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Sharing is Sparing: Open Knowledge Sharing in Fab Labs

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Abstract:

The commitment of the Fab Lab community to participate in processes of commons-based knowledge production thus also includes global knowledge sharing. For sharing back into the global commons, new knowledge needs however to be documented in a way that allows to share it by the means of information and communication technologies. So far, there are no empirical studies that provide insights into the question whether and how knowledge is indeed shared globally in the Fab Lab community, and how the above mentioned challenges are experienced and dealt with by the Fab Lab members. This paper reports an empirical study that aimed at closing this gap based. The study was based on qualitative interviews with sixteen Fab Lab users. In these interviews, the responded seventeen projects that were analysed as case studies. The case studies revealed, that knowledge sharing is not impeded by the barriers discussed elsewhere in literature such as motivational or technological impediments. Nevertheless, the cases showed that global open knowledge sharing was far from the norm, and sharing remains mainly local and personal.

Keywords: FabLabs, open knowledge sharing, commons-based knowledge production

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The movement towards open design (Abel et al. 2011) is a core driver of digital maker communities, i.e. groups of "high-tech do-it-yourselfers who are democratizing access to the modern means to make things" (Gershenfeld 2012, 48). Fab Labs (fabrication laboratories) are one example of digital maker communities. They offer open access to a range of low-cost fabricators and many of them operate based on a commons-based peer production approach (Benkler 2004; Troxler 2010; Troxler and Wolf 2010). The granting of access to high-tech prototyping machines for "everyone" is a cornerstone of Fab Lab. Since 2003, this vision spurred the creation of over 250 physical meeting places for specialists and enthusiasts to engage with technology bottom-up.

Beyond providing local points of access to digital production devices, Fab Labs have the ambition to share digital fabrication blueprints as well as operating instructions for using the machines in the worldwide community. They hold altruistic values of open and reciprocal knowledge sharing and implicitly understand knowledge as a public asset, as a commons (Hess and Ostrom 2007a; Verschraegen and Schiltz 2007). The term knowledge refers in this context to "all types of understanding gained through experience or study" (Hess and Ostrom 2007b, 8). Hess (2008, 8) observes that the groups building a commons [2] share "a persistent type of commons-like thinking: a belief in the common good and working toward shared outcomes based on voluntary participation and reciprocity."

The commitment of the Fab Lab community to participate in processes of commons-based knowledge production thus also includes global knowledge sharing. From a theoretical standpoint, this is challenging because it raises the questions on whether and how the knowledge transformed by makers in Fab Labs as local public spaces can be shared in virtual environments like online platforms. Assuming that other than data, knowledge cannot be transferred but has to be transformed for becoming altered (Wolf and Hilse 2014), learning in the Fab Labs is part of making things, of crafting. For sharing back into the global commons, new knowledge needs however to be documented in a way that allows to share it by the means of information and communication technologies. Although Sennett (2008, 37) underlines the usefulness of these technologies for the development of craftsmanship because they allow for dynamic feedback, it seems as if there is a set of challenges that potentially does not favour global knowledge sharing in the Fab Lab community. Global knowledge sharing relies on documentation, and particularly tacit knowledge that is important for making things might be difficult to represent in formal documentation (Polanyi 1967). Moreover, our review of extant literature below suggests that there might be further motivational, social, technological and legal barriers to the participation of the Fab Labs into global processes of commons-based knowledge production.

So far, there are no empirical studies that provide insights into the question whether and how knowledge is indeed shared globally in the Fab Lab community, and how the above mentioned challenges are experienced and dealt with by the Fab Lab members. This paper reports an empirical study that aimed at closing this gap based on qualitative interviews with 16 Fab Lab users. In these interviews, the respondents reported 17 projects that we analysed as case studies. The case studies are meant to provide insights into the questions whether and how knowledge was shared, what supportive and restraining conditions were and how the latter were experienced and dealt with by the interviewees.

The article will proceed as follows: After a literature review, the methods section will present the sample as well as methods for data gathering and data analysis. The subsequent findings section will provide a descriptive overview on the thematic areas that respondents talked about in the interviews. The final section discusses the findings and concludes on the insights gained from this study.

1 Knowledge sharing in the global Fab Lab community: A literature review

The Open Design movement (Abel et al. 2011) can be understood as one of the recent approaches that strive for democratizing access to knowledge and production devices. These approaches share the basic values to "empower people against specific threats to their freedom, and move us closer to a free society" (Reinish 2013) with more open content creation and free software projects. *Online mass collaborators* contribute to open content creation and information resources such as online encyclopaedias like Wikipedia, digital libraries such as arXiv.org, the Public Library of Science (plos.org) or the Digital Library of the Commons (dlc.dlib.indiana.edu) as well as bookmark sharing sites such as Delicious. They thereby build new knowledge commons (Hess 2008). The Free Software movement started in the 1980s as a reaction to restrictive

licences of business software; Richard Stallman (Stallman 1985) and colleagues created licences based upon the principles of the four freedoms to use, study, share and fork the code – for example in the GNU project (gnu.org).

Open design however differs from the above democratizing approaches because it additionally strives to qualify citizens to use digital fabrication technologies for participation in knowledge transformation processes for societal development and change. Moreover, the collective action for the creation of the commons that open design initiatives stimulate happens also in real world physical spaces. Digital maker communities who drive the open design movement are groups of "high-tech do-it-yourselfers, who are democratizing access to the modern means to make things" (Gershenfeld 2012, 48). O'Duinn (2012, 1) highlights three characteristics of the maker culture: First, there is a strong emphasis on learning through hands on creation. Second, due to the different backgrounds of the people involved, the maker community lives a trans-disciplinary approach. Third, sharing is a must: similar to open source communities, maker project details are made freely available online.

Fab Labs (fabrication laboratories) are one example of maker communities. They can be described as "place[s] to make (almost) anything" (Gershenfeld 2005) where everybody can design, fabricate, test and debug innovations (Mikhak et al. 2002). Fab Labs offer open access to a range of low-cost fabricators and they are based on a commons-based peer production approach (Troxler 2010; Troxler and Wolf 2010). Fab Labs strive to achieve more equal participation and inclusion of citizens in knowledge transformation processes for a future society by establishing integrative public spaces where citizens

- are provided with open access to information and knowledge, and are supposed to share new information and knowledge back into the commons,
- receive training on the usage and further development of digital technologies
- gain affordable or free access to the technologies and/or methodologies for the production of the commons.

In the recent version of their Charta (Center for Bits and Atoms 2012), the Fab Labs are characterized as "a global network of local labs, enabling invention by providing access to tools for digital fabrication" and claim to "share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared". Accordingly, sharing knowledge – design blueprints and instructions or tutorials on how to use the tools and machines for certain purposes – not only in local Fab Labs but also globally is one of the core values and aims of the Fab Labs. Sharing newly created commons back globally and accessible to everybody however implies the use of online communication means and therefore previous documentation as conditio sine qua non. The Fab Charta (Center for Bits and Atoms 2012) consequently lists "contributing to documentation and instruction" as one of the three most important responsibilities of Fab Lab users.

From our work with the Fab Lab community during the last seven years, we however had the impression that it is notoriously difficult to convince even altruistic users of local public spaces who are aware of and agree with the importance of contributing new knowledge back into the commons to invest time and effort into documentation and open knowledge sharing at online platforms. Extant literature on open knowledge sharing in online environments likewise suggests that there are several obstacles and barriers to collective action and global open knowledge sharing. The reasons for this can be found in four different aspects. For reference, we provide here a compressed overview of the main lines of arguments:

First, there are motivational barriers – individuals have to be willing to share experiences and insights openly in a virtual environment (Spaeth et al. 2008; Rangachari 2009). Chiu, Hsu and Wang (2006) show that personal outcome expectations engender knowledge sharing in virtual communities. Moreover, for sharing efficiently, users have to complete the usually difficult, sometimes mundane, and possibly arbitrary task of documenting what they have done (Barnes, Guggiari and Märki 2013). This is particularly relevant for maker communities where knowledge is transformed in the interaction with the material, in processes of fabrication, and in the interaction with the physical world of hardware (Troxler and Zijp 2013). Here, particularly embodied practical skills – tacit knowledge that forms the basis for craftsmanship (Sennett 2012) – are important for making things. However, tacit knowledge per definition eschews formal documentation (Polanyi 1967).

Second, there are certain barriers regarding the social aspect. Sharing of tacit knowledge – socialization in the terms of Nonaka and Takeuchi, (1995, 72) – plays an important role in making. Yet socialization is difficult to be effectively achieved by the means of online communication as they require some degree of externalisation. Hence, there is a trade-off between the usefulness of local versus global collaboration. Moreover, the willingness to share information, ideas and knowledge grows with the opportunity of establishing or leveraging social capital. This is usually possible in networks of mutual acquaintance, i.e. friendships or memberships of a university class (Nahapiet and Ghostal 1998, 243). Strangers in groups decrease this motivation – Camera, Casari and Bigoni (2013) recently showed that the willingness to cooperate with strangers declines when going from small to large groups, even if monitoring and payoffs from cooperation were invariant to group size.

Third, as in all virtual environments, there are technological barriers to communication, documentation and sharing (Riege 2005). The technology of a virtual community platform has to be designed in a way that ensures compatibility of programs and infrastructure, as well as accessibility to information (Gibson and Cohen 2003). When working in global virtual communities, there are various barriers to overcome – in addition to time and geographical differences, disparities in national, cultural and linguistic attributes have to be dealt with by technology (Zakaria, Amelinckx and Wilemon 2004). Suitable technology can help communities to share information and ideas in an efficient way (Wenger, White and Smith 2009). Ghani (2009, 34) lists four requirements that IT tools have to incorporate to support knowledge sharing: to facilitate information contextualization; to intelligently transfer information by taking into account the user, the content, and the time of transfer; to facilitate social interactions and networking; and to represent a customized, easy to use human-computer interface.

Fourth, there are legal issues related to sharing knowledge openly through the Internet, as some forms of knowledge receive preferred legal protection from copying. Recent discussions refer to the unprecedented access to knowledge online and at the same time to increasing intellectual property legislation, (over?)patenting, licensing, and lack of preservation of the public domain (cf. Boyle 2003; 2004; Dussolier 2011). Fab Labs were created on the basis of open design (Määttä and Troxler 2010) to generate new knowledge on making or (personal) manufacturing, and to share it throughout the making process and make it available to everyone within the community.

It is highly probable that the above challenges to open knowledge sharing also affect global knowledge sharing in the Fab Lab community. However, there are so far no insights into the question whether and how knowledge is indeed shared globally in this community, and how the challenges in the above-mentioned aspects are experienced and dealt with. This paper aims to address this research gap.

2 Methods

A qualitative research approach seemed to be the most appropriate to investigate the open exploratory research question at hand. Qualitative research helps to study complex phenomena when there is no previous research, empirical or theoretical, available (Davies 2007).

2.1 Sample

According to Davies (2007, 143), the core sample of a qualitative study is the people who make up the "pivotal target group" and are therefore able to provide the essential insights necessary to answer a project's research questions. The objective is to learn from the persons involved, to contrast their views and to take into account the deeper situational context (ibid, 148). In the setting of this study, the research question seeks to provide a deeper understanding of whether and how knowledge sharing takes place in the global Fab Lab community. Thus, the overall population to be explored are all Fab Lab users. However, conducting interviews with all Fab Lab users is neither feasible – considering time and resource constraints – nor is it necessary. Patton (1990, 169) suggests narrowing the population down to a purposive sample that allows the most appropriate participants to be selected. This should allow the exploration of different and comparative experiences relevant to the research question.

Extreme case sampling was therefore chosen as sampling strategy to identify interviewees and interesting cases. Extreme case sampling purposively uses extreme or deviant cases as sample for qualitative research (Flick 2009, 122). In order to gain access to potential interviewees, the two managers of a local Fab Lab in Switzerland were contacted first. They indicated relevant cases and supported the establishment of contact to members of the worldwide Fab Lab community who suited the requirements. These people were interviewed and asked to indicate at least one further person who was involved in the case(s) they talked about and who would be willing to participate in an interview. The idea behind holding several interviews on the same case was to look at the same case from different perspectives of people involved. This increases the validity of case study research (Flick 2009).

For this study, the requirement to ideal interviewees was that they should have been involved in projects (cases) within the global Fab Lab community where knowledge sharing was applied extensively. More precisely, the minimum requirements to the criterion "extensive knowledge sharing" were that interviewees had been part of project groups

a) that had successfully completed an open sharing project within the Fab Lab community which included some elements of reciprocity in sharing,

b) where the realization of the output was the result of a collaboration between different, not co-located Fab Lab users, and

c) where sufficient documentation on the process was recorded.

Finally, 16 members of the Fab Lab community were selected for the interviews who talked about 22 different cases (see table 1 below).

Case Nr.	Interviewee	Role	Country of Residence	Case	Knowledge sharing	
					locally	globally
1	A	Manager of Fab Lab I	The Netherlands	University course	yes	no
2	B	Concept developer at Fab Lab II	The Netherlands	Graduation project	yes	yes
3	C	PhD student at Fab Labs III and IV	Spain	Unrelated	yes	yes
4	B	Concept developer at Fab Lab II	The Netherlands	Toys	yes	no
5	D	Intern at Fab Lab III	Spain	Video screen	yes	no
6	B	Concept developer at FabL ab II	The Netherlands	Medical	yes	no
6	E	Backend developer at Fab Lab II	The Netherlands	Medical	yes	no
7	E	Backend developer at Fab Lab II	The Netherlands	Medical	yes	no
8	F	PhD student at Fab Labs III and IV	Spain	Crockery	yes	yes
8	G	Student assistant at Fab Lab IV	Spain	Crockery	yes	yes
9	G	Student assistant at Fab Lab IV	Spain	Furniture	yes	yes
9	H	Freelance designer	Norway	Furniture	yes	yes
10	H	Freelance designer	Norway	Fashion	yes	yes
11	H	Freelance designer	Norway	Medical	yes	yes

Case Nr.	Interviewee	Role	Country of Residence	Case	Knowledge sharing	
					locally	globally
			12	H Freelance designer	Communication	yes yes
13	C	PhD student	United States of America	Retail	yes	no
14	C	PhD student	United States of America	Installing Fab Labs abroad	yes	yes
15	G	Student assistant at Fab Lab IV	Spain	Setting up a Fab Lab abroad	yes	yes
16	I	Hacker and lecturer	Switzerland	Preparing to set up a Fab Lab abroad	yes	yes
17	J	Hacker	Switzerland	Scientific instrument	yes	yes
17	I	Hacker and lecturer	Switzerland	Scientific instrument	yes	yes
17	K	University student	Switzerland	Scientific instrument	yes	yes
17	L	University student	Switzerland	Scientific instrument	yes	yes
18	I	Hacker and lecturer	Switzerland	Biohacking equipment	yes	yes
19	J	Hacker	Switzerland	Biohacking equipment	yes	yes
20	M	Chair of an Artists' Association	Switzerland	Musical instrument	yes	yes
20	N	Manager of Fab Lab V	Switzerland	Musical instrument	yes	yes
			20	C University student	Switzerland Musical instrument	yes yes
20	P	Manager of Fab Lab V	Switzerland	Musical instrument	yes	yes
21	I	Hacker and lecturer	Switzerland	3D printer	yes	yes
21	P	Manager of Fab Lab V	Switzerland	3D printer	yes	yes
22	P	Manager of Fab Lab V	Switzerland	Audio equipment	yes	yes

Table 1: Sample

As visible in table 1, not all cases completely matched the criteria – those that did not are marked in grey:

- In five of the cases (4, 5, 6, 7, 11, 13), knowledge was shared only locally.
- In three of the cases (10, 22, 22), a blueprint and production knowledge was shared with other locations either by the designer traveling there or by uploading it to Thingiverse, but there was no reciprocity in the process, nobody from another location revised or co-developed the design.
- Another three cases (14, 15, 16) reported about people from established Fab Labs travelling abroad to support the setting up of a Fab Lab. These cases have a focus completely different and more complex than the others where knowledge was shared virtually around design objects.

The remaining eight cases completely matched our criteria. For two of them (11 and 12) it was not possible to find a second interview partner. Though not all cases match the selection criteria completely, the authors decided not to restrict the corpus of data only to them because the other interviews contained interesting information on the question why global knowledge sharing in these cases did not happen.

2.2 Methods for data gathering

The nature of the research question at hand requires data that reflects the experience of the interviewees. Thus, for data gathering, semi-structured interviews were conducted. This type of interviews allows gaining access to deep levels of individual experiences because it "stimulates reflection and exploration" (Davies 2007, 29). It is a good mean for collecting data on cases, because it enables the interviewer "to learn what happened in a specific instance" (Rubin and Rubin 2012, 5-6), in this case in processes of knowledge sharing in Fab Lab projects. Elements of narrative interviews were used to generate the interviewee's main narrative on each theme using a "generative narrative question" as the main question for each theme (Flick 2009, 177). The questions were designed with the aim of

obtaining the targeted vividness in descriptions and stories, and the necessary precision, nuances, richness, depth and detail of answers (Rubin and Rubin 2012, 114).

The interview guideline was built up based on the theoretical background and tested in a pre-test interview session. It consisted of questions concerning several topical areas of interest regarding the research question. These topical areas refer to the aspects that impact knowledge sharing in global communities according to the theoretical background: motivational, social, technology, and legal issues (Flick 2009, 156). Table 2 below presents the structure of the interview guideline:

Phase	Themes	Details
Beginning	Introduction interviewer	Personal information
	Information about study	Information about study Data handling
	Personal information of interviewee	Name Age Work/study situation Participation in relevant Fab Lab projects
Main questions	T 1: Social aspect and motivation to share	Motivation to share Drivers Benefits
	T 2: Technological aspect	Documenting technology Efficiency of technology Communication technology Connectivity between Fab Labs
	T 3: Legal aspect	IP registration Requirements/guidelines for Fab Lab Difficulties (negligence)
Ending	Leading out	Thanking for contribution Suggestions for changes Comments from interviewee

Table 2: Interview structure (adapted from Hollemann et al. 2013, IX)

As most interviews were held by telephone or Skype, the interview guideline contained a set of warm up questions at the beginning "that provide the interviewee with a comfort level about their ability to respond" (Rubin and Rubin 2012, 108-109). After this phase, an open narrative question was asked so that the interviewees could describe in their own words what they believed led to the successful knowledge sharing throughout the course of a specific Fab Lab project they were involved with. Afterwards, the conversation was led towards detailed questions that were more difficult to answer and that had specific objectives (main questions phase). At the end, the interviews were thanked for their contributions, asked for suggestions for changes or further comments. The length of the interviews was between 25 and 70 minutes. They were recorded and transcribed verbatim. Transcriptions comprise 255 pages.

2.3 Methods for data analysis

The research team that analysed the data consisted of three professors involved in the research project (including the project manager) and two groups of student-researchers, group 1 with three and group 2 with four members. Open coding was used for being able to identify emergent topics (Miles and Huberman 1994).

As a principle, each step in data analysis was conducted in various iterative circles: The first step of data analysis was conducted by all student-researchers involved and two of the professors separately (e.g. coding 'first-level' codes individually). Then, student-researchers came together in groups and developed a common interpretation (e.g. a list of 'first-level' codes and related text passages), thereby iteratively refining the initial result of individual analysis. Thereafter, the codes of the student-researcher groups were compared to those of the professors and refined again. In the last step, the findings were presented to the third professor who went again through the codes and looked for inconsistencies in the codes and for additional topics.

In a final step, the code map was analysed with regard to which topics had been identified in relation to which case. This allowed to perform a cross-case analysis and to differentiate between findings that were specific to cases with more and less extensive global or local knowledge sharing. Cross-case analysis generally deepens the understanding of the question at hand and findings are likely to be more robust than those coming only from a single case (Yin 2009, 156).

3 Findings

This section displays and describes the major topics that emerged from the data analysis.

3.1 The Fab Lab environment

Fab Labs and their global network formed the backdrop for this study. Because the connectivity between Fab Labs was explicitly addressed in this study, the individual definition of the respondents of what a Fab Lab is and why they started to use Fab Labs was often part of the narrative. Interviewee J outlines exemplarily that *"the idea of the Fab Lab is that it is open to everybody. It's also a place for beginners to learn things. So the people that are in the Fab Labs, or in the Fab Lab environment are very encouraged to teach people."* Fab Labs were mainly described as creative environments, places that allow people to materialize their ideas and to use facilities and machines and to tap into the skills and experience of lab staff. Interviewee B for example reports that she *"(…) started using the Fab Lab for my job, yeah, to materialize the ideas and concepts into something tangible."*

Fab Labs were seen as *"part of the whole maker, open hardware scene"* (interviewee J), similar to hackerspaces, makerspaces. At these places, one could meet diverse but like-minded people who would share values of an *"open culture environment"* (interviewee J), who want to teach, learn and share, and who have similar attitudes. As interviewee G puts it: *"It's cool if you go there, you know people who go there (…) are ready to share, their tools, software, maybe material, maybe ideas."* Like this, often collaborations among Fab Lab users turn out to be very helpful and interesting because *"there are people who are able to, what I program, transform into a product"* (interviewee O).

Public, open access to the lab was referred to as an important characteristic of the Fab Labs. Yet occasionally it was also depicted as endangered, particularly in the case of labs that are attached to a university, as these are described as suffering from *"knowledge and closed access, right? You need to be a registered student and you need to in order to have access."* (interviewee H)

3.2 Motivational and social aspects of sharing

Sharing as moral principle and practical advantage

Sharing was often mentioned as an underpinning, moral principle of Fab Labs. Respondents alluded to the Fab Charter that states that "Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared" and that "[d]esigns and processes developed in fab labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from" (Center for Bits and Atoms 2012). An earlier version of the Charter was even stronger in this respect, stating that "[d]esigns and processes developed in fab labs must remain available for individual use although intellectual property can be protected however you choose" (Center for Bits and Atoms 2007). Interviewee G summarizes this moral principle as *"sharing is caring."*

Arguments for why sharing is desirable covered a wide range of arguments. Some interviewees provided the outright altruistic argument that sharing of knowledge and technology would have a positive impact on society and could help to solve global challenges, like interviewee I: *"aspects that are important to this society is also the science outreach so that we bring knowledge of technology to people that are not like in research as a science field."* Others refer to more compassionate feelings towards fellow Fab Lab users to help them not having to start from scratch and to avoid errors and mistakes one made: *"I was really frustrated that there was no documentation for; this was even at [name of the university], right, in the class I was taking. No documentation for how to do anything. And it was really frustrating. But I wrote all of these tutorials about – once I learned how to do, I was like: I hope nobody has to suffer what I suffered, so I wrote all these tutorials"* (interviewee C).

Very pragmatic reasons for sharing were also mentioned: Sharing as a way to improve own projects, to enlarge the community whose members would *"continue working on it [a project, the authors] or contribute from their background"* (interviewee I) and in doing so make the project cheaper and simpler. *"We can form a larger team and find better solutions"*, interviewee K concludes. In addition, one's own visibility and the positive appreciation of a project was another reason why one would share projects: *"The cool thing is: we eventually uploaded the thing to Thingiverse and about 200 or 300 people have already downloaded it and I'm sure some of them would have built it, find it awesome and would even have made changes to it. I was the first to have the idea and now it grows publicly."* (interviewee N)

Documenting projects and sharing

Documenting projects, preferably online and in a way *"that somebody else can replicate it and understand it without the context that you are in"* (interviewee C) was in general seen as desirable. But it was also described as not easy and not necessarily part of the primary process of making.

Some respondents reported that they were keeping track of what they were doing, primarily for themselves and for their team, but also to share with others. They so far used different means for documenting the work of the team, from *"a little notebook (…) to write down everything"* (interviewee D) to *"taking pictures or taking notes of what we are doing"* (interviewee G), also *"because if it is photographed one does not forget it"* (interviewee N). Interviewees reported that particularly in more formalized projects they were taking notes, but mainly to track progress, define actions and deal with bugs and issues. Rarely the connections between those notes as process related communication and project documentation was made like here by interviewee F: *"But I think the person that did more notes was [name]. This was the girl who was sending the information through Facebook and Email. Simple notes, pictures and videos."*

Still some interviewees also thought it could be valuable to document works in progress to show ones ideas and to share those ideas with others. They expressed the feeling that "it's important to share before something is finished. To show your idea." (interviewee O).

Creating documentation so that others can follow, replicate and rebuild a project was however not seen as easy, as opposed to just having ones own notes. *"It also requires knowledge how to draw and show ideas which have not fully been developed (…) how you convey them, in order to enable others to see what your idea actually is"* (interviewee O). Consequently, documentation of a project was often mentioned as something that requires additional skills: *"It's one thing to keep track of what you are doing but the other thing is to make a real nice description of it"* (interviewee I). Documentation for the benefit of others in the community was seen as something extra that needs to be done after completion of the project because it would mean *"to take a step further, then you spend a couple of days documenting it properly"* (interviewee N).

…or not documenting and not sharing

Respondents found various reasons why documentation was often superficial or projects were not documented at all. Despite best intentions, documenting was often seen as *"tedious and boring work so nobody wants to do it. It is not paid and not fun"* (interviewee J). One main reason was attributing the lack of documentation to people's nature: geeks, innovators, designers and artists have other priorities, *"prefer making things and using them"* (interviewee J) and outright don't like to document.

Another major reason given was the lack of time for documenting. Interviewee F explains that she is not documenting *"not because I don't like but because I don't have time."* Reasons for not having the time were also given – working long days on a project, time eaten up by bug fixing, and generally trying to keep up with working on projects and running labs that there would be no room for the extra effort of documenting. *"Imagine like you are in the water and you're just spending so much energy in the chaos, just keeping from sinking, that adding that additional effort of documentation is sort of too much"*, interviewee H explains. Even in more formal projects people did not have time to document their work because time for documentation had not been formally allocated or as they were not well organized: *"(…) at the moment it would not be that well documented. So if we would do that, we would have to decide it from the beginning"* (interviewee B).

Major motivational drivers for sharing

Analysing interview data across cases indicates three major motivational drivers to document and eventually share the making process. These are, in order of descending frequency:

- the fun factor – making awesome stuff in a way that is visible to and recognized by the outside world,
- the satisfaction of making itself, often in collaboration or at least in contact with others,
- the drive to help others and society at large, often also referred to as a general attitude.

Business or monetary motivation is occasionally mentioned in the context of making and documentation; however such motivation appears to play an inferior role according to our interview data.

Two of the three main motivational drivers are hedonistic in character, the first is more strongly socially related, the second more individually. This confirms what others have found in open source software communities (cf. Harhoff, Henkel and von Hippel 2000; Lerner and Tirole 2002; Kelty 2001). Respondents also argue that in the absence of fun or a contribution to one's ego gratification, to reputation or to the core making process, documenting (or documentation) and sharing receives less attention, and less time and resources are allocated to it. The same holds for money as motivator.

The third motivational driver is purely altruistic. In our data, making an altruistic contribution is always a positive driver for willingness or effort to document and/or share knowledge, and we found no indication that

respondents would not document because it would not help others.

Social aspects of sharing

The social aspect we found in the interview data generally support what we found on the motivational aspect above, while they show a slightly more varied picture. Again, in order of descending frequency, the social reasons why interviewees share and contribute to the commons are:

- social capital – receiving attribution for a "thing" or project and reaching a (sizeable) audience,
- open source culture – the notion of belonging to a community that highly values sharing of knowledge,
- learning, teaching and helping others,
- the satisfaction of making itself, often in collaboration or at least in contact with others,
- the relation with other Fab Labs and the global network.

Occasionally mentioned in relation to the social aspects were meeting people and business issues.

The responses reflect the expectations that social capital would be an important factor; yet we did not find the aspect of mutual acquaintance as limiting, as predicted by Nahapiet and Ghostal (1998). A possible explanation is that there was very little practice of online social networks at the time of Nahapiet and Ghostal's study (1998). Belonging to an 'open source culture' was the next most mentioned social aspect that influences sharing in a positive way. The aspects of 'learning, teaching and helping' and 'making itself' mirror the second and third points we found for the motivation for sharing above. One could argue that the Fab Lab network indirectly supports sharing, as sharing is an explicit value in the network (Center for Bits and Atoms 2012) and the findings show that belonging to an 'open source culture' was influential.

3.3 Tools and technology for documenting and sharing

For documenting projects and sharing this documentation, it was important to the interviewees to use cool, fun tools – *"making it fun is my key, making the documentation part fun"* (interviewee J). Ideally, this would be a single dedicated repository including "collaboration tools. So this is something I'd love to see more" (interviewee H). In the absence of such a repository, existing third-party solutions for sharing project documentation and instructions were used such as Thingiverse and Instructables, Flickr for sharing photos as well as smaller sites and solutions of individual labs. These sites were however occasionally criticized for belonging to commercial companies.

Some labs reported they were experimenting with tools to automate at least part of the documentation process, for example with *"a camera that posts photos directly on Flickr"* (interviewee N) or some purpose-built computer to log activities. Interviewee A reported that he had heard about another Fab Lab that

"tried to make it more fun to share your knowledge. (…) They made some sort of computer when you log out (…) and there is some questionnaire incorporated in this log-out process. So then you have some sort of automatic, how do you say, filling of this product space."

Many times more process based and often closed user group communication tools such as Twitter, Facebook, e-mail, Skype or Google hangouts were used to share ideas, knowledge and "things", often in form of pictures and videos. These tools were used as means to communicate with people the interviewees knew previously and selected according to the ease of use like interviewee L exemplarily outlines: *"It's mostly over Skype or e-mail, I mean it's easy to show pictures."*

In general, the technical aspect appeared to be discussed in much less detail in the interviews, and technology was in general referred to as being available and fit for purpose. Two major aspects could be found in the cross-case analysis:

- the availability of online platforms – as a means for sharing process information and promoting results, and
- the availability of machines – as a reason to participate in the community.

The main aspects mentioned for platforms were not the ones we expected from literature. It was rather important whether a platform was fun and cool or burdensome and boring to use. More indirectly, the size of the audience that could be reached with a certain platform was a matter of concern. Interestingly, the main the platforms mentioned – in particular Google Hangout, Facebook, Skype or Twitter – are platforms respondents probably not only use for sharing their Fab Lab projects but mainly for many more kinds of everyday (social) interaction. In that way they don't fall into the category of bespoke enterprise knowledge management systems that were the basis for Ghani's (2009) analysis and his findings might just not apply.

3.4 The legal and business environment

The legal and commercial side of sharing was explicitly addressed in the interviews. Respondents showed a certain awareness of copyright and design rights and were familiar with licensing copyrighted works under Creative Commons licenses. These were widely used to allow re-use of designs, either in the simple attribution-only option or in the attribution, non-commercial option. Interviewee N demonstrates this knowledge exemplarily when he explains: *"We always had the intention to make this open, accessible for everybody, with a Creative Commons license version 3. That means it can be used for non-commercial purposes. It can be changed if attribution is given. That is the standard license."* One respondent reported to be even more open and to not even require attribution, because the result of his work *"doesn't belong to someone, we don't claim, we don't even have any attributed rights, I guess. So it's really free and open to share"* (interviewee I). In general, however, respondents often highlighted the importance of giving credit to the initial source of a project: *"In the sense that knowledge is share, it's open source, so it's important to refer to where you've got something from"* (interviewee O).

However, respondents were also aware of contractual limitations to sharing, such as employment contracts that assign ownership to the employer, or in commercial projects where ownership often is transferred to the client: *"We also use the Thingiverse account (…) – obviously we cannot upload the files that are property of our clients – that stays just inside the Fab Lab"* (interviewee D).

Further issues of legal protection – such as the copyleft options of Creative Commons licensing or the possibility of patenting an invention – and consequences for sharing were rarely discussed in the projects. Due to this lack of initial discussion, several interviewees express that they are not really aware of what results they can or can't share: *"I don't think it would be an invention that you could patent or something, uhm, and I'm not sure, I would have to find out (…) the process of making we can share. But I don't think it's really protected or something (…)"* (interviewee B).

Interviewee H even reported using Creative Commons licenses rather as *"a way to signal my intent" of being open for business proposals, not as a form of legal protection. A way to earn a living when designs are shared freely was, however, depicted as something yet to be found – "I'm looking sort of to the bigger picture to find a business model based on sharing"* (interviewee H). At the same time, there seemed to be some straight-forward steps towards business models in place, such as being able to *"cover our expenses with our watch, because we participated at certain exhibitions"* (interviewee M). Another opportunity is running (paid for) workshops.

It was also suggested that business and open source were not compatible, as business-oriented companies would only use open source models as

long as they got input from other that helped their business: *"[W]hen the project gets good, they think, ah, if I close it I can earn more money"* (Interviewee M). This dichotomy was characterized as rather one-dimensional: *"It is a little bit about an attitude to life, you know you wanna run a business practice based on sort of like paranoia and fear and protecting, or do you wanna run a business practice based upon open, curious, creative attitude"* (interviewee H). Finally, the notion of helping other people or more generally improving human life could also good for acquiring funding.

The two competing aspects of "intellectual property" and "open source" appeared approximately with equal frequency in the interviews:

- "intellectual property" – copyright, design rights, patents, and generally creations, designs and inventions "belonging" to the author, and
- open source and Creative Commons – as principles and licenses for sharing creations, designs and inventions.

This again reflects the findings from the other aspects where altruistic motivations to help society and share the results stood across from the motivation to make money or earn a living from the designs developed. However, there is a specific notion in the search for business models resulting from open design processes: None of the respondents mentioned that he or she intended not to share their results openly but that they were searching for a possibility to earn money together with contributors. Knowledge generated in the Fab Labs – except that one from commercial projects with clients – was understood as commons as suggested by Hess and Ostrom (2007) and McConnell, Brue and Flynn (2009), and development processes as open design processes (Abel et al. 2011). At the same time, it seems that indicating ownership and contributions in open design processes is much more difficult than in open software projects where authors of lines of codes could be easily identified.

3.5 Fab Labs as a global network?

As the connectivity between Fab Labs was initially addressed under the technological aspect, respondents discussed the technical means available in the Fab Lab community and elsewhere to make connections. The FabLab concept was criticized for not providing technical infrastructure or *"procedures regarding documentation and filing"* (interviewee K) to facilitate interconnectivity. Or, as interviewee I puts it: *"(…) all Fab Labs (…) have a list of machines that you should use but they have no list of communication tools. (…) It's just not part of the concept."*

As seen above, various methods and platforms for publication of and publicity for projects and events were used, and their impact was generally evaluated as fruitful to increase public visibility and *"making this thing bigger"* (interviewee G), since *"[o]therwise it feels that the event has not taken place"* (interviewee M). They were also judged as being good means for connecting between labs: "When I posted this on Facebook, through our own website, we suddenly got a lot of requests from Fab Labs worldwide" (interviewee N). But to really know other Fab Labs appeared to be difficult if there was no face-to-face contact, ideally beyond the occasional visit but through longer, co-located collaboration of individuals, discussing different things and working on different projects: *"Sometimes it is just very difficult for a Fab Lab to know about another Fab Lab. Right, so (…) there I pretty much only [know] the ones that I have visited"* (interviewee C).

The rapidly growing size of the network was seen as impeding the development of interconnections between the Fab Labs as there were more people with different backgrounds and for the time it takes to get to know each other. Interviewee I for example explains that *"(…) many community things grow slowly and you get to know each other while developing it. And with this Fab Lab being a pretty famous concept that spread around the world maybe it spread so fast that the network couldn't follow."* The result of this situation, so the respondents, was that collaboration and sharing was limited to the local community of a Lab or to those few people who do have the connections with other members of the community: *"The Fab Labs are very decentralized (…) and there are 2 or 3 people there who do something"* (interviewee M).

4 Discussion and conclusion

This paper asked whether and how knowledge is shared globally in the Fab Lab community, and what enablers and constraints to global knowledge sharing are experienced and dealt with by the users. In this section, we discuss our findings and draw preliminary conclusions.

4.1 Challenges to global open knowledge sharing in the Fab Lab community

Our data show that many barriers we expected to find – extrapolating from what literature mentions as challenges to global open knowledge sharing in virtual communities – do not exist or are non-issues in the Fab Lab community.

Regarding motivation, challenges result not from a missing willingness to share knowledge and insights openly. If there is no client involved, the analysis shows that Fab Lab users hold many intentions, altruistically or hedonistically motivated, to take the idea of open design seriously. This is reflected in the legal aspect where interviewees freely associate Creative Commons licences or even do not claim any rights because they feel that the results of their work belong to the community as a whole. The opportunity to establish social capital helps this motivation, but at the same time it quite often supports the development of local rather than global networks. This again is not a result of mistrust of strangers as suggested by Camera, Casari and Bigoni (2013). Moreover, despite there being no common platform for sharing, we also did not come across huge technological barriers to sharing – on the contrary the Fab Lab users avoid problems like incompatible programs and infrastructure or with the accessibility of information that Gibson and Cohen (2003) suggested by using established technological solutions such as Skype, Facebook or Google Hangouts for sharing knowledge globally. Barriers like time and geographical differences or disparities in national, cultural and linguistic attributes that have to be dealt with by technology (Zakaria, Amelinckx and Wilemon 2004) were not mentioned.

How does it come then that within the Fab Lab community global open knowledge sharing is far from the norm, despite the high claims of the Fab Charter? From the interviews, we identified a complex bundle of issues around documentation that make global knowledge sharing difficult and inefficient. As Barnes, Guggiari and Märki (2013) suggested, for sharing efficiently, volunteers have to complete the usually difficult, sometimes mundane, and possibly arbitrary task of documenting what they have done (Barnes, Guggiari and Märki 2013). In accordance to that, the respondents in our study characterized the task of documenting as difficult, time consuming and extra work that is not fun. Although they agree that knowledge developed should be treated as a public good (Hess and Ostrom 2007; McConnell, Brue and Flynn 2009) and shared, Fab Lab users often do not find or do not take the time to document in a way that they feel is good enough to be shared online and globally.

There is an additional issue that plays a role in this vicious circle: a lot of tacit knowledge is involved in making physical things (as opposed to writing software code), and sharing this knowledge with virtual means is difficult (Polanyi 1967; Sennet 2012). Sharing often remains on local level or in the exclusive circle of experts who already know each other. The data reflect this, showing that in most cases when knowledge is shared globally, this happens with friends with whom the users have close(r) relationships and regular contact.

When sharing takes place in a virtual environment, many of the tools preferred by the respondents in our study – Skype, Facebook, Google Hangouts – are better suited to facilitate real-time or near real-time interaction and offer weak, if any, instruments to retrieve interactions and

artefacts shared in such interactions at a later point in time. Even the frequently used repositories such as Thingiverse lack the retrieval power and richness Fab Lab users expect (Troxler and Zijp 2013). We can only speculate if a preference for these platforms stemmed rather from a desire to increase one's ego-gratification through "likes" rather than to altruistically share knowledge and contribute to a new commons.

However, here might be a way out: As making things and having fun are two of the major motivations to participate in the Fab Lab movement, it would be interesting to study how documenting could be turned into a fun activity, possibly closely tied to the (digital) manufacturing processes. Preaching to users that documentation is part of the making process apparently does not have sufficient effect, so providing them with easy to use and "fun" technology that builds upon users' pride and might indeed be a possible solution, at least to solicit more contributions to a commons of documentation. This does not solve, however, the questions of maintaining such a commons which might be seen as an even duller and boring exercise.

4.2 Building a global Fab Lab digital fabrication commons

The rapid growth of the Fab Lab community was indicated in the interviews as contributing to the lack of knowledge sharing on a global scale. While this assumption might hold if envisioning one single global community, we don't think that rapid growth necessarily impedes community building and knowledge sharing. Sure, establishing an all-encompassing Fab Lab sharing platform under fully democratic circumstances, i.e. including a maximum of labs and lab users in its design would be a rather herculean task. Yet local projects, practices and platforms may well emerge, as our study has shown. Based on that development, one could picture Fab Lab as a polycentric network of small and local or regional sub-networks. In terms of the aim of becoming "a global network of local labs" (Center for Bits and Atoms 2012) such a polycentric network not necessarily fosters global interconnection and potentially carries the risk of compartmentalizing the community. In mitigating such risk, on a global level the network would need to address interoperability of (sub?)communities and try to establish Fab Lab protocol layers – such as the notion of "shared capabilities" (Center for Bits and Atoms 2012) rather than proposing "one-size-fits-all" solutions. Such endeavours are already underway when it comes to the machines used (see e.g. the proposal for a "10-k-Fab Lab" (Bakker 2013)). The community will have to learn that such an approach could also be valuable for the more organizational aspects of the network.

The fact that sharing of projects is already happening on public social networks should be an indication for the Fab Lab network that a virtual or "transportable" dialogue is already part of the community activities. Beyond describing how this informal communication among peers is happening (cf. Menichinelli 2013), there is a need to develop an understanding of how it can contribute more consciously to building a global community and to expanding the qualities of sharing. There is an additional dimension to using public social networks that has been alluded to in some of the interviews. Relying on Google, Facebook and sharing platforms that are owned by individual corporations create somewhat risky dependencies – such as for example when the owners of the popular online 3D-drawing platform Tinkercad decided to shut down operations. And they create somewhat uneasy relationships, for instance in the case of Thingiverse and its inventors Makerbot whose practice of filing patents that might or might not relate to inventions shared on Thingiverse repeatedly get heavily disputed. After Makerbot had been bought out by Stratasys, one of the few dominant 3D printer manufacturers, these discussions got even more heated.

Fab Labs are founded on a unique mix between educational and communal activities, intertwined with commercial interests on the one hand and informal, private affairs on the other hand. Hence, Fab Labs are neither usual institutions nor traditional private places, rather they form a type of third places (Oldenburg 1989; 2000). In line with that argument, the educational function of Fab Labs as places that provide a new and more conducive type of STEM (science, technology, engineering and mathematics) education – as the cases also indicate – would need revision in the light of the practice of collaboration and sharing. Such an approach would not only inspire the general understanding of how to teach science, but also a way of practicing science as a process of communal involvement and invention as opposed to the passive reproduction of knowledge practiced at schools and the secretive, behind closed-door discovery processes common to corporate R&D laboratories. In this way, Fab Labs and their potential global fabrication commons would contribute to what others have aptly named "do-it-yourself citizenship" (Ratto and Boler 2014), an umbrella term for initiatives that share altruistic values of open and reciprocal knowledge sharing, understand knowledge as a public good and strive for establishing integrative public spaces. In doing so, DIY citizens repudiate the neoliberal patterns of forced privatization, exclusion and enclosure.

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Endnotes

[1] Urs Gaudenz contributed to the study as one of the respondents and also in the discussion of (anonymized) results.

[2] Commons in the sense of Hess' definition as "a resource shared by a group where the resource is vulnerable to enclosure, overuse and social dilemmas. Unlike a public good, it requires management and protection in order to sustain it" (Hess 2008, p. 37)

References

Abel, B. van, Evers, L., Klaassen, R. and Troxler, P. eds. 2011. Open Design Now. Why design cannot remain exclusive. Amsterdam: BIS publishers.

Bakker, B. 2013. On small Fab Labs. Presentation at the Fablab1.5 Conference. MISiS – the National University for Science and Technology, Moscow, 14-19 October 2013. [online] Available at: http://fablab.nl/2013/11/06/10k-fab-labs/ [Accessed 16 November 2013].

Barnes, K., Guggiari, L. and Märki, T. 2013. Open knowledge sharing in the FabLab – global. Project dissertation. Lucerne University of Applied Sciences and Arts.

Boyle, J. 2003. The second enclosure movement and the construction of the public domain. Law and Contemporary Problems, 66(1/2), pp. 33-74.

Boyle, J. 2004. A manifesto on WIPO and the future of intellectual property. Duke Law and Technology Review 2004, 9, pp. 9-15.

Boyle, J. 2008. The public domain: enclosing the commons of the mind. New Haven: Yale University Press.

Camera, G., Casari, M. and Bigoni, M. 2013. Money and trust among

strangers. Proceedings of the National Academy of Science of the United States of America, 110(37), pp. 14889–14893.

Center for Bits and Atoms 2007. The Fab Charter. [online] Available at: http://fab.cba.mit.edu/about/charter/ [Accessed 10 January 2008]. Archived version available at: https://web.archive.org/web/20080110205326/http://fab.cba.mit.edu/about/charter/.

Center for Bits and Atoms 2012. The Fab Charter. [online] Available at: http://fab.cba.mit.edu/about/charter/ [Accessed 20 October 2012].

Chiu, C.-M., Hsu, M.-H. and Wang, E.T. 2006. Understanding knowledge sharing in virtual communities: an integration of social capital and social cognitive theories. Decision Support Systems, 42, pp. 1872 – 1888.

Davies, M. B. 2007. Doing a successful research project. New York: Palgrave Macmillan.

Dusollier, S. 2011. Scoping study on copyright and related rights and the public domain. [pdf] Geneva: WIPO (World Intellectual Property Organization). Available at: http://www.wipo.int/edocs/mdocs/mdocs/en/cdip_4/cdip_4_3_rev_study_inf_1.pdf [Accessed 17 January 2014].

Flick, U. 2009. An introduction to qualitative research. 4th ed. London: Sage.

Gershenfeld, N. 2012. How to make almost everything. Foreign Affairs, 91(6), pp. 43–57.

Gershenfeld, N. 2005. Fab. The coming revolution on your desktop. From personal computers to personal fabrication. Cambridge: Basic Books.

Ghani, S. R. 2009. Knowledge management: tools and techniques. Journal of Library & Information Technology, 29(6), pp. 33-38.

Gibson, C.B. and Cohen, S.G. eds. 2003. Virtual teams that work. Creating conditions for virtual team effectiveness. San Francisco: Jossey-Bass.

Harhoff, D., Henkel, J. and von Hippel, E. 2000. Profiting from voluntary information spillovers: how users benefit from freely revealing their innovations. MIT Sloan School of Management working paper no. 4125, Harvard.

Hess, C. 2008. Mapping new commons. In: The International Association for the Study of the Commons, 12th Biennial Conference of the International Association for the Study of the Commons. Cheltenham, UK. [online] Available at: http://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/304/Mapping_the_NewCommons.pdf [Accessed 14 July 2014].

Hess, C. and Ostrom, E. 2007a. Understanding knowledge as a commons. From theory to practice. Boston: MIT Press.

Hess, C. and Ostrom. E. 2007b. Introduction: An overview of the knowledge commons. In: C. Hess and E. Ostrom, eds. 2007. Understanding knowledge as a commons. Cambridge/London: MIT Press. pp. 3-26.

Holleman, T., Röllin, C., Spielhofer, T. and Wismer, A. 2013. Open knowledge sharing at the FabLab – Lucerne and beyond. Project dissertation. Lucerne University of Applied Sciences and Arts.

Kelty, C.M. 2001. Free software/free science. First Monday, 6(12), [online]. Available at: http://www.firstmonday.org/ojs/index.php/fm/article/view/902/811 [Accessed 23 December 2013].

Lerner, J. and Tirole, J. 2002. Some simple economics of open source. Journal of Industrial Economics, 50(2), pp. 197-234.

Määttä, A. and Troxler, P. 2010. Developing open & distributed tools for FabLab project documentation. [pdf] Available at: http://www.academia.edu/1964060/Developing_open_and_distributed_tools_for_Fablab_proproj_documentation [Accessed 23 December 2013].

McConnell, C. R., Brue, S. L. and Flynn, S. M. 2009. Economics: Principles, problems, and policies. 18th ed. Irwin: McGraw-Hill.

Menichinelli, M. 2013. Mappando la comunitá italiana di Makers e Fabbing. [online] Helsinki, Finland: Openp2pdesign. Available at: http://www.openp2pdesign.org/2013/social-network-analysis/mappando-la-comunita-italiana-di-makers-e-fabbing/ [Accessed 15 January 2013].

Mikhak, B., Lyon C., Gorton, T., Gershenfeld N., McEnnis C. and Taylor, J. 2002. FabLab: an alternate model of ICT for development. [online] Available at: http://cba.mit.edu/events/03.05.FabLab/FabLab-dyd02.pdf [Accessed 10 December 2012].

Miles, M.B. and Huberman, A.M. 1994. Qualitative data analysis. A source book of new methods. 2nd ed. Beverly Hills: Sage.

Nahapiet, J. and Ghostal, S. 1998. Social capital, intellectual capital, and the organizational advantage. The Academy of Management Review, 23(2), pp. 242-266.

Nonaka, I. and Takeuchi, H. 1995. The knowledge-creating company. How Japanese companies create the dynamics of innovation. New York: Oxford University Press.

O'Duinn, F. 2012. Tinkers: Maker culture for librarians. In: Information today. Computers in Libraries Conference 2012, 21-23 March 2012. Washington D.C.: United States.

Oldenburg, R. 1989. The great good place: cafes, coffee shops, community centers, beauty parlors, general stores, bars, hangouts, and how they get you through the day. New York: Paragon House.

Oldenburg, R. 2000. Celebrating the third place: Inspiring stories about the "great good places" at the heart of our communities. New York: Marlowe & Company.

Patton, M.Q. 1990. Qualitative evaluation and research methods. 2nd ed. Newbury Park, CA: Sage.

Polanyi, M. 1967. The tacit dimension. New York: Anchor Books.

Rangachari, P. 2009. Knowledge sharing networks in professional complex systems. Journal of Knowledge Management, 13(3), pp. 132-45.

Ratto, M. and Boler, M. 2014. DIY citizenship: critical making and social media. Cambridge, MA: MIT Press.

Reinish, L. 2013. Current campaigns. [online] Boston, MA: Free Software Foundation. Available at: http://www.fsf.org/campaigns/ [Accessed 10 April 2014].

Riege, A. 2005. Three-dozen knowledge-sharing barriers managers must consider. Journal of Knowledge Management, 9(3), pp. 18-35.

Rubin, H. J. and Rubin, I. S. 2012. Qualitative interviewing: The art of hearing data. Thousand Oaks, CA: Sage.

Sennett, R. 2008. The craftsman. New Haven and London: Yale University Press.

Sennett, R. 2012. Together. The rituals, pleasures and politics of

collaboration. London: Allen Lane.

Spaeth, S., Haefliger, S., von Krogh, G. and Renzl, B. 2008. Communal resources in open source software development. Information Research, 13(1), paper 332. [online] Available at: http://informationr.net/ir/13-1/paper332.html [Accessed 21 December 2013].

Stallman, R. M. 1985. The GNU Manifesto. Reprinted in: R. M. Stallman and J. Gay 2009. Free software, free society: Selected essays of Richard M. Stallman. 2nd ed. Paramount, CA: CreateSpace. pp. 33-41.

Troxler, P. and Wolf, P. 2010. Bending the rules: The Fab Lab innovation ecology. In: Continuous Innovation Network, the 11th International CINet Conference: Practicing innovation in times of discontinuity. Zürich, Switzerland, 5-7 September 2010. Overdinkel: Continuous Innovation Network.

Troxler, P. and Zijp, H. 2013. A next step towards fabml. A narrative for knowledge sharing use cases in Fab Labs. In: International Fab Lab Association, the 9th International Fab Lab Conference, Fab 9, Research Stream. Yokohama, Japan, 21-27 August 2013. [online] Available at: http://fablabinternational.org/system/resources/BAhbBlsHOgZmSSItMjAxNC8wNS8zMC8xNi8xNy81NC83NDIvVHJveGxlcl9aaWpwLnBkZgY6BkVU/Troxler%20Zijp.pdf. [Accessed 17 January 2013].

Verschraege, G. and Schiltz, M. 2007. Knowledge as a global public good: The role and importance of open access. Societies without borders, 2, pp. 157-174.

Wenger, E., White, N. and Smith J. D. 2009. Digital habitats: Stewarding technology for communities. Portland, OR: CPsquare.

Wolf, P. and Hilse, H. 2014. Wissen und Lernen. In: R. Wimmer, J. O. Meissner and P. Wolf, eds. 2014. Praktische Organisationswissenschaft. Lehrbuch für Studium und Beruf. 2nd ed. Heidelberg: Carl-Auer Verlag. pp. 167-191.

Yin, R. K. 2009. Case study research: Design and methods. 4th ed. Thousand Oaks, CA: Sage.

Zakaria, N., Amelinckx, A. and Wilemon, D. 2004. Working together apart? Building a knowledge-sharing culture for global virtual teams. Creativity and Innovation Management, 13(1), pp. 15–29.