportion of the mailing list traffic concerns the problems of what the community refer to as 'edge cases', hypothetical interpretations or extrapolations of features of the CERN license. The 'edge case debate' is the community's own way of negotiating with the dialectic of constituted and adaptive authority, and their interpenetration. These evocations of "edge cases" are evidence of the flexible interpretation that most participants have: they conceive of open hardware as something not entirely defined by its license. The difficulty in interpreting whether a more firm or fluid interpretation should be applied is part of how the dialectic is negotiated, and worries about edge cases can be seen as deliberations about the unintended consequences of a particular part of the license text. In this message, the poster quotes another article describing a limitation of the license.

> I thought this comment was astute and should be taken into account: https://lwn.net/Articles/478233/
>
> "2.1. ... By exercising any right granted under this License, the Licensee irrevocably accepts these terms and conditions....
> 3.2 The Licensee may use, copy, communicate to the public and distribute verbatim copies of the Documentation ..."
>
> Does this mean that using the documentation requires me to agree to the terms of the license?
>
> I would assume that the law has no power to bind someone to a license just for reading a document, but perhaps one of the sections listed should be modified so that such binding is not implied. (Stafford, 01/31/2012)

This comment illustrates how 'edge cases' permit negotiation between different types of authority. The writer worries that the authority of the license will extend further than it needs to, potentially even 'chilling' more flexible interpretations of openness where documentation is used but where a license is not.

In the discussion of the new version of the CERN OHL, a distributed community of practice negotiated with the constituted authority provided by CERN and the adaptive authority of the community itself, navigating a continuum of different ways to define open hardware. These definitions ranged from firm interpretations that see open hardware as defined by licenses to flexible interpretations that understand open hardware to be whatever the people who are making it think that it is.

Infrastructural Tendencies – and barriers

This dialectic negotiation raises some interesting questions about what happens when the practices and norms in these kinds of dynamic communities become more solidified? As indicated earlier, Star's (2010) conception of infrastructure refers to the point at which particular interpretations of things become more significant because they interlink with other parts of systems. Will a firm interpretation of open hardware become infrastructural? This appears to be supported by CERN's process of engaging adaptive authority to legitimate the definition of open hardware through its licensing, but significant opposition remains to the idea of a license defining open hardware and partly because of the seemingly insoluble edge cases that the community identifies. It is still possible to argue, as Weinberg does, that:

> Most hardware projects are "open" by default because their core functionality is not protected by any sort of intellectual property right. Of course, in this case "open" means that their key functionality can be copied without legal repercussion, not that the schematics have been posted online or that it is easy to discover how they work (critical elements of open source hardware). (Weinberg, 2012, np.)

Weinberg's statement contains two interpretations of the importance of open hardware – one that focuses on intellectual property protection and the other that stresses open knowledge. He identifies the tension between firm and flexible interpretations of licensing. A firm interpretation, at least from the perspective of intellectual property protection, would require adherence to the conventions of at least

one of the mechanisms that Weinberg mentions: copyright, patent or trademark. Yet this contravenes another core interpretations of open source hardware, the idea of knowledge sharing through online posting of schematics so as to illustrate how they work.

The paradox of open hardware is that both interpretations of openness are important, but that facilitating a flexible interpretation and expansion of knowledge might invite abuse by actors who are not committed to the adaptive authority of the open source community of practice. This is potentially a feature of other cultural spheres where authority and knowledge are collectively created and governed by social norms.

In the CERN OHL case, constituted authority cedes to adaptive authority. The most recent version of the license removed a stipulation that people making subsequent modifications to a design would have to inform the original designer of their modifications. The collaborators felt that insisting on this would prove burdensome to the original designers who might then receive dozens of updates to projects they had abandoned, but the CERN representatives worried that removing it would make it difficult to track the adoption of the open hardware designed within the institution.

The new version of the license takes a more flexible interpretation of open hardware, creating a situation more beneficial to the distributed community of practice than to the institution. This suggests that a future normative frame for open hardware might fit the needs of a distributed community of practice – forcing institutional players to shift in the same way. Finally, it is important to consider how CERN's constituted authority plays a role, not because it is legitimate simply by virtue of being a site of constituted authority, but because of Serrano's (and the institution's) willingness to contribute to the development of adaptive authority for its own sake – and for the public good.

Conclusion

These attempts to build legal frameworks for open hardware are interesting because they represent a key aspect of contemporary cultural production: the negotiation between a mode of knowledge formation that valorizes distributed, peer produced knowledge and one that is attached to institutional legitimacy. As cultural production

moves from well-constituted institutions to emergent collectives, new norms emerge. New standards establish ways to accommodate forms of authority, and that accommodate both firm and flexible interpretations of the objects they use. This may encourage a conception of 'openness' as an instance of the integration of some of the norms of both constitutive and adaptive authority.

The CERN OHL case demonstrates that this can occur, although the value of adaptive authority is still legitimated through reference to constituted authority. In addition, there may be significant differences in the nature and orientation of constituted authority: CERN has a responsibility for disseminating research results in the public interest, and a tradition of supporting this dissemination via a variety of means. This creates the conditions through which constituted and adaptive authority may be integrated despite their paradoxical relationship. Other entities may not have the same concerns about public interest knowledge: for example, Facebook has recently launched an open hardware project called the Open Compute project, which aims to open specifications for networks, server racks and data centre hardware.

The project includes a license, but the purpose of this agreement is to allow companies to share specifications via the project repository while retaining their patent rights, rather than attempting to release more knowledge for re-use through peer production processes. In other words, it's economically open but doesn't create a knowledge commons. Thus, the nature of integration between constituted and adaptive forms of knowledge can significantly influence cultural production and innovation. As cultural innovation occurs at boundaries between social worlds, we need to better understand how to negotiate different forms of authority, and as such we may need to become better at tolerating paradox, tension and uncertainty.

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