JOURNAL OF PEER PRODUCTION

The Journal of Peer Production
New perspectives on the implications of peer production for social change
Journal of Peer Production Issue 12: Makerspaces and Institutions
http://peerproduction.net — ISSN 2213-5316

THE SOCIOMATERIALITY OF FABLABS: CONFIGURATIONS OF A PRINTING SERVICE OR COUNTER-CONTEXT?

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FabLabs can be studied as a technology- and product-oriented movement. In this study, I review material objects in European FabLabs as sociomateriality that represents and embodies the ways FabLabs are institutionalising. This refers to FabLabs' relationships with incumbent institutions and how they impact the formation of norms and routines internally. Labs may adopt procedures familiar in mainstream organisations, borrowing from formal institutions in a quest for public inclusion and mainstream legitimacy, or they may seek to innovate in organisational structure, establishing themselves as informal institutions to maintain their counter-culture identity. Examining sociomateriality helps make visible how Labs manage the contradiction between 'openness' and recruitment of allies, and maintaining alterity. The studied FabLabs' institutionalising processes are ongoing, performative and heterogeneous, encompassing mixed tactics oriented towards both public inclusion (commodification and conforming) and counter-culture (reconstitution and transforming). We also propose that analysis conducted through three types of objects, work, knowledge and imaginative objects, provides a more articulated account of the tensions in material peer production.

Keywords: FabLabs, sociomateriality, sustainability, institutionalising, STS, ethnography

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by Cindy Kohtala

INTRODUCTION

As sites for research, shared community spaces for digital fabrication offer insight into how (or if) citizens engage in material production and with fabrication technologies. They reveal how people shape peer-to-peer communities and what future impacts, social, economic or environmental, these spaces and practices may entail. The MIT FabLab network is a type of makerspace community that grew from an outreach project by MIT's Center for Bits and Atoms (CBA) in the early 2000s. FabLabs around the world are free to establish their own spaces, activities and networks, but they also share an identity and are encouraged to have some common working practices in order to foster inter-lab collaboration (Gershenfeld 2005). A shifting dynamic involving network identity, lab autonomy, regional collaboration, bottom-up agency and top-down governance, renders the network a fascinating subject of study, particularly given its rapid growth, diversity of operating environments and range of lab ages. The oldest labs may be seen to have established routines while the youngest have yet to establish their norms and conventions – and in practice this institutionalising process is in constant change.

As a network entity, FabLabs promote their role in expediting the 'new industrial revolution', marked by citizen participation in all forms of socially useful production and the 'democratisation' of production technologies. In enacting these visions, some labs innovate in ways to collaborate while others adopt routines of business-as-usual. In their successful branding and the global spread of their particular type of 'maker culture', FabLabs have been accused of maintaining the values and structures of the current economic system and thereby merely reproducing capitalist ills. Simultaneously FabLabs aim to be open-access community workshops, and

attracting and retaining users necessitates procedures that are at least somewhat familiar to a wider audience.

The FabLab global network comprises a logo and charter, online and offline collaboration, participation in the worldwide educational undertaking the Fab Academy, international and regional meetings, and responsibility for much sponsorship and global communications being managed by one body, the Fab Foundation. Nevertheless as individual entities FabLabs are also diverse, local and situated. They are actual spaces – rooms, buildings, offices, former factories – peopled by actual bodies; filled with actual, tangible materials; surrounded by neighbours and built upon particular local histories. Lab managers must carry out their own strategy work, earn income and target desired users. Equipment may be chosen according to identified local needs, or the equipment selected may then shape who enters and who stays. Projects may be promoted as valuable by managers or users, while other projects remain unfinished, unremarked and unseen. Technologies become invisible as infrastructure or tools remain broken and unmaintained.

Things *are* produced in FabLabs, so of course things are important. But it is instructive to bear in mind how the social and the material are intertwined. Does the thing become a 'story' – a symbol of success and material realisation of a certain vision? Is one object – an open-source 3D-printer – favoured explicitly over another – a proprietary printer? How does an object constrain the group and what they want to achieve? What work-arounds do they adopt to counter this? How each lab goes about its business, each decision and configuration, constructs many micro-trajectories. Some procedures become routines and experiments become practices; other aims sit on to-do lists and continually reappear in various tactical forms. Objects make visible these trajectories of how the lab is institutionalising: how relations with other, more formal institutions – the mainstream, incumbent entities with whom the lab collaborates or competes – shape the norms, procedures, operating systems and values the lab adopts.

Some labs are staunchly committed to open software and hardware, for instance, and this commitment is visible in their sociomaterial arrangements such as the tools they use to organise assemblies. Some labs emphasise transformation to a more 'sustainable' and participative society; examining objects in these labs can help identify how they keep both discourse and activities concerning environmentalism and social justice in play. The current diversity of labs therefore offers some idea as to what pathways are possible: the types of 'innovation' various labs foster indicate the forms these shared machine shops may take as they settle in and out of alignments.

With this in mind, I set out to observe a group of European FabLabs, to begin to understand some of the range of people, practices and places. This study reflects upon this research material to explore the tensions in establishing norms and routines. How do FabLabs react to the dominant sociotechnical culture in which they operate? To what cultures and practices do they align and what do they wish to redress? How do material objects reveal these processes? The following sections will elaborate upon the theoretical understandings of sociomateriality and institutionalising relevant to this study, as well as the research gaps addressed. The fourth section describes the research material and study methods. The key themes of FabLab objects are then discussed, followed by conclusions.

INSTITUTIONALISING IN TECHNOLOGY MOVEMENTS

In discourse, the FabLab mission is to bring groups the *means* to make their own technologies locally, rather than the technologies themselves (Gershenfeld 2012). But FabLabs court controversy in their day-to-day activities by appearing to be catering to a myriad of objectives and partnering with a range of bedfellows. Commercialising is often 'construed as a sensible means for sustaining the

activity (and livelihoods)' for some, while signalling 'disappointing co-option' for others (Smith et al. 2017, p. 122). Hess's (2005) concept of technology- and product-oriented movements well captures this phenomenon. Technology- and product-oriented movements are 'mobilizations of civil society organizations that generally are also linked to the activity of private-sector firms, for which the target of social change is support for an alternative technology and/or product' (Hess 2005, p. 516). Since these alternative technologies can be linked to a wider agenda such as lifestyle change, there are advantages to examining their creators as 'mobilized publics' in social-movement theoretical frames, as well as Science and Technology Studies (STS) (Hess 2016). Some technology movements utilise 'alternative institution building as means for change' and some become incorporated, thereby diluting the original social movement goals (Hess 2005, pp. 517-18; 2016).

Hess (2016) draws on the framework of 'institutional logics' from institutional theory (Friedland and Alford 1991) in his analysis, meaning that each institution has its own 'set of material practices and symbolic constructions' (Friedland and Alford 1991, p. 248). To study industrial transitions is to study the conflicts and changes in institutional logics when social movements challenge incumbents: that is, when different systems of meaning – systems of design, systems of ideology – meet (Hess 2016, pp. 17, 146-150). In simplified terms (and incorporating the perspective of Transition Studies), these alternative systems either 'fit and conform' to incumbent institutions (in regimes) or serve to 'stretch and transform' them (Smith and Raven 2012; Dickel et al. 2014). (For reasons of simplicity, in this study incumbent organisations in dominant regimes will be referred to as formal institutions and FabLabs, as challengers, termed informal institutions, even though it is recognised some FabLabs register themselves formally as associations, cooperatives or companies.) In practice, when incumbents and challengers meet, various syntheses and combinations occur (Hess 2016, pp. 146-150), and both the logics and their interactions are seen as ambiguous, inconsistent and open to interpretation (Pfaffenberger 1992, p. 297). What is most relevant in this study is examining the meeting of different logics (design and ideological systems), how they impact the formation of accepted norms and procedures in a FabLab (i.e. how it institutionalises), and how this is visible in sociomaterial terms.

These processes can be illustrated by imagining two extreme FabLabs. The first lab is the most visitor friendly, we could call it Peer Production as a Service (PPaaS). The lab is well branded and organised. Instructions to both the use of the lab and use of individual machines are easily found. Displays of projects show what can be done and with what techniques. Tutorials and information relevant to users are organised and accessible. Back-office activities such as the lab manager's own task list or strategic priorities are likely to be less visible, deemed less relevant to visitors. Such an office may be physically tucked away elsewhere, away from the main working and social space. The fabrication service stops at making the artefact for the visitor.

At the other extreme we have a lab that is the least accessible to first-time visitors, rather like a community space by insiders for insiders (see Wu, Whalen and Koskinen 2015, for an example of such an 'anarchist' workshop). Instructions are not forthcoming. Tools, equipment, materials and components may appear to have their own system of organisation not apparent to the visitor. Objects the community uses to organise itself, from meeting agendas to maintenance logs, are visible and accessible, even if not necessarily understandable. There are no clear differentiations between spatial functions: office and management, working and experimenting, socialising and playing. First-time visitors enter and do not know what to do or even who to ask for further guidance.

In these hypothetical examples, the first lab is oriented to the incumbent institutional logics of familiar printing services and has configured aspects of its infrastructure and artefacts accordingly. Its

norms and routines fit and conform to formal institutions in an effort to maximise users' ease and convenience: taming the wildness of the otherwise rebellious technologies and revolutionary access to them, in order to accommodate a wider public. The second lab, in contrast, confronts incumbent institutional logics by *pre*figuring: establishing a counter-culture space, a 'counter-context' (Pfaffenberger 1992) in which both technologies and behaviours are actively reshaped. Alternative beliefs and procedures are put into practice, in an alternative institutionalising process to redress the perceived dominance of a capitalist, consumerist system and render it symbolically (and materially) obsolete. Pfaffenberger (1992) has called such self-conscious reshaping of technological processes and artefacts 'reconstitution', and in this study reconstitution is seen in direct opposition to processes of commercialising and commodifying.

Obviously these dynamics continue, with incumbents challenging reconstitution efforts (at times resulting in co-option) and informal institutions settling into routines that still others resist. In the FabLab network, individual labs and regional networks also establish their *own* procedures as explicit acts of deviance from FabLab network norms (Troxler 2014; Neale and Hobern 2017), which in turn were established as acts of deviance from dominant corporate technology development and mass production logics. This double manoeuver, a re-reconstitution, evidences the ongoing-ness and dynamic nature of institutionalising processes.

Useful as Hess's and Pfaffenberger's concepts are for understanding the role of challengers to industrial incumbents in sociotechnical change, the analyses remain mainly at a macro level that loses the granularity of how organisations like FabLabs negotiate their sociomaterial practices from day to day. Insights into how labs attempt to enact 'revolution' at a material level – the challenges they face and tactics they adopt in doing so – are helpful if we are to understand these shared machine shops' potential to transform consumer capitalism.

SOCIOMATERIALITY

Focusing on materiality in DIY maker culture tends to aggrandise solutions, resulting in a mere cataloguing of projects. To counter this, critical academic studies have examined, for instance, material attachment and sustainability implications in makerspaces (Maldini 2016), questions of identity as mediated through materials (e.g. Toombs, Bardzell and Bardzell 2014) and the more interventional Critical Making line of inquiry (Ratto 2011). Whether studies explicitly use the term 'sociomaterial' or not, they generally acknowledge the bundling, entanglement (Barad 2003) or assemblage (Law 2004) of the social and material.

However, relatively few studies on DIY making thus far have examined materiality to deliver insights into how community workshops arrange themselves as collective enterprises. This dearth contrasts with the legacy of STS scholarship that has addressed the relationality between the human and non-human in collaborative work. Sites of STS studies have included, most famously, scientific laboratories and software development organisations, but also architecture offices, energy retrofitting projects, activists' repair workshops and others (e.g. Suchman 1987; Orlikowski 2000; Büscher et al. 2001; Latour 2005; Callén and Sánchez Criado 2015; Buser and Carlsson 2017). In turn, relatively few STS studies on collaborative work and institutionalising have examined social movements and informal collectives. FabLabs are not science laboratories, workplaces nor home (Kohtala and Bosqué 2014), and the work is neither job nor hobby but somehow both (Menichinelli et al. 2017). The *symbolic* role of objects is therefore arguably even more important in examining FabLabs, in how they represent objectives and recruit and galvanise participants (Pfaffenberger 1992; Hess 2016, p. 167).

The conceptualisation of 'objects' in the STS analytical framework Symbolic Interactionism (Blumer 1969) understands them as both materials and concepts, and it is helpful in retaining the epistemologically important entanglement of the

material and discursive. Symbolic Interactionist studies examine how collective discourse and action unfold in interaction. FabLabs are seen as part of a social world (Strauss 1978) that interacts with other social worlds such as incumbent institutional logics; subworlds shift 'as patterns of commitment alter, reorganize, and realign' (Clarke and Star 2008, p. 119). The materiality of DIY making renders visible how social worlds of production elide and collide. Our technical environments are clearly not seamless; to the contrary they are messy and *seamful* (Chalmers and Galani 2004; Vertesi 2014). Objects 'allow' people into alternative acts, inventive bricolage and production of disobedient counter-objects as much as they shepherd them into familiar conventions. The work of putting messy, disparate systems – of design, technology and culture – to work together, elicits possibilities to question and transform, or repeat and freeze routines. How FabLab collectives attempt to order a seamful mess thereby signals how they institutionalise.

The next question is then whether the spaces, activities and objects of FabLabs can or should be analysed as work (Berg 1997); as knowledge creating assemblages as in science laboratories (Latour and Woolgar 1986 [1979]); as citizen-science social movements producing alternative knowledges (Papadopoulos 2015), or 'unruly publics' attempting to change policy or behaviour (de Saille 2015); or if all these frames can be kept in play simultaneously. FabLab objects are about organising work, but they are also about exploration and building knowledge. As a technology movement, FabLabs create symbols and use imagination, play and ritual in constructing ideological discourses that muster and mobilise. But what happens at the seams? What do objects anchor: what systems, worlds, logics and possible futures?

In subsequent sections, we will examine further the concepts of work objects, knowledge objects and symbolic, imaginative objects, with examples from my empirical data to illustrate. Before this discussion, a clarification of the research sites follows below.

THE RESEARCH SITES

FabLabs are useful sites for a study on materiality, as they are encouraged to procure the same inventory. Many labs participate in the network's own online and offline training programme Fab Academy, which further encourages sharing ideas on processes and practices.

This study comprises data gathered in thirteen European FabLabs. One lab was the target of a longitudinal ethnographic study examining how environmental sustainability was represented (Kohtala 2017). The field studies in the other twelve sites were conducted to understand the range of labs (who hosts, who funds and who visits) and objectives. Attention was paid to and notes were made on equipment, displays, documents, projects and lab layouts, as well as what managers and users themselves highlighted. Digital artefacts such as booking systems on websites are also material, as people access them with their bodies via physical interfaces such as keyboards and screens; such objects were noted when they were used and actors explicitly discussed their development. Because of the more general objectives at the time, details on objects were not systematically recorded for purposes of strict cross-comparison. This analysis thus relies on data gathered at the time. The data nevertheless consist of extensive fieldnotes backed with audio and video recordings and substantial photo documentation (see Table 1, Appendix 1). Such analysis must acknowledge the subjective attention of the researcher and what may have gone unrecorded and unnoticed, but it also garners strength from observations sensitised to design and materiality due to my design background.

Two labs in the study were initiated with European Commission project funds, and one lab's initial equipment procurement was funded by the Fab Foundation, in the first round of FabLabs established outside the US in the early 2000s. Six labs were founded by private individuals, as entrepreneurs, as

people in the creative sector needing a workspace and willing to offer a shared facility, and as a private experimental space. Two labs are funded by universities and one by an arts association. One is hosted by a municipality and two labs by professional industry associations. The labs are also notably art and design 'heavy', meaning they are located in design and architecture schools, run by professional designers and artists or have the local design council or association as a founding member (nine of the thirteen). The other labs have engineers or technology analysts as founders or a technology- and product-development association as host (four of the thirteen). All labs bar one are in cities; one of the city labs is in a peri-urban area of a large city. (See Appendix 1.)

Beyond this dataset, ethnographic observations have continued in the main FabLab site and visits have been made to fifteen other FabLabs, hacklabs and makerspaces, including sites outside Europe. Participant- and non-participant observations have been made at three international FabLab meetings and during Fab Academy implementation, as well as during community events held in the Helsinki DIY maker scene. Key impressions from this fieldwork have therefore also informed this analysis.

For this study, identifying the role of objects was a primary task. The three categories of objects derived from examination of STS theoretical discussion on objects, reflected against other empirical studies on FabLabs and makerspaces as well as my own research material. In thematic analysis, the notes, transcripts and photos in the dataset were examined with these guiding questions: what objects appear in all or most labs and what objects are particular to some labs? What do participants highlight to the researcher and make visible to others; what issues may be rendered invisible? From the perspective of norms and routines, what do the objects represent in terms of collaboration and communication? Examples from the data were selected that best illustrated the three types of objects, and the institutionalising dynamics made visible by the objects were articulated in narrative memos. The following sections will elaborate on the study's key insights.

ON OBJECTS

The concept of *work objects* (Casper 1998) is helpful in drawing attention to how social order is negotiated to get things done. Things make work visible, whether they are to-do lists on a whiteboard, unconference agenda posters for participatory organising, or hacks and work-arounds. Work objects also point to how different technical worlds come together, such as when things-and-practices from a computer science educational culture meet things-and-practices from the manufacturing world.

Another important STS concept is *knowledge object* (Knorr Cetina 1997), and particularly in questions pertaining to sustainability, knowledge work is important. Citizen groups rally on topics of importance and fight to have their expertise recognised (Ottinger 2010). They build their knowledge experientially, with hands-on work, using their bodies and engaging with materials (Marres 2015). DIYbio labs and hackerspaces produce 'alternative ontologies' (Papadopolous 2015). The knowledge object therefore appears capable of bridging the concerns of STS and social movement studies, and we can employ it when examining FabLabs' pursuit of knowledge: both the present-oriented, practical exploration of how to localise production, and the future-oriented pursuit of how to shape commons-based peer-to-peer communities. Such objects thus embody both pragmatism, in local fixes, and utopianism, in visions of self-sufficient, ecologically conscious, convivial futures (cf. Sadler 2012).

This leads us to another type of object I argue is important in FabLabs but perhaps receives less attention in STS scholarship: the symbolic role objects can play in imagination, conveying a particular vision and animating actors. Objects such as the interface for event-organising software – where some functions can be automatised, allowing participants to take on the role of co-organisers –

help this group build knowledge on horizontal governance and values-in-design in interface choices (Flanagan, Howe and Nissenbaum 2008). But they also represent and legitimise, by partially realising, a particular vision where self-organising groups work to preserve a particular commons. These visions form part of the alternative institutional logics – the material practices and symbolic constructions – labs co-produce.

In considering the history of science, Wartofsky argued for the role of the 'imaginative' object: how 'constructions of alternative imaginative perceptual modes, freed from the direct representation of ongoing forms of action, (…) feeds back into actual praxis, as a representation of possibilities which go beyond present actualities' (Wartofsky 1979, p. 209). For Judith Gregory (2000), building on Wartofsky, utopian visions need not be realised to have resonance, and their very incompleteness is in fact propitious. 'Incompleteness and heterogeneity are desirable because by their openness they provide opportunities for new and/or different actors, new elements which may be discontinuous from historical precedents, and alternatives that may be oppositional or engage resistance' (Gregory 2000, pp. 101-102). Visions of alternative futures resist incumbent systems of meaning (such as consumer capitalism) and evoke new lifeways. Visions mobilise actors, particularly when they begin to emerge in material form – as resources for imagination: 'The "impact" of technology begins when imagination and aspiration begin to be shaped by it, often long before any "working" technology exists' (Hyysalo 2010, p. 251). We can thereby call these partial realisations in FabLabs *imaginative objects*.

There is nevertheless a flipside to how visions help shape group norms. Symbolic objects are used to keep a community unified and, in so doing, keep other people out. In other words, we should be aware of sociomaterial processes of boundary *spanning*, but also boundary *policing* (Ottinger 2010). What is especially important in FabLabs, because it is easily under-addressed, is the question of intentionality: keeping people out is not only achieved through active and knowing boundary policing. Dynamics related to expertise and community identity can create unintended hierarchies in peer communities (Schor et al. 2016; Toombs 2016). Moreover, community building aligned with certain institutional logics can keep consequences (such as environmental impacts) invisible – outside the realm of the FabLab (Kohtala 2017). In this way, I see imaginative objects also acting as a *membrane* – strengthening the identity of the community inside, but (intentionally or unintentionally) keeping people, issues or impacts out.

FabLab communities do not represent a particular professional or scientific practice, hence imaginative objects will represent varying institutional logics, from those that orient more to an industrial world (such as machines-that-make-machines) to visions of a better world in socio-environmental terms (such as beehives or aquaponics projects). These heterogeneous visions appear likely to foster a splintering of the FabLab movement into various trajectories as it matures; analysing imaginative objects, alongside (or as hybrids of) work and knowledge objects, in peer production offers a more articulated account of the tensions involved in FabLab institutionalising and these possible trajectories.

ON WORK OBJECTS

When we look around a FabLab we see documents (order forms, instructions and manuals, project documentation, posters and manifestos, newspaper clippings, certificates); tools, machines and instruments; components and materials; and projects in various states of display and completeness. When the ethnographer is in a lab, tours involve tours of the equipment. When she shadows the participants, and when new actors are inducted into the lab, we learn how things are to be done. We regularly hear the phrases "this is how it is done in FabLabs"; "usually in FabLabs…"; "in FabLabs we…". But FabLabs are not plug-and-play.

It is spring 2012. The lab I am in is in the process of being built, its workflows as well as walls to isolate the noisiest and dustiest machines. The two lab managers have been acquiring equipment, deciding on its placement in the lab and doing the necessary set-up and calibration work. Most of the equipment choices have followed CBA's inventory recommendations. Both managers have worked in FabLabs previously in other countries. The lab is not yet open for users, but a teacher from the Media department in the university brings his students in to get a demo of the machines. Getting the Modela milling machine running has been one of the managers' greatest challenges. The one manager has been able to do a test run, cutting the traces of a PCB (printed circuit board) successfully after many attempts. Now it is time to cut out the outline of the board using a different end-mill. It is an opportune moment to show the students how the machine works and how they can mill circuit boards instead of etching them using 'dangerous' materials, particularly if they need only one board.

Manager 1: "For using the Modela, (…) we need to use software that runs on Linux, so basically we will have a virtual machine. (…) You log into Mac and then it will start with Linux."

student: "What if the software is not available for OSX, is it just for Linux?"

Manager 1: "You can try to start on Mac but–"

Manager 2: "It doesn't work."

Manager 1: "Yeah, basically it doesn't work and no one has been able to access the server yet."

Manager 2: "And this is the software that MIT, the original FabLab, these are the tools that *they* have been using, so for the Modela we thought that would be the *best* way. Because we really had problems trying to get it running with Windows, to print the boards, and all kinds of things, that the driver software was not compatible with the new operating systems and so forth. Annoying. So we went with Linux."

Manager 1: "And in any case if you want to talk with the other FabLabs to ask for help, they will explain to you how to use this software, everybody uses this."

The manager continues to show them how to insert the end-mill and set the zero point.

Manager 2: "One of the complications, we also had to get the US-sized milling bit holder for the thing, so the cable was wrong, and we didn't have the proper sized milling bit holder, so lots of things to prepare."

Manager 1 then shows how to operate the Fab Modules interface, for changing settings and sending the job to the machine.

Manager 1: "Sometimes it's a bit slow because we need to have these two cables to communicate with it, and there's a chip inside this, so these are the small tricks."

student: "Is that a serial port that connects with it, so USB to serial? Interesting trickery!"

Manager 1: "Yeah, when you see a machine that doesn't do what it is supposed to do, you understand there is something wrong."

Manager 2: "The Modela doesn't come with a USB port or anything else except a serial port, and then you have to find a computer that can hook up with it, or you have to run a cable that can deal with modern computers. So finding a computer that can run Windows XP and have a printer port, well, by now that's a bit difficult. So I went chasing after laptops of ten years ago, from the design department and a few other people. We're happier with this now. [slight pause] It works when it works."

By no means is this an unusual exchange; workplaces are seamful spaces (Vertesi 2014) full of multifarious technology standards and practice histories in a bricolage that reassembles itself with

each new project (Büscher et al. 2001). The example above shows well the articulation work that needs to be performed to achieve results, the 'work done in real time to manage contingencies: work that gets things back on track in the face of the unexpected' (Bowker and Star 1999, p. 310). While such articulation work is not unique to shared machine shops, it is notable that the FabLab network has designed and implemented its own solution for joining seams, Fab Modules: software for generating toolpaths and visualising workflow, spearheaded by founder Gershenfeld and CBA with self-selecting contributors from across the network. As a work object, it is innovative in a way easily unrecognised as product 'innovations' that capture media attention, the work of infrastructure repair and maintenance (Jarzabkowski and Pinch 2013). The software settles labs into FabLab network institutional logics and allows bricolage of diverse systems. But not all labs use the Fab Modules at all times, as the software itself – in aiming for ease and modularity – tends to black-box some settings and removes some amount of control that competent lab managers resist.

In norm forming, the history behind the "in FabLabs we…" phrase is rarely discussed, in my hearing. People, after all, come from varied backgrounds, and even people with an education in computer science or machine engineering will have different habits, preferences and terminology, depending on their background. At times lab managers or users become flummoxed at some of the Fab Academy procedures, as they would go about the task in a completely different way. Still, in FabLabs, the Fab Academy way often presides without being questioned. In Christina Dunbar-Hester's (2014) study, a similar non-questioning of technical antecedents, a lack of awareness of the technical cultures at play in a media activist community, appeared to strengthen the narrative of a male-dominated technical culture – despite espousal of a desire to universalise and democratise technology. 'Construing DIY to be the universalist antidote to hierarchical engineering culture was ironically reproducing some of the very problems the activists sought to evade' (p. 85).

Much of the FabLab model is put across as 'design from nowhere', akin to technical systems construed as 'commodities that can be stabilized and cut loose from the sites of their production long enough to be exported *en masse* to the sites of their use' (Suchman 2000, p. 5). FabLab actors know there is no stable model: there is much work to be done onsite to build the community of users, establish practices and workflows and develop strategies of action and identity. It appears there is little time to question or pursue the whys and wherefores of FabLab ways. However, it also appears that – in order to be inclusive – FabLabs need to *pre*figure some of their procedures, to counteract unquestioned (and often undetected) inheritances. Hierarchies of norms, routines and best practices from other technical cultures prevail throughout the network, despite espousal of democratic, nonhierarchical and non-technocratic procedures. Individual labs may resist these undiscussed hierarchies and will 're-reconstitute' work objects such as the Fab Modules or even the Fab Academy to regain power locally and establish their own norms and routines.

ON KNOWLEDGE OBJECTS

The growth of innovation labs and living labs in the global North, including FabLabs, is seen as a signal of attachment to an 'experimentalist culture' (Leadbeater 2014). In FabLabs, activities and knowledge-building processes are geared to the expectation that a mix of people will spur invention and innovation through hands-on play and experimentation, but these expectations are constrained by what the equipment affords.

It is 2013. I am speaking to a university FabLab manager, one responsible for the electronics. He used to work in an electronics workshop in another part of the university, which he says has the same facilities. "Or maybe even more. Because we tried to keep it simpler [here] than the [other workshop], because we thought the artists might not need that

accuracy, or–. For example, in buying the oscilloscopes and meters and stuff, we didn't get the best ones, or not the most accurate ones–no, that's not a good word either." He smiles and hesitates. "What should I call it. For example we have an oscilloscope for 40 megahertz and for 60 megahertz and for 120 megahertz, and when you are doing some RF [radio frequency] things, then you use the 120 megahertz. But because no one is doing RF things here, there wasn't any need for that. I mean it like that, I don't know a good word for that."

I try to help: "The scale, or the–."

He replies, "Yeah, the specialised, or–, yeah. So we got everything based on the *need* we expected the people would require. And it has been sufficient so far."

Experiments in FabLabs are logged in an unsurprisingly diverse way. Experiments in DutchLab4, for instance, are oriented to citizen science and natural resource commons, and some of them are visibly marked in what could be called a scientific way to improve future experiments. Experiments with 3D-printing various materials in DutchLab5 are also catalogued and carefully documented. In contrast, experiments with the biodegradability of locally manufactured bioplastics in DutchLab6 were more oriented to proof-of-concept and community-building. In this case, the lab manager and a regular user first tested the bioplastic filament by printing the user's sculpture designs and then burying them in the back garden, digging them up from time to time to visually gauge the amount of degradation. This is the kind of object that bounds the concept of knowledge object and imaginative or symbolic object together, but it also signifies that these participants do not see the need for my earlier manager's named values of 'accuracy' or 'specialisation' – that is, incumbent institutional notions of legitimate knowledge – particularly if they are seen as instrumentalist and stemming from cognitive capitalism. What is important is rather the embodied participation in the process, its incompleteness and 'ongoing-ness' (Hobson 2016), and the visibility of results. As also in DutchLab4, issues related to environmental sustainability and peer production are better understood when they are *experienced* and 'performative' (Corvellec 2016) – prototyping low-carbon, one-planet lifestyes.

Knowledge objects thus make visible alignments with a myriad of institutional logics, from the natural sciences to engineering traditions to artistic conventions, even within one community. Labs orient themselves in sundry ways to achieve the level of authority, 'accuracy', 'specialisation' or even 'unruliness' they see most appropriate to their future vision of 'sustainability'. This may mean partnering with chosen stakeholders, whether a research institute or a municipal library, and institutionalising proceeds according to these interactions (and conflicts). In some cases the lab seeks to maintain counter-culture alterity, acknowledging that the path entails high thresholds and impacts inclusivity: who is able to use the lab (Hielscher 2017). In still other cases the selection of collaborative partners is ad hoc, reactive rather than proactive and directed at ensuring short-term financial revenue.

For the FabLab network, open access and wide, all-inclusive participation in production is espoused as the primary objective. For the most strategic and enduring labs, however, participation is rather seen as a *means*, to get to a knowledge *end* the local lab must define (cf. Powell 2016), whether this is empowerment through experiential sustainability prototyping, development of biomaterials suitable for industrial machining, or knowledge creation for localised manufacturing. Each end entails different logics of design and meaning, from the artistic to the highly specialised, and each will involve its own trade-offs in terms of inclusion and exclusion.

ON IMAGINATIVE OBJECTS

As previously mentioned, much of the literature on FabLabs and open material peer production has tended to catalogue the most salient examples without deeper analysis. Particularly the open

source artefacts, such as the RepRap, that travel – and the mobility is quite well documented by the followers themselves – are used as symbols of the imminent peer production future, and they spark the imagination of others. What of projects that are not taken up: what are the reasons for their mutable immobility (cf. Latour 2005)? What of projects that are built but then not taken into routine use? What of projects that are regularly pointed out in tours of the lab, always in progress but never yielding visible outcomes? For example, FabLabs are particularly fond of prosthetics projects, as they have clear social benefit for marginalised groups and the nature of the product is entirely suited to low-cost customisation prototyping. (And this is not to say prosthetics are not being made and there are not users benefitting from them: I have witnessed several excellent examples.) But when I mentioned one such (European Union-funded) project casually to a long-experienced hacker, he replied, "Yeah, several labs were involved in draining funds from the EU, just *no one ever made a leg*." Keeping in mind the intentional exaggeration here, ongoing, incomplete projects of this type are strongly symbolic – so much so that the lab itself does not always recognise how outsiders view them simply as projects unfinished and undelivered, in the most pragmatic sense.

The symbolism of sociomaterial FabLab projects cannot be over-emphasised. The network gives out Fab Awards to projects every year at the international meeting, sending a message to insiders of what activities are most valued and to outsiders of what types of 'innovation' are possible when peers work together without hierarchies or disciplinary boundaries. The projects displayed at SouthLab1 distinctly convey the topics of interest in this lab: renewable energy, permaculture and eco-building. The projects in CentralLab2, in contrast, signal a completely different orientation to sustainability – as well to FabLab materials and equipment.

It is late 2014. I am in a lab that continually perplexes me, wondering if it "is a FabLab"; if so, why and if not, why not. The reason is the lab, or workshop, is filled with conventional woodworking tools, none of them computer controlled and therefore not 'digital fabrication' tools as in the FabLab parlance. (There is one new 3D-printer in the other room.) Members come here and make furniture and other projects, from reclaimed wood that has been discarded by other businesses throughout the large building in which the FabLab is housed. A lab board member tells me that reusing materials in furniture, especially well-designed furniture, teaches people from the neighbourhood how waste can be revalorised. For professional designers, the design competitions the FabLab hosts are intended to introduce eco-design and LCA (life cycle assessment) concepts in an entirely different way, an embodied and research-through-practice manner, where designers learn hands-on what it is to (in my own terms) design-for-reuse or design-for-disassembly.

It is a young lab, so the organisers are learning their relationship with their members, who should have a say in what the lab does and how feedback and decision-making should be organised. There will be a large CNC router acquired; use of the machine will be shared with another business in the building. There is a sudden meeting called: the lab manager stands up and calls the attention of all the members in the room and the wood workshop. Discussion on the CNC router ensues, particularly on the amount of the extra fees members should pay to access this machine. It becomes somewhat heated. (It is conducted in a language I do not know well so my fieldnotes are scant, but I am given a rough summary afterwards.) One of the lab employees appears quite moved subsequently, and he emphasises to me how significant the meeting was to the lab. He is full of praise for the lab manager for initiating this foray into self-organising and decision-making by consensus. It was brave, and a symbol of the future they want to co-create with their members.

In all respects, this *was* a FabLab. There was the guy working with Arduinos; the shy adolescent male

sitting off to the side; the anthropology student shadowing a user; a local journalist filming; the unreserved commitment of the employees, director and board members to allowing a space for people to make their own projects. There were material explorations, even a material library; the eccentric inventor and maker of curious objects; there was the same collection of books as in other labs, more or less; there were unfinished and finished projects in disarray. But I also felt to some extent I had travelled back in time, to the beginnings of the eco-design movement twenty years previously, where part of our exploration then was directed to the reuse and recycling of materials into new products. Have we not come further? Do we, as a design community, need to revisit this exploration space with each new generation?

I also wondered if this was the future, recognising the importance of material engagement in knowledge building, the way repair communities are operating in Europe today. What looks simply like repurposing material cast-offs into one-off and small-batch products could be deeply symbolic, redefinitions of 'waste' and the value of material. Especially in the context of this region, described to me as politically red-green and awash with cooperatives, the idea of a circular economy appears closer to implementation than abstract hype, with national legislation on circularity in development and the national minister of the environment coming to open this particular lab at its opening ceremony. This neighbourhood rallied and managed to close the nearby road, a major motorway, on a Sunday and took it over for a local festival. The design objects fabricated from reclaimed materials in the lab were displayed and sold to a receptive public. It is as easy to over-romanticise these efforts as it is to dismiss them as too local and situated to have true impact in socio-environmental terms.

As imaginative objects, these projects have the explicit goal of making visible and apparent supply chains and environmental issues in mass production, as well as opportunities for eco-design. This FabLab was orienting more towards a traditional community-workshop institutional logic than a university engineering lab, and its activities and equipment were shaped accordingly. Other FabLab projects appear to have the reverse effect: imaginative objects symbolic of technology-driven, innovation-for-innovation's-sake logics obfuscate where components are made and under what working conditions, fail to acknowledge the global story of e-waste, and acquire materials and equipment according to cost and convenience rather than any principle of empowering local production. These imaginative objects act as membranes filtering out the inconvenient truths of DIY maker culture related to male-dominated (and Anglo-Saxon-dominated) engineering-culture histories; global energy problems (CNC equipment cannot operate without electricity); and deskilling – if the individual lab in question does not explicitly set out to address this invisibility.

Alignment to engineering technical cultures appears an easy default for FabLabs; unacknowledged, such default configurations lead facilely to 'expert rule and problems of gender-, class-based and racial exclusion' (Powell 2016, p. 613). The espoused objective of participation-for-all ironically results in an exclusive, elite space. When rather addressed as a *means*, however, the objectives of participation and openness prefigure procedures to prevent exclusionary practices from taking root. In the example described above, norms related to participatory governance were new for what was otherwise a conventional design association, but were taken into use – in a prototyping of alternative co-governance practices.

It appears FabLabs must make a choice. If they choose an orientation of Peer-Production-as-a-Service, a 'design-from-nowhere' model that seeks mainstream legitimacy, they have greater potential to reach a wider variety of users. But the more one opens the lab doors, lowers thresholds, enhances usability and makes DIY making accessible and easy, the more the revolution is tempered and FabLabs elide with business-as-usual.

Commodification means black-boxing procedures, which goes counter to the espoused objective of opening technologies. If, on the other hand, labs choose the anti-service, counter-culture, 'anarchist' institutional logics, they risk appealing to a tightly defined group that may find it difficult to evolve as conditions change or to collaborate on shared projects with wider impacts outside the lab doors. Founding principles are adhered to, but the lab can easily become an echo chamber that is oriented to individualism rather than collective good.

CONCLUSIONS: DESIGN FROM SOMEWHERE

This study has illustrated how material objects in FabLabs represent and embed institutionalising processes that orient the community to business-as-usual or alternative trajectories. Grassroots technology movements attempt to redress perceived inequalities by setting up counter-contexts (FabLabs) and reconstituting products, technologies and practices by establishing alternative norms and procedures. These dynamics are not only directed externally, as challengers to incumbent institutions in the dominant sociotechnical regime of mass production; they are also internal and within the counter-culture FabLab social world, as groups react to parts of the movement that consolidate power and produce discourses and practices that are found wanting. In institutionalising, FabLab managers thus find themselves constantly making decisions that land on a spectrum between open source and open doors. Open source requires particular protocols, governance models and ways of working that must be learned; open doors require a conforming of procedures and practices if they are to be taken up by the mainstream. Ideals oriented to alterity thereby easily become watered down, or ideals are maintained and the community becomes walled.

When variegated sociotechnical environments, histories, cultures and practices come together, work objects demarcate or meld 'seams'. Knowledge objects show how knowledge production for sustainability is messy, situated, negotiated, ongoing and performative, deliberately not oriented to reductionist quick-fixes. Examining things in FabLabs as imaginative objects reveals what logics and systems of meaning gain staying power. Imaginative objects are in danger of remaining *too* incomplete, of *never making a leg* – but their very incompleteness appears to be pivotal to aspirations for transformation, ongoing prototypes of a grassroots-designed sustainable life. Things in FabLabs quickly become inevitable, taken for granted, invisible – yet they reveal much about how this collective intends to govern itself and accomplish things. FabLabs then need to routinely interrogate what forms of *openness* are aimed for, what they should deliver and what trade-offs are implied in their institutionalising pathways.

ACKNOWLEDGEMENTS

This study was supported by the Academy of Finland, Grant 289520 Getting collaborative design done, and the KAUTE Foundation. Sincere thanks to Sampsa Hyysalo, Luisa Mok and Daniel Pihl for comments during early phases of the study. The constructive comments from the two anonymous reviewers and guest editors Adrian Smith and Kat Braybrooke were extremely helpful in improving the manuscript.

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APPENDIX 1

Table 1: summary of research sites

LAB	TYPE	AGE OF LAB AT TIME OF VISIT. FOUNDING YEAR	DURATION OF VISIT	INTERVIEWS	OTHER DATA
NorthLab1	university-hosted (art, design, media school); in medium-sized city in the Nordic countries.	from 0 to 3 years. 2012	longitudinal ethnography (3 years) late 2011-early 2015	19 interviews with 13 people (on average about one hour each) (fully transcribed)	1150 photos, 5.5 hours of video, 79 sets of fieldnotes
NorthLab2	independent: owner-operated (family run); in small village in the Nordic countries.	10 years. 2002	3.5 days, autumn 2012	3 interviews with 2 people (average 75 minutes each) (fully transcribed)	200 photos, 5 sets of fieldnotes
SouthLab1	university hosted (architecture school). in peri-urban area of large city in Spain.	5 years, 7 years. 2008	2 days, summer 2014	2 interviews with 2 people) (about 20 minutes each) (mainly transcribed with extensive notes)	110 photos, 2 sets of fieldnotes
			1 day, summer 2016	2 interviews with 2 people) (one hour, half an hour) (mainly transcribed with extensive notes)	155 photos, 1 set of fieldnotes
SouthLab2	independent: owner-operated. in small city in Spain.	half a year. 2013	0.5 day, summer 2014	1 interview/ conversation with 1 person (30 minutes, notes)	60 photos, 1 set of fieldnotes
DutchLab1	art association hosted. in medium-sized city in Benelux.	about 5 years, 7 years. 2007	1 day, summer 2012	1 interview with 1 person (one hour, extensive notes, partly transcribed)	110 photos, 1 set of fieldnotes
			1 day, winter 2014	4 interviews with 3 people (from 20 mins to one hour) (mainly transcribed, extensive notes)	50 photos, 1 set of fieldnotes

DutchLab2	professional industry association-hosted. in medium-sized city in Benelux.	6 years. 2008	1 day, winter 2014	1 interview with 1 person (1.5 hrs) (mainly transcribed, extensive notes)	80 photos, 1 set of fieldnotes
DutchLab3	independent: owner-operated. in medium-sized city in Benelux.	about 1 year. 2013	half a day, winter 2014	1 interview with 1 person (1.5 hrs) (mainly transcribed, extensive notes)	30 photos, 1 set of fieldnotes
DutchLab4	independent: owner-, art collective-, volunteer-operated; in small city in Benelux.	4 years, 6 years. 2010	1 day, autumn 2014 2 days, summer 2016	5 interviews with 4 people (average 30 minutes each) (includes interview with founders in 2012) (partially transcribed with extensive notes)	100 photos, 1 set of fieldnotes 215 photos, 2 sets of fieldnotes, 3 hours recorded conversations and presentations, some video (partly transcribed)
DutchLab5	independent: owner-operated. in small city in Benelux.	almost 5 years. 2010	half a day, autumn 2014	1 interview with 1 person (one hour) (partially transcribed with extensive notes)	60 photos, 1 set of fieldnotes
DutchLab6	independent: owner-operated; in small city in Benelux.	10 months. 2014	2.5 days, autumn 2014	3 interviews with 2 people (average 30 minutes each) (includes short interview with founder earlier that year) (fully transcribed)	115 photos, 3 sets of fieldnotes
DutchLab7	independent: owner-operated. in medium-sized city in Benelux.	2 years. 2013	half a day, winter 2014	1 interview with 1 person (20 minutes, on video) (fully transcribed)	35 photos, 1 set of fieldnotes
CentralLab1	municipality-hosted. in small city in Benelux.	2 years. 2012	2 days, winter 2014	7 interviews with 5 people (from half an hour to 1,5 hrs) (includes previous interviews with two founders, 2012, 2014) (partly transcribed with extensive notes)	170 photos, 3 sets of fieldnotes

CentralLab2	professional industry association hosted; in small city in France (adjacent to large city)	about 1 year. 2014	2 days, autumn 2014	8 interviews with 4 people (average 30 minutes each) (includes short interview with founder earlier that year) (partially transcribed with extensive notes)	130 photos, 2 sets of fieldnotes, some video and audio of lab conversations

