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Making “Making” Critical: How Sustainability is Constituted in Fab Lab Ideology

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ABSTRACT Fab Labs, fabrication laboratories, are shared workshops where citizens can access digital fabrication equipment to design and make their own objects. They are proliferating rapidly and represent an alternative to mass production and consumption, an ideology whose environmental and social benefits their “makers” like to espouse. A longitudinal ethnographic study in a Fab Lab in a European design school examined the Lab’s ideology building, how ideals were enacted and where compromises were visible. Environmental issues were intertwined with other ideological concerns, but they were rarely promoted in their own right. Engagement with sustainability-oriented makers and stakeholders is recommended.

KEYWORDS: Fab Lab, digital fabrication, open design, distributed production, sustainability

Introduction



Fab Labs, makerspaces and hackerspaces are varieties of community digital fabrication workshops where people use equipment such as laser cutters and 3D-printers to create their own artefacts. “Personal fabrication” or “making” is often social and collaborative, entailing sharing and modifying of designs online, cooperation on projects and/or shared use of tools in shared spaces. These communities are forerunners in how they organize spaces and activities for digital fabrication.

Fab Labs are the most organized makerspaces with the clearest identity; they are therefore the target of the current study. These workshops are listed in MIT’s Center for Bits & Atoms Fab Lab Program,¹ a largely self-organizing international network. Network members are strongly encouraged to comply with the Fab Charter,² to acquire a common inventory of equipment³ to facilitate cross-lab projects and to allow open access to the public. Fab Labs share an identity, but each Lab is also free to determine its own activities, target user group and form of revenue depending on its own local conditions. There were about 150 Labs worldwide in November 2012 (Maldini 2013), 300 in June 2014⁴ and over 660 by May 2016.⁵ In contrast, hackerspaces do not explicitly commit to inter-lab collaboration nor open public access. Members tend to focus on electronics projects (Maxigas 2012). Makerspace is the general term for any shared workshop, and those that are not Fab Labs are independent workshops in all forms, from commercial services to labs in museums and libraries (Troxler 2013).

Fab Labs regard themselves as offering “democratic”, “widespread access to the means for invention” (Gershenfeld 2005, 42). There are environmental and social benefits embedded in this ideology, which are explicitly espoused by some actors. Such benefits include the ability to build, disassemble and reassemble products (Gershenfeld 2005, 243–244); to explore sustainable solutions (Gershenfeld 2005, 80–92; Lassiter 2013, 255); and to produce objects in small volumes, locally and only according to need (Gershenfeld 2005, 249–250). Making in Fab Labs is seen as a harbinger of a new paradigm: a “new revolution”, in the words of network founder Gershenfeld (2005). However, there are few empirical studies that detail the everyday activities in individual Labs to reveal how these ideals are being carried out in practice.

Examining how these communities articulate sustainability concerns in their ideologies and strategies can reveal much about what meanings and values attached to technologies become dominant, communicated to and ultimately adopted by the wider public (cf. Flichy 2007). One must also examine what groups *do*, to determine if there is a gap between discourse and practice. Investigating digital fabrication activities organized particularly by designers, moreover, sheds light on

the implications for the field of design: what futures are envisioned and what the sustainability implications may be.

The aim of the study was to examine these cross-connections: how a new Fab Lab in a design school built its ideology collaboratively, how it enacted it, what hurdles it faced, and how its discourse and activities related to ideas of a sustainable future implicating designers. The research question can be phrased as such: *how is sustainability represented in both ideology and everyday practice in a Fab Lab in the global North, one where design and designers play an important role?*

The topic is important and timely. Personal fabrication may become an alternative to mass consumption for more citizens than these forerunner makers, as more people gain access to digital fabrication opportunities. Along with the rapid rise of makerspaces, where people make their own objects directly, 3D-printing and other design and fabrication services online⁶ and on the high street are increasingly available. The potential to do away with certain negative impacts of mass production (and decouple them from socio-economic prosperity) is as great as the potential that new, unforeseen environmental consequences of digital fabrication will arise and spread.

Background

Research on Fab Labs is beginning to emerge but remains scant. The main English-language references are founder Gershenfeld's own account (2005); a volume of essays on Open Design collated by a group associated with Dutch Fab Labs (van Abel et al. 2011); a volume from cultural and media studies (Walter-Herrmann and Büching 2013); and a special issue of the *Journal of Peer Production* (Maxigas and Troxler 2014). The Human–Computer Interaction (HCI) field also features many studies on personal fabrication (e.g. Mota 2011).

Researchers are also paying increasing attention to environmental issues and the wider socio-environmental implications in digital fabrication. While there are few empirical studies (De Decker 2014; Kohtala 2015), there are nascent inquiries into opportunities for a circular economy (e.g. Charter and Keiller 2014) and the sustainability potential of such “grassroots innovation” (Hielscher, Smith, and Fressoli 2015; Smith et al. 2017).

Personal fabrication is also represented in studies on citizen activism and socio-technological change, a line of inquiry known as “Critical Making” (Ratto 2011; Ratto and Boler 2014). Critical Making is designed as a set of participatory activities that is both physical (hands-on making) and conceptual, aimed at cultivating a more critical understanding of socio-technical issues among more citizens (Ratto 2011). Critical Making is not always explicitly environmentally oriented. Nevertheless, as inquiry aligned with Social Shaping of Technology (Williams and Edge 1996) and Values in Design (Flanagan, Howe, and Nissenbaum 2008) research, it plays a role in making visible the often

hidden values that guide how design and technology projects are conducted and that have sustainability implications.

Critical viewpoints have also come forth in academic and non-academic channels (e.g. Hertz 2012). The special issue of the *Journal of Peer Production* (Maxigas and Troxler 2014) published editorials that questioned the role of Fab Labs: are Labs espousing democratized, open access to small, non-proprietary, decentralized tools for production, while in practice kowtowing to the agenda of the existing consumerist system, with its large multinational stakeholders (Nascimento 2014; Troxler 2014)? This critical discourse has served both as background and as empirical material in the current study, with both observable and potential impact on the studied communities.

A concept that contributes to the analysis is that of “countercontexts”, distinct spaces for activities considered counter to the mainstream (Pfaffenberger 1992). In this understanding, technologies are taken up by communities who appropriate and distribute them, as a reaction to perceived inequalities or injustices such as access to means of production or to education (Pfaffenberger 1992). Makers create ideologies to support their counter-position, and they stage events such as FABx (the annual Fab Lab general meeting) as performances and rituals, to engage current members and attract new ones. Fab Labs as countercontexts are thus sites where practices geared towards openness and rejection of hegemonic hierarchies meet new technologies.

Data and Methods

The focus of this longitudinal ethnography (Van Maanen 1988) was a design school's Lab in a university in northern Europe, a university being a typical, representative context for a Fab Lab.⁷ The study began as the Lab was being constructed, thus offering both easy access and the rather rare opportunity to observe the building of a new Lab. Information on events and decisions before this period was solicited in interviews and by reviewing online archival materials and internal documents (such as photo collections and internal presentations). The author visited the site most frequently during the building period, with less frequency in the subsequent two years.⁸ The author also visited 13 Fab Labs in Europe and interviewed key actors in the Fab Lab network (managers but also consultants and other stakeholders to whom managers referred). This last data set is not fully incorporated in this study, i.e. analysed for cross-comparison purposes, but the general themes of field notes and interviews were taken into account when considering different contexts.

The data was analysed using open coding and themes identified as arising from the data itself (not from any external theory or framework) (Strauss and Corbin 1998). Themes were noted according to what was often seen and heard in the data, what subjects themselves reported as important and what topics or situations provoked strong reactions such as arguments or expressed joy. Foregrounding environmental

sustainability⁹ in particular was a lens by which the researcher could examine how Fab Lab actors saw their role in society, articulated ambitions for the present and future, and set action priorities. Attention was paid to when subjects themselves raised topics relevant to sustainability or acted accordingly and when the author herself had to prompt the topic. “Sustainability” in this study was thus detailed as the subjects understood, defined and operationalized it.¹⁰

To pay attention to the dynamics between discourse and practice, the analysis employed Symbolic Interactionism (SI) (Blumer 1969) and its social world framework (Clarke and Star 2008), from the field of Science and Technology Studies (STS) (Hackett et al. 2008). STS offers conceptual tools for design research to systematically examine the mutual social shaping between people and technologies (Woodhouse and Patton 2004, 5). SI focuses on collective action, how social groups negotiate and co-create meaning. From this perspective, “making” was analysed as a combination of an individual’s interactions with things, technologies and materials; interactions with other people; and even interactions with herself, in learning, acquiring skills and deciding what to pursue, how and why. A Fab Lab is a place where design happens, as a performance of interactions between people and materials: where objects being designed are technologies and material artefacts, but also concepts and constructs (Blumer 1969, 10–12). People also come into personal fabrication from different directions, from other social arenas. How social worlds intersect is an important part of SI analysis (Strauss 1978, 122–123).

According to this framework, the relationships among the actors and their social worlds, the concepts they held dear (and their opposites) and the meanings they attached to objects (tangible and intangible) were mapped in diagrams (Clarke 2005) and written out in memos and narrative summaries. The narratives were shared and discussed with a mentor. A long, compiled narrative was produced, structured chronologically, which was shared with the research subjects for respondent validation. Considering the research question, four themes were elaborated in the narrative as best capturing the empirical material. The themes are summarized in Findings section 2 (“Realizing Ideology”) and depicted in Figure 1. The following section describes the context of the Lab and the first phases of building the Lab’s identity and ideology.

Findings 1: Building Ideology

The roots of the studied Fab Lab stem from a proposal to form platforms in the host university for innovative, multidisciplinary research and teaching: where academia, companies and the public sector could meet, develop new ideas, and design and prototype products. The platform in the design school focused on research and production in media and was prescribed its own public premises in 2011. Rather than establishing an electronics workshop closed to media department students, Media unit staff members began to discuss founding the country’s first official MIT Fab Lab. The unit’s identity as multidisciplinary

platform to create “societal impact” was seen as compatible with Fab Lab ideology: open access to fabrication technologies encouraging a diversity of users. The key actors were the decision-makers in the Media unit, “Lab Coordinators” organizing external events and “Lab Managers” inside the Lab.

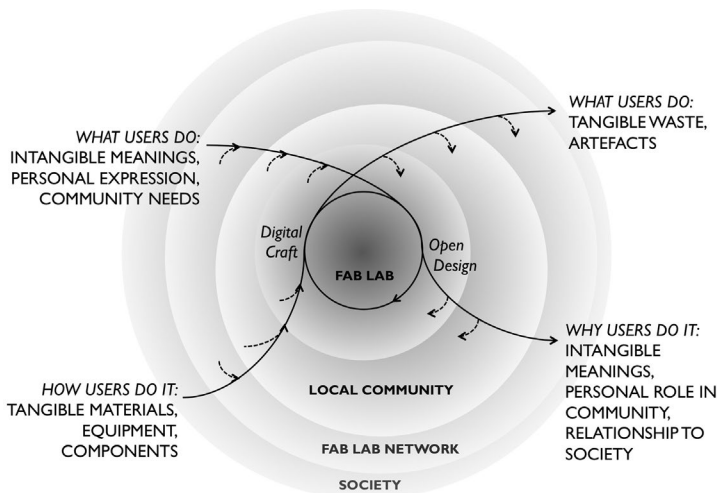
In developing the initial concept for the Lab, Lab Coordinator 1 sought to bring two communities together: the city’s maker subcultures, including hacklab members and electronics art groups, and the art and design students. The makers would benefit from exposure to the university’s “theoretical knowledge and ... design and artistic concepts and thinking”; the maker community would bring the electronics skills the students lacked, as well as “street credibility” and a maker “aura of doing stuff”. Moreover, the sharing and peer learning ethos of Fab Labs could differentiate the Media unit as the foremost platform for “openness” in the university.¹¹

Operations began in earnest in spring 2012 once the Lab was built. The two main actors in the first year, Lab Manager 1 and Lab Coordinator 2, promoted the philosophy and practice of openness and Open Design, particularly when conducting Digital Fabrication courses for the students: documenting and sharing one’s work, modifying others’ work to suit one’s own purposes and collaborating on projects using open source protocols. They also emphasized how personal fabrication was neither craft nor industrial manufacturing: it was a relationship between digital design and material realization, a dialogue between the “bit and the atom”. Designing for such a context, which they termed “Digital Craft”, required a particular design sensitivity.

In defining their objectives, the Lab organizers thus referred to the interplay between often repeated dualities such as the digital and material; the craft and industrial modes of production; and working from intuition and working to a design or plan. These elements can be visualized as in Figure 2. To the organizers, a Fab Lab in a design school and design/designing in a Fab Lab relied on all four elements. Open Design offered a new design paradigm and Digital Craft a new production mode, and the Lab organizers regularly distinguished this paradigm from mass production.

Sustainability implications were explicitly discussed in the Lab from time to time, but they were also woven through other ideological discussions and practical actions. This weaving is best illustrated in moments where organizers and users negotiated the meaning of their activities.

In the following exchange, Lab Coordinator 2 was encouraging a student to design the Fab Lab way, to eliminate screws or glue as a joinery system in his product and to design for press-fit. This was a salient interaction as it caused a lengthy and almost heated discussion. “But not because it’s forbidden”, the Coordinator emphasized, pointing to a steel bolt. “Because you don’t even need to use this [bolt] if you design in a clever way. ... It’s a very different mindset”. The student continued to argue for bolts, as in his original design. “I’m trying to

**Figure 1**

Four objects that contribute to ideology building and enactment, as material and conceptual inputs and outputs.

get you to do fewer operations and use less components”, the Coordinator argued back. In near frustration the Coordinator turned to another rationale, where ultimately screws and bolts would not even be available “if industry collapsed”. The student replied, “If this was the case, if I had known this part about the *politics* of doing, then the aesthetics would be very different”.¹²

The interaction reveals how the organizer expected ideology to be enacted and why: in his view, products should be more easily disassembled and even weaned from the current industrial system. Digital Craft in this Lab was thereby a design ethos where materials, components and processes were to be considered in new ways and material conserved.

Another example marked an important phase in the Lab's trajectory, as it was the first opportunity for organizers to work with outside test users, the makers desired by the Coordinator to precipitate a maker “aura”. The context was a Media-unit-funded project called Waste-lab.¹³ Two outside experimental artist-hacker groups collaborated with university researchers (from design, media and waste management) on the project, which aimed to explore artistic, ethical and practical perspectives on e-waste, repair, obsolescence and over-consumption. The Fab Lab facilities were to be used if and where needed. Lab Manager 1 was especially keen to participate and facilitate, having worked with waste issues in the past. From the outset, the challenges were laid out. The artist-hackers pointed out how they work: with post-consumer waste, which required much storage space and slow building processes. One of them complained: “This is a new area for us, to think about how to *design* a machine”.¹⁴

In the end, no collaborative projects were produced. The project coordinator summarized: “Oh, they’re very critical of it [the Fab Lab]. It depends on the pragmatics of how you work. If ... you just use

what you've got, what you've got lying around and what you find in flea markets ... then that's the starting point. If you decide, well, I need *this* to go with this thing I have, then ... Fab Lab could be the bridge between the fixing or the additional bit you need, or the customization of things. But I knew the conflict was there from the beginning, so it was like, is there any way you can compromise?"¹⁵

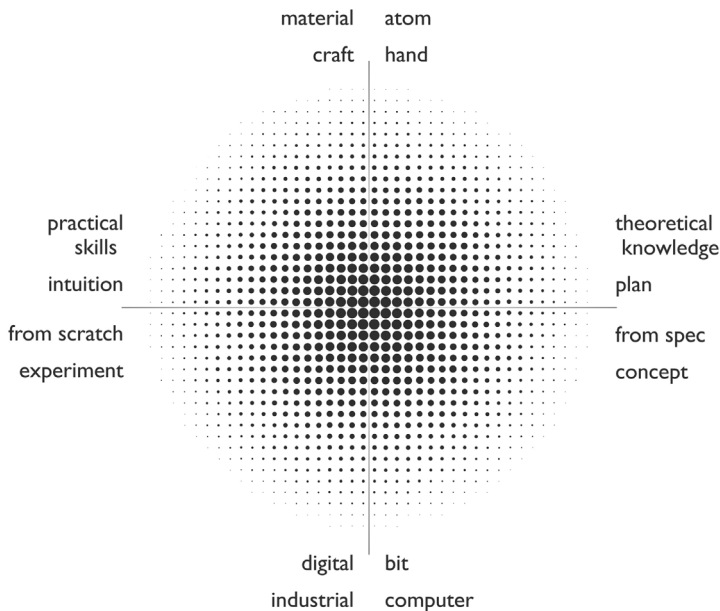
The artists in Waste-lab prioritized working in an experimental, ad hoc manner using materials they had to hand; to them the Fab Lab represented working with virgin materials, as "design" and from "a design". It also represented the university, which was elite and exclusive. In Figure 2, Waste-lab's principles remained in the top-left side of the diagram; group members forfeited the opportunity to engage with digital fabrication, enhancing their own design skills and potentially even shaping the Lab ideology towards their own environmentally oriented concerns with reuse and waste. For their part, the Lab was not able to accommodate Waste-lab's "from scratch" way of working. Both groups lost the possibility to build upon the best of both worlds (see Figure 2).

This section has presented how the Fab Lab community co-created and represented its culture of Open Design and Digital Craft to others. There are socio-environmental implications embedded in the ideology, and how they become acknowledged or disregarded becomes apparent through interactions among organizers, users and others. The following section will discuss this in more detail.

Findings 2: Realizing Ideology

The study also examined how certain concepts, i.e. "objects" (Blumer 1969), travelled through the development process, how their meanings were co-constructed and how or if their ideological content was visible in everyday practices over time. Four objects, as key themes, were identified in the analysis phase as best illustrating how socio-environmental concerns were manifest or neglected in the ideology building. The objects represent key inputs and outputs for any Fab Lab, tangible and intangible. With regard to what users make in Labs, they use materials and equipment as provided and supported by organizers (see Figure 1, bottom left). These material elements may come from the local neighbourhood, but they may also be sourced from global supply chains. The activities produce tangible outputs, in the form of waste and actual artefacts, which travel out of the Lab and into the local community or beyond (see Figure 1, top right). Closer examination of these material elements reveals a Lab's ideals, their successes and struggles to realize them and their socio-environmental orientation.

There are also intangible elements that impact making. Lab users must decide *what* to make, and these ideas can stem from various sources: personal or local community needs; inspired by activities at the level of the Fab Lab network; or from wider societal considerations (see Figure 1, top left). Such elements provide meanings of the activity for the user and the Lab, and they are thus repeated in Fab Lab discourse

**Figure 2**

Depiction of the studied Fab Lab's ideology and concepts of importance to the actors in this study. All words and concepts as antitheses are taken directly from the data.

(Gershenfeld 2005; Lassiter 2013). Making also has intangible consequences: revealing to the user what role they may play in the Lab, the community or in the network. The Lab may also reflect upon its present and future context: its impact on the local community, the network or society, particularly considering the discourse of revolution and new paradigms and how socio-environmentally sustainable they may be (see Figure 1, bottom right).

In this study, the diagram helped analyse and cluster the issues. It helped make explicit what meanings and consequences of actions were collectively negotiated and what remained invisible and unaddressed. The four objects will be described in the following sections with illustrative examples.

Equipment

The SI framework becomes particularly useful when one examines the activities around procuring equipment and materials, one of the most important activities when setting up the Lab (see Figure 1, bottom left). The technologies come to represent processes and intersections with another social worlds. The decision to purchase an Ultimaker, for instance, was voiced by the actors as related to interpersonal connections: Lab Manager 1 knew the company founders personally, as well as the product itself and how to use it, while the unit Manager did not know the equipment but met the company founders at an event.¹⁶ The Ultimaker was ordered even if it was problematic in the university's procurement regime.¹⁷ Moreover, as an example of

open hardware, it was nearly always pointed out to visitors as the open source 3D-printer in the Lab.

In contrast, other equipment and materials were chosen precisely because of the ease of ordering. Some items, for instance, were readily available from MIT's US-based inventory and less available from a European supplier. Components were also ordered in discussion with someone in another unit on another campus, because he had the contacts to order electronic parts directly from China. For both equipment and materials, local suppliers were indeed explicitly stated as preferable. However, the preference was voiced in terms of ease of ordering as well as access to technical support, and not in terms of any ideology related to local economy models.

Such examples show how ideology is materialized in practice. They also illustrate how ideals that are espoused (such as localizing production, which has clear environmental implications) are easily compromised when they come into a trade-off with structural conditions such as institutional rules and norms.

Waste

A consistent finding encountered in the main research site but also in many other Fab Labs was how Lab managers struggled to find time for both strategy work and everyday duties. In the studied Lab, this even extended to problems dealing with their material waste, an issue the Managers often discussed with the author (see Figure 1, top right). Over the years the Managers were occasionally able to squeeze in time to fabricate temporary solutions for sheet materials, but these were not durable. Eventually Lab Managers 2 and 3 were able to prioritize the task, and their more solid storage box beside the laser cutter meant that users were taking off-cut pieces first before going to the storage room to take a fresh, uncut piece of sheet material (Figure 3). This appeared to contribute to reducing the amount of off-cut waste.¹⁸

The Waste-lab project could have been the obvious stakeholder with whom to tackle this very visible practical and environmental issue, with Lab Manager 1 as a key ally, but they did not find enough common ground for collaboration. The example reveals how consequences outside the Lab such as waste streams become easily eclipsed by everyday concerns, but also how applied design can make problems visible and solvable.

The Meaning of Making: "The Question is, Why?"

The title of this section derives from a telling moment in one of the videos recorded during the first Digital Fabrication Design course. A group of three students are discussing what project they would like to pursue. One of the students has printed out a two-dimensional graphic pattern on an A4 sheet; he is trying to explain how it could be turned into a tangible fabbed object. Perhaps the graphic layers are layers of laser cut material assembled together. Perhaps this could

**Figure 3**

The ad hoc way of dealing with sheet off-cuts despite the obvious inconvenience as well as occasional rhetoric espousing concern with waste. The final solution of the plywood box kept the stacks neat, visible and easy to access.

make an interesting lamp, or a complex, interlocked puzzle. The student beside him says in a faux-dramatic way, leaning forward: “The question is, *why?*” He laughs and quickly adds: “But it’s cool”.¹⁹

This thereafter became a key theme and the author’s code for every moment where people wanted to question *what* people chose to fabricate in Fab Labs (see Figure 1, top left). A student in the first Digital Fabrication course, a member of the only group explicitly using reclaimed materials for their projects, explained her perspective: “We were ... making jewellery and objects we don’t need that much, so it was nicer to use recycled, reused materials, so we were not wasting resources or materials for things that are just for fun”.²⁰

Later, in their strategy discussions the Media unit began to focus on *what* users were making. Too much attention to daily,

mundane tasks had resulted in compromises and undesirable results, and the Lab had become “too much like a printing facility”. The unit needed to discuss how to tactically re-engage with users to encourage collaboration and innovative projects: to focus more on “community”.²¹ Such a need was also voiced by other Fab Labs during site visits and FABx meetings: ad hoc management was leading them to become mere “printing services”. A strategic redirection was needed to support meaningful production and community-building.

The Context of Making: The New Industrial Revolution

The fourth object addressed the question of *why* people become engaged in making and what these organizers thought this Fab Lab was for (see Figure 1, bottom right). For actors in Fab Labs, making is more than just a hobby. It is part of a new industrial revolution, beyond the circumscriptions of the current industrial system: networked, distributed and enabling people’s full potential.

As an ideological object, this vision stood for what kind of society Fab Labs were making. The Fab Lab was the physical and conceptual space, a countercontext, for exploring new models for open design, open innovation, open education and so on. A lecturer who brought her business students into the Lab emphasized she was not interested in what they did on the laser cutter: “They actually did very interesting projects, but the most interesting thing is that the need to *think* in this openness brought a new aspect into the discussion”.²² The Digital Fabrication courses became training grounds for the revolution: learning how to share knowledge and co-create in a peer-to-peer network.

Interactions with other actors in the Fab Lab network are relevant at this level of vision shaping. The critiques and discourses mentioned in the Background section are discussed in and shared among Labs. The presentations, discussions, workshops and local Lab tours during regional meetings and the FABx conferences are important in this regard. A manager from a Lab in north-central Europe who attended FAB10, for example, was inspired by hearing Gershenfeld speak: for him, it was “good to know where Fab Lab was coming from ... because ... quite a few Fab Labs are focusing on toy[s], and 3D printing and Arduinos, and I really like the bigger picture, about this economic industrial revolution”.²³ He, and many other FAB10 delegates, were awed by the beauty and vision of Barcelona’s Valldaura Self-Sufficient Lab, and it was much discussed. In Valldaura, explorations on sustainable solutions for a city, as part of the city’s “metabolism”, involve digital fabrication but also permaculture and experiments with bio-based materials. “It’s not about laser cutting baby cars, it’s about using the laser cutter to produce things that matter, that have function, that have a reason to be built”, the Manager said about Valldaura.²⁴ FAB10 inspired this Manager to begin to form strategies to shape local distributed production networks in his region, connecting industrial actors,

designers and potential customers in a new production-consumption model, guided by socio-environmental considerations.²⁵

These examples illustrate how ideology building and realization engender a tension between future ambitions and current routines. In this study, other social worlds and subworlds beyond one Lab’s walls, the Fab Lab network and FABx meetings, were also implicated in co-creating visions of a better world. The potential environmental benefits of this new world were visible and praised in one exemplary Lab, but many Labs in the global North appear to struggle to create and realize an equally strong vision.

Discussion

This study presented a community of designers promoting and practicing Open Design (van Abel et al. 2011; Tooze et al. 2014) and simultaneously makers experimenting with digital fabrication. It demonstrated what was rendered visible and invisible in the dynamics between discourse and practice: as new practices became routines and as countercontexts met incumbent infrastructures. It illustrated how the actors were addressing the meanings and values of their work at three levels, all of which embedded clear socio-environmental sustainability issues.

The first was the material level of things and processes in fabrication choices. As stated previously, claims have been made about the benefits of making in terms of localizing production (reducing transport emissions) and producing only according to need (fostering material eco-efficiency). However, material consumption, waste prevention or reuse were not taken into account consistently in this study, bar some particular actors. Despite espousing local production, Fab Labs still order equipment and components from global, opaque sources in practice. Further research could explore how personal fabrication could be more localized and when and how this delivers socio-environmental benefits (following for example, Russell and Allwood 2008; See also Quilley, Hawreliak, and Kish 2016).

Nevertheless, such findings need to be embedded in a Lab’s routines in conscious practice, and Lab organizers need to find them meaningful; this implies another level of reflection. At this level, Labs were asking strategic questions about the meanings and values of making for individuals and groups. The implications for socio-environmental sustainability were also contained within these meanings: fabricated artefacts would not become material and cultural waste if they were locally relevant, connected to personal expressiveness and/or community needs. On the one hand, Maldini (2016) has suggested personal fabrication does not appear to generate products with long lifespans nor diminish production and consumption by replacing mass production, despite the value and attachment makers adhere to their creations. On the other hand, the very openness embedded in Fab Lab ideology and the competence in open design processes has

facilitated sustainability-oriented experimentation in spaces such as the Valldaura Lab. Open design fosters transdisciplinarity, commitment and willingness to accept complexity (Tamminen and Moilanen 2016), conditions that Kadish and Dulic (2015) argue are ripe for addressing wicked environmental problems through digital craft experiments.

Quilley, Hawreliak, and Kish (2016) further suggest that such open peer production offers openings for alternative, eco-oriented, post-growth political economies, if maker culture can sever its links to the current consumerist growth economy. This is another level at which Fab Lab actors were co-negotiating meanings: that of future visions. The study indicated how actions were perceived and critiqued in various ways. Is making a superficial, consumerist hobby or a creative, enabling and empowering endeavour? In this study, critique did see results, even in the protected space of the countercontext. Lab organizers needed to reconsider not only what kinds of “making” were deemed desirable, but also what future visions of production they were espousing. Critical discourse can thus lead to change, creativity and innovation (Strauss 1993, 202–203). Performative events such as FABx and exemplary role models played a role in these dynamics.

In this study, however, critical engagement did not always lead to change. When considering the Waste-lab’s reaction to the Fab Lab, the perceived identity of the Lab as “cool”, elite, design- and technology-driven rendered invisible those issues most important to Waste-lab members. On their side, the Fab Lab organizers were unable to maintain Waste-lab’s engagement, even if their strengths in ad hoc, experimental processes were desired (see Figure 2). This would appear to confirm emerging research that indicates maker communities are divided in their sustainability orientations and knowledge, and they may need scaffolding to be able to engage robustly with important sustainability issues (Fleischmann, Hielscher, and Merritt 2016; Kadish and Dulic 2015; Kohtala and Hyysalo 2015).

In this study, the Lab’s identity as a countercontext for open design did not consistently take into account implications for localizing and distributing production. Very real, potentially far-reaching consequences of personal fabrication often seem to be invisible in Fab Labs in the global North: the reality of the supply chains outside the Labs, the reality of electronic component manufacturing and the toxic reality of e-waste. Simply identifying desired stakeholders for collaboration is not enough. Much work needs to be invested in establishing common ground to better ensure long-term engagement, but the Lab benefits from the investment by avoiding becoming “just another printing service”.

Conclusion

Forerunner communities in Fab Labs and makerspaces play a key role in shaping and transmitting the meanings and values of digital fabrication and Open Design within the maker movement, to the design community and to the wider public, thereby having a strong role in what message becomes dominant. This study has shown how

issues are rendered invisible in the dynamics between discourse and practice and has offered suggestions for ensuring more socially useful and environmentally aware production in these contexts. In making “making” critical, it appears that involving a range of stakeholders is key: engaging those with technical and/or environmental expertise, who are willing to raise the visibility of problematic issues and work to tackle them collaboratively. Exemplary Labs with strong ecology-oriented visions and programmes also provide important role models, and they prove that open-design, digital-craft processes can serve sustainability-oriented priorities.

Whether personal fabrication activities and discourses become commodified and linked to commerce or retain their more justice-oriented ambitions will be an ongoing and shifting process, “even as they generate new research programs, technologies, and material culture” (Hess et al. 2008, 487). There is a need for further narratives and empirical research from a variety of makerspaces and Fab Labs, to understand how widely the findings of this study may be applied: the range of activities, espoused ideologies and importantly, over time, potential trajectories. This includes the need to identify who is *not* included in such activities.

Commercial services in digital fabrication are rapidly expanding, and Fab Labs and digital designers in the global North may easily become subsumed in the normal business of digital production and “tech shops”. If they are associated with other institutions such as universities or municipal actors, they will encounter ever more pressure to account for their funding and communicate their impacts. Socio-environmental sustainability is likely to count among the most important concerns, given the maker movement’s position in the production of tangible artefacts using rapidly changing processes and materials.

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Notes

1. www.fablabs.io (accessed 13 May 2016).
2. www.fabfoundation.org/fab-labs/the-fab-charter/ (accessed 13 May 2016).
3. www.fablabs.io/machines (accessed 13 May 2016).
4. The count on <http://wiki.fablab.is/wiki/Portal:Labs> on 25 June 2014.
5. The count on www.fablabs.io/labs on 13 May 2016.
6. In Shapeways alone, an online marketplace for 3D-printed products, the number of shops selling designs (many run by design entrepreneurs) increased from 13 500 in 2013 to 23 000 in 2014 (Hagel, Seely Brown, and Kulasooriya 2014; Mansee 2014).
7. Especially in some countries such as the US, based on an examination of Labs listed in www.fablabs.io/labs in January 2016. Design students and practitioners are also markedly present in Labs as organizers or users, particularly in northern Europe (based on conclusions from the author's fieldwork).
8. The data set included about 80 sets of field notes, 20 interviews (and numerous more informal conversations), 1300 photographs and 120 video recordings.
9. Environmental issues such as resource use are intertwined with social sustainability issues, such as inequitable access to these resources and inequitable distribution of the harmful consequences of production. The terms environmental and socio-environmental sustainability are thus used interchangeably in this study.
10. The understanding of environmental issues in this study was also based on a review of the literature (Kohtala 2015), as well as the author's extensive background in Design-for-Sustainability.
11. Interview, 24.04.2012; internal documents.
12. Field notes 20.06.2012.
13. The name has been changed.
14. Field notes 18.02.2012.
15. Field notes 05.05.2012.
16. Interview 24.10.2012.
17. Interview 24.10.2012.
18. Field notes 10.10.2014.
19. Field notes 07.05.2012.
20. Interview 29.01.2015.
21. Interview 30.01.2014.
22. Interview 31.05.2013.
23. Field notes 04.12.2014.
24. Field notes 04.12.2014.
25. Field notes 04.12.2014.

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Biography

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