Sharing is Sparing: Open Knowledge Sharing in Fab Labs

Patricia Wolf, Peter Troxler, Pierre-Yves Kocher, Julie Harboe, Urs Gaudenz[1]

The worldwide FabLab community is based on the idea of networking, cooperation and open source. The availability of high-tech prototyping machines for “everyone" is a cornerstone of FabLab. Since 2003 this vision has created meeting places for specialists and enthusiasts to engage with technology bottom-up. The 250 FabLabs provide access to digital tools and have the ambition to share digital fabrication blueprints as well as operating instructions for using the machines in the worldwide community.
However, insights from Open Software Communities suggest that it is notoriously difficult to activate collective action and knowledge sharing in virtual communities because this depends on members’ willingness to voluntarily share experiences and insights (see Spaeth et al., 2008; Rangachari, 2009). This raises the question to what extend this is also true for knowledge sharing within the FabLab Community.
To answer this question, we interviewed 16 people active in the worldwide FabLab Community. In these interviews we encountered 17 projects that we could define as knowledge sharing case studies. The case studies investigated how knowledge was shared, and what supportive and restraining conditions were. The paper particularly looks at four aspects: motivation, social interaction, technology and legal framework. Through this analysis we developed a model that explains whether and how knowledge is indeed shared globally in this community, and how the challenges in the above mentioned dimensions are experienced and dealt with.
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 next section analyses the findings through discussing them in terms of how the FabLab community deals with challenges in the four aspects and by developing a conceptual framework of open knowledge exchange in the FabLabs. The final section will conclude on the insights from this paper.

1 Knowledge sharing in the global FabLab community: A literature review

Digital maker communities are groups of “high-tech do-it-yourselfers, who are democratizing access to the modern means to make things” (Gershenfeld, 2012, p. 48). O’Duinn (2012, p. 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.
FabLabs (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 (Mikhaket al., 2002). FabLabs offer

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

open access to a range of low-cost fabricators and they are based on a commons-based peer production approach (Troxler and Wolf, 2010). In the recent version of their Charta (Fab Charter, 2012), the FabLabs 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 openly and globally is one of the core values and aims of the FabLabs.

Based on a literature review of 76 articles published between 1999 and 2008, Wang and Noe (2010, p. 117) defined the term knowledge sharing as follows: “knowledge sharing refers to the provision of task information and know-how to help others and to collaborate with others to solve problems, develop new ideas, or implement policies or procedures”. In FabLabs, the focus of such ambitions lies on “in situ” and online sharing instructions or tutorials on how to use the tools and machines for certain purposes as well as blueprints of the “things” created while working in the Lab. Thus, the Fab Charta (FabLab Community, 2012) lists “contributing to documentation and instruction” as one of the three most important responsibilities of FabLab users.

Literature on knowledge sharing in virtual and Open Software Communities however also suggests that there are several obstacles and barriers that make collective action and knowledge sharing notoriously difficult integrate. 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 et al. (2006) show that personal outcome expectations of members engender knowledge sharing in virtual communities. Moreover, for sharing efficiently, volunteers have to complete the usually difficult, sometimes mundane, and possibly arbitrary task of documenting what they have done (Barnes et al., 2013). This is particularly difficult in maker communities where users focus on materialisation, fabrication, and the interaction with the physical world of hardware (Troxler and Zijp, 2013).

Second, there are certain barriers regarding the the *social* aspect. Related to the motivational aspect, 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, p. 243). Strangers in groups decrease this motivation - Camera et al. (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. Another problem concerning the social aspect is that not all knowledge that community members wish to share is explicit knowledge and thus even more difficult to be shared virtually than face to face (Polany, 1967; Sennett, 2012).

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, despite time and geographical differences, also disparities in national, cultural and linguistic attributes have to be dealt with by technology (Zakaria et al., 2004). Suitable technology can help communities to share information and ideas in an efficient way (Wenger et al., 2009). Ghani (2009, p. 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. Recent discussions refer to the unprecedented access to knowledge online and at the same time to increasing intellectual property legislation, (over-)patenting, licensing, overpricing, and lack of preservation. Authors argue for understanding knowledge as a commons (Hess & Ostrom, 2006) and for open design (Abel et al., 2011) – a trend that is taken up by digital maker communities and changing not only furniture but more importantly how designers who cooperate online make a living. Open design applies the principles and the philosophy of the open-source movement to the development of physical objects, machines and systems (rather than software). FabLabs were created on the basis of open design (Määttä and Troxler, 2010): The idea behind the FabLabs is to generate new knowledge on making or (personal) manufacturing and to share it throughout the making process, to make it available to everyone within the whole community. Like this, knowledge would become a (quasi-)public good (McConnell et al., 2009).

It is highly probable that challenges to open knowledge sharing in virtual communities from these four aspects – motivational, social, technical and legal – also affect knowledge sharing in the global FabLab 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

To a study with an open, exploratory research question as the one this paper deals with, a qualitative research approach seemed to be the most appropriate. Qualitative research helps study complex phenomena on which there is currently no extant literature on previous research, empirical or theoretical, available (Davies, 2007).

2.1 Sample

According to Davies (2007, p. 143), the core sample of a qualitative study is the people who make up the "pivotal target group" and provide the essential insights in order to answer a project's research questions. The objective is to learn from the persons involved, contrast their views, and take into account the deeper situational context (ibid, p. 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 FabLab Community. Thus, the overall population to be explored are all FabLab users who use the facilities of FabLabs in their respective location. However, conducting interviews with all FabLab users is neither feasible - considering time and resource constraints - nor is it necessary. Patton (1990, p. 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.
In this study, ideal interviewees should have been involved in projects (cases) within the global FabLab community where knowledge sharing was applied extensively. More clearly, the minimum requirements to the criterion “extensive knowledge sharing” were that interviewees had to be part of project groups

a) that had successfully completed an open sharing project within the FabLab community that 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 FabLab users, and
c) where sufficient documentation on the process has been recorded.

Hence, The sampling strategy chosen to identify interviewees and interesting cases was extreme case sampling. Extreme case sampling refers to – purposive use of extreme or deviant cases as the sample for qualitative research (Flick, 2009, p. 122). In order to gain access to potential interviewees, the two managers of a local FabLab in Switzerland were contacted first. They indicated relevant cases and supported the establishment of contact to members of the world wide FabLab community who suited the requirements. These people were interviewed and asked to indicate at least one further person who was involved into the case(s) they talked about and who would be willing to give an additional 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).
Finally, 16 members of the FabLab community were selected for the interviews who talked about 17 different cases (see table 1 below).

Case Nr.	**Interviewee**		**Country of Residence**	**Case**	**Knowledge sharing** locally	globally
1	*A*	*Manager of FabLab I*	*The Netherlands*	*University course*	*yes*	*no*
2a	B	Concept developer at FabLab II	The Netherlands	Graduation project	yes	yes
2b	C	PhD student at University	United States of America	FabLab tutorials	yes	yes
3a	B	Concept developer at FabLab II	The Netherlands	Toys	yes	no
3b	D	Intern at FabLab 3	Spain	Video screen	yes	no
4	B	Concept developer at FabLab II	The Netherlands	Medical	yes	no
4	E	Backend developer at FabLab II	The Netherlands	Medical	yes	no
5	E	Backend developer at FabLab II	The Netherlands	Medical	yes	no
6	F	PhD student at FabLabs III and IV	Spain	Crockery	yes	yes
6	G:	Student assistant at FabLab IV	Spain	Crockery	yes	yes
7	G	Student assistant at FabLab IV	Spain	Furniture	yes	yes
7	H	Freelance designer	Norway	Furniture	yes	yes
8	H	Freelance designer	Norway	Fashion	yes	yes
9	H	Freelance designer	Norway	Medical	yes	yes

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

Table 1: Sample

As visible in table 1, not all cases completely matched our criteria (marked in grey):

- In the five cases (3a, 3b, 4, 5, 11), knowledge was shared only locally.
- In three of the cases (8, 15, 17), 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 (12a-c) report about people from established FabLabs travelling abroad to support the setting up of a FabLabs. These cases have a focus completely different an 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 (Prosthetics program and FabFi project) 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 used. This type of interviews allows gaining access to deep levels of individual experiences because it “stimulates reflection and exploration” (Davies, 2007, p. 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, pp. 5-6), in this case in processes of knowledge sharing in FabLab 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, p. 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, p. 114).

The interview guideline was build up based on the theoretical background and tested in a pre-test interview session. It consists of questions concerning several areas of interest regarding to the research question. The 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, p. 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 FabLab 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 FabLabs
	T 3: Legal aspect	• IP registration • Requirements/guidelines for FabLab • Difficulties (negligence)
Ending	Leading out	• Thanking for contribution • Suggestions for changes • Comments from interviewee

Table 2: Interview structure (adapted from Hollemann et al., 2013, p. 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, p. 108-109). After this phase, an open narrative question was asked so that the interviewee could describe in their own words what they believe led to the successful knowledge sharing throughout the course of a specific FabLab project they have been involved. Afterwards, the conversation was led towards detailed questions that are 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 comment. 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.

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 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, p. 156).

3 Findings

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

3.1 The FabLab environment

FabLabs and their global network formed the backdrop for this study. As the connectivity between FabLabs was explicitly addressed in this study, the individual definition of what a FabLab is and why respondents started to use FabLabs was often part of the narrative.

Interviewee J outlines exemplarily that *"the idea of the FabLab is that it is open to everybody. It's also a place for beginners to learn things. So the people that are in the FabLabs, or in the FabLab environment are very encouraged to teach people."* FabLabs 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 FabLab for my job, yeah, to materialize the ideas and concepts into something tangible."*

FabLabs 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 (…) ahm, are ready to share, their tools, software, maybe material, maybe ideas.“* Like this, collaborations often

among FabLab 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 FabLabs. 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 Sharing as moral principle and practical advantage

Sharing was often referred to as an underpinning, moral principle of Fab Labs, as alluded to in 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" (Fab Charter, 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"(Fab Charter, 2007). Interviewee G summarizes this moral principle in a moral verb as follows: *"Sharing is caring."*
Arguments for why sharing is desirable covered a wide range. 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 FabLab 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 practical 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, often"*, interviewee K concludes. In addition to the enlargement of the community working on a project, 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)

3.3 Documenting projects and sharing – or not

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 use 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 that 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)

3.4 …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 outrightly 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)

3.5 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 FabLab 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."*

3.6 FabLabs as a global network?

As the connectivity between FabLabs was initially addressed under the technological aspect, respondents discussed the technical means available in the FabLab 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 FabLabs (…) 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), and good means for connecting between labs: *"When I posted this on Facebook, through our own website, we suddenly got a lot of requests from FabLabs worldwide."* (interviewee N) But to really know other FabLabs 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 FabLab to know about another FabLab. 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 FabLabs 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 FabLab 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 FabLabs are very decentralized (…) and there are 2 or 3 people there who do something."* (interviewee M)

3.7 The legal and business environment

The legal and commercial side of sharing was addressed. Respondents often mentioned the principle 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)

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 participant 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)

However, respondents are 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 FabLab."* (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, uhm (…) 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) – while 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.

4 Discussion

This paper asked whether and how knowledge is shared globally in the FabLab community. It particularly aimed at studying the four aspects of open knowledge sharing in the FabLab community which we found predominant: motivation, social interaction, technology and legal framework.

In this section, we first align the findings above to the four aspects and shortly discuss them individually. We then relate our findings to a conceptual model that allows us to synthesise and reflect on open knowledge sharing in the FabLabs at a more abstract level. From this analysis, we draw preliminary conclusions on changes in conditions as a starting point for initiatives that would enable knowledge sharing in the FabLab community based on inclusiveness, transparency and exchange.

4.1 The four aspects

4.1.1 Motivational aspect

A cross-case analysis of interview data 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 (c.f. Harhoff et al., 2000; Lerner & Tirole, 2000; Edwards, 2001; 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.

4.1.2 Social aspect

The aspects of the social aspect that we found in our interview data support to the findings of the motivational aspect, and they show a slightly more varied picture. Again, in order of descending frequency, the social aspects that made the interviewees join the FabLab community 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
- Learn, teach and help others
- The satisfaction of making itself, often in collaboration or at least in contact with others
- The relation with other FabLabs 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. A possible explanation is certainly that there was no 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 'learn, teach and help' and 'making itself' mirror the second and third aspect of the motivational aspect. The relation with other FabLabs and the global network was only mentioned as a factor that was not instrumental for documenting and collaboration; this was already apparent from the findings reported above (section 3.6). However, one could argue that the FabLab network indirectly supports sharing, as sharing is an explicit value in the network (Fab Charter 2012) and the findings show that belonging to an 'open source culture' was influential.

4.1.3 Technical aspect

The technical aspect appeared to be discussed in much less detail in the interviews, as technology seemed in general 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
- 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, but how fun and cool or burdensome and boring a platform was to use, and more indirectly, how big an audience could be reached with a certain platform. Interestingly, the many of the platforms named – in particular Google Hangout, Facebook, Skype or Twitter – are platforms respondents probably not only use for sharing their FabLab projects but for many more kinds of (social) interaction, so they don't fall in the category of bespoke enterprise knowledge management systems that were the basis for Ghani's (2009) analysis.

4.1.4 Legal/business aspect

Regarding the legal aspect, 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

- 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 FabLabs – except that one from commercial projects with clients – was understood as commons as suggested by Hess and Ostrom (2006) and McConnell et al. (2009), and development processes as open design processes (Abel et al., 2011). At the same time, it seems as if 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.

4.1.5 Conclusions from the aspects

From the literature review, we assumed that challenges to open knowledge sharing in virtual communities in the above four aspects – motivational, social, technical and legal – would also affect knowledge sharing in the global FabLab community.

From our analysis, we can see that a lot of barriers that were mentioned in literature as challenges to open knowledge sharing in virtual communities do not exist or are no issue within the FabLab community. At the motivational aspect, challenges result not from a missing willingness to share knowledge and insights openly. If there is no client involved, the analysis shows that people hold a lot of – altruistically or hedonistically motivated – intentions to take the idea of open design seriously. This is reflected in the legal aspect where people 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 strangers as suggested by Camera et al. (2013). Moreover, despite that there is no common platform for sharing, we also did not come across huge technological barriers to sharing – on the contrary the FabLab users avoid problems like incompabilities of programs and infrastructure or with the accessibility of information that Gibson and Cohen (2003) suggested by using established technological solutions such as Skype, Thingyverse 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 et al., 2004) were not mentioned.

How does it then come that within the FabLab community, global open knowledge exchange is far from the norm? From the interviews, we identified a complex bundle of issues around documentation that make global knowledge sharing difficult and inefficient. As Barnes et al. (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 et al., 2013). In accordance to that, the respondents classified the task of documenting as difficult, time consuming and extra work, that is not fun. Consequently, and although they agree that knowledge developed should be treated as a public good (McConnell et al., 2009) and shared, FabLab users often do not find or take the time to document things 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 (Polany, 1967, Sennet 2012). The data reflect this, showing that in most cases when knowledge is shared globally, this happens with friends with whom the users have close(er) relationships and regular contact.

There might be a way out: As making things and having fun are two of the major motivations to participate in the FabLab movement, teaching users that documentation is part of the making process and providing them with easy to use and fun technology might be a possible solution.

4.2 A conceptual model of open knowledge sharing in FabLabs

A conceptual model should allow us to synthesise and reflect our findings on open knowledge sharing in the FabLabs at a more abstract level. We develop it based upon the Institutional Analysis and Development (IAD) framework proposed by Ostrom (2010). The IAD has been selected because it has the capacity to frame “institutional arrangements for governing common-pool resources (…) and public goods at multiple scales (…) to explain phenomena that do not fit in a dichotomous world of ‘the market’ and ‘the state’.” (Ostrom, 2010; p. 641) This framework requires defining and analysing

- biophysical conditions, attributes of the community and rules in use as external variables
- action situations, interactions, outcomes and evaluative criteria to describe what happens within the community (ibid, pp. 646-647).

The framework that would evolve from such an analysis of our data on open knowledge sharing in the FabLab community looks as displayed in figure 1.

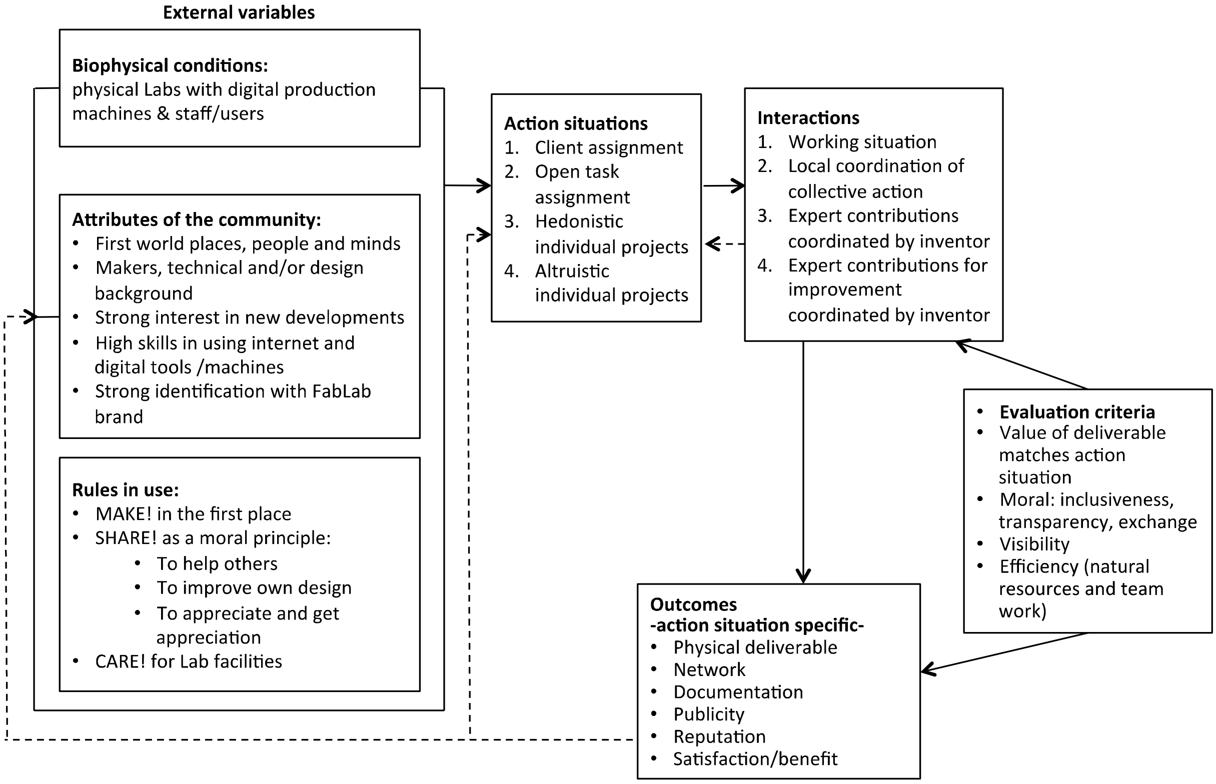

Figure 1: Conceptual model of open knowledge sharing in FabLabs (based on Ostrom, 2010; p. 646)

In terms of the biophysical conditions, the respondents of the study mentioned the FabLab environment consisting basically of (local) physical Labs with digital production machines, staff and users. Referring to attributes of the community, it should be mentioned that it is a community of makers coming from Western countries. They are mostly white and highly qualified in either a technical (rather hackers than engineers) or a design subject. Gender distribution in the community is quite balanced. FabLab users possess high skills in using internet and digital tools and machines and exhibit a high interest in new developments within these areas. They identify strongly with the FabLab brand. There are three dominant rules in use: First, making things is the primary objective for that time in the FabLabs should be used. Second, sharing is a moral principle for FabLab users. Sharing knowledge and experience enables to help others, to improve the own design and to appreciate and get appreciation. Third, it is important to take care of the Lab facilities so that they can be used further.

Action situations differ in their characteristics. From the data of the study, it was possible to distinguish four types of action situations. These are described in table 2 below:

Type	Characteristics
1) Client assignment	Client assignment predefines expected outcome, deadlines, milestones, and resources. Local team performs a job. Outcome belongs to client.
2) Open task assignment	Content wise unspecific assignment for a course or an event on which a self-selected global team with local core works. The local core is funded or works on the project as part of their class work, global contributors are not funded but like the idea. The local core is in need of a high quality outcome until the deadline. Creative Commons is applied to the outcome with a particular effort

	to mention everybody involved.
3) Hedonistic individual projects	A project developed locally by an inventor as a hobby, for fun or to try something out with the help of expert-friends and then uploaded and shared. There are no sanctions if project fails, it is not funded, and the outcome belongs to the inventor(s) who however do(es) not claim it but publishes it under an non-commercial Creative Commons licence.
4) Altruistic individual projects	A project that develops a solution to a specific need, the result is important as it benefits others (often an underprivileged group). An initial prototype is developed locally with the help of expert-friends and then improved in global use. Projects like this are often not funded, sequential, slow developments that take time. The inventor(s) explicitly state(s) that this is a community project and that IP rights will not be claimed at all.

Table 2: Action situations in the FabLab environment

Both interactions and outcomes are strongly intertwined with the action situation type. Interactions exhibit action-specific forms of team formation, leadership and coordination as well as application of communication and documentation mechanisms and means. Outcomes are always an action specific composition of the following components: deliverable (physical prototype), documentation, network, publicity, gain in reputation and satisfaction and/or benefit for a group of users. Table 3 below specifies action type related interactions and outcomes:

Action Type	Interactions	Outcomes
1) Client assignment	working situation: • formal team meetings • hierarchy: team manager pushes task accomplishment • making/working according to contract and deadlines as well as necessary documentation and reporting, • professional background is relevant for role in the team	• A set deliverable: a concrete product as ordered by client • Client satisfaction and benefit • Reputation/ reference by client • Relationship with client becomes stronger • Non-public report according to client demands • (Publicity)
2) Open task assignment	local core coordinates collective action: • stressful situation to the local core before the deadline due to uncertainty about quality and time of delivery by global contributors, • use of social networks for publicity of project, documentation and communication with global contributors • locally assigned project leader who pushes for task accomplishment until the deadline, most other members are self-selected • locally regular team meetings	• Any deliverable/ design (unspecified by assignment, self-selected) • Satisfaction and benefit for all contributors – the closer to the core the more • Network build up globally, around local core team • Reputation • Open accessible blueprint + instructions (text, photos and videos) how to make it • (Workshop to build it) • Publicity
3) Hedonistic individual projects	Expert contributions coordinated by inventor: • Inventor calls in experts with complementary knowledge for development of prototype • Expert contributions are coordinated by the inventor	• A set deliverable as defined for the individual project • Satisfaction and benefit for inventor and all contributors • Network build up around inventor • Increase in reputation of the inventor

	• Prototype is extensively brought to other places (travelling and uploading/posting), presented and improved • Instructions (text, photos and videos) about how to make it are developed as extra effort by inventor	and main contributors/ experts • Open accessible blueprint and instructions (text, photos and videos) published at common platforms (easy to find) • Publicity • Workshop to build it
4) Altruistic individual projects	Expert contributions for improvement coordinated by inventor: • Inventor calls in experts to solve a specific problem of an underprivileged group or societal issue • Local expertise-based team of contributions is coordinated by the inventor • Experts have meetings with the inventor, but seldom with the whole team due to time constraints (everybody works on the prototype as a hobby and for free) • Instructions (text, photos and videos) about how to make it are developed as extra effort by inventor • Protoype is produced and physically disseminated, visits: Users from the personal network are asked for contributions for further development • Sequential, never finished process	• A set deliverable as a contribution towards a design in progress • Limited-lot production of the design • Concrete benefit for a specific underprivileged group, satisfaction for inventor and contributors • Network starting around inventor, then spreading globally • Open accessible blueprint + instructions (text, photos and videos) published on specialized small websites • Publicity • Workshops to build and develop it further

Table 3: Interactions and outcomes related to action situation types

Evaluation criteria are used by the participants to evaluate the outcomes as satisfactory. In the study, the evaluation criteria identified relate back to the rules-in-use: The importance of sharing as a moral issue is mirrored in the evaluation criteria of inclusiveness, transparency and exchange as well as visibility of the process, person(s) involved and/or outcome(s). The dominant rule to make things necessitates as evaluation mechanism to check whether the value of the deliverable matches the action situation (client satisfaction/successful task assignment/fun/benefit for a specific underprivileged group). Finally, the importance of taking care of Lab facilities is evaluated in terms of efficiency in the use of natural resources and team work as well as of public appreciation of contributions.

The framework provides insights that go beyond the above analysis of challenges in the four aspects. It shows that these challenges emerge from the external variables of the FabLab community and that the challenges in the different aspects are interrelated. This confirms and extends the general finding of extant studies on knowledge sharing in virtual communities that suggest that the specific characteristics of virtual communities impact the motivation of members to share knowledge as well as the design of knowledge sharing processes (Dube, 2006; Wolf, Christen and Meissner, 2009). The biophysical conditions, attributes and rules-in-use pave the way for particular evaluation criteria and action situations that then have an impact on the interactions and outcomes from the activity situations. For example, the importance of making things in a maker community with the available machines in the local labs limits the motivations to document, leads to a primacy of local knowledge sharing in the social aspect, a lack of easy-to-use technological solutions for documenting and a certain unawareness or unimportance of legal protection of the results.

5 Conclusions

This paper presents the findings of a study aimed at understanding the FabLab community in sharing, transferring and transforming knowledge across national, cultural, professional and language boundaries. From the analysis of 17 knowledge sharing cases in the worldwide FabLab Community, the authors studied how the FabLab members experience and deal with motivational, social, technical and legal challenges to global open knowledge sharing. It furthermore developed a framework that explains why, whether and how knowledge is indeed shared globally in this community.

The analysis shows that in practice, the potential of sharing knowledge through collaboration between the global FabLabs is far from exhausted. FabLab users are very much locked into a world focused upon developing physical "things" by the use of digital fabrication devices in local labs. That they are actually involved in a unique process of sharing of knowledge which can be expanded is less in the focus of their activities.

This is a surprise because the rules-in-use explicitly include sharing, and the analysis of motivational barriers to open knowledge sharing revealed that FabLab users understand sharing as a moral principle. However, unlike making and caring for FabLab facilities, sharing often remains on local level or in the exclusive circle of experts who already know each other. Sharing does not suffer from motivational barriers but from the fact that documentation – as a precondition to sharing – is not seen as part of the making process but rather as a way to present results. Presenting results, however, is probably more than just showing off one's own achievements, but could also be understood as an attempt to motivate others, particularly from outside the community, to become part of a movement that is perceived to be 'new' and 'cool'.

It has already been mentioned that the rapid growth of the FabLab community must be seen an obstacle for a sustainable development of and reflection on of the inherent qualities of the Labs. The FabLabs have a lot in common, but they cannot be defined as traditional institutions, rather they are founded on a unique mix between educational and communal content next to interacting both with commercial and informal, private interests. Because of its high profile as open and non-hierarchical it is often overlooked that the FabLabs deal with science and technology and thus a central part of the educational system, which is having serious recruiting problems. Part of the FabLabs challenge of establishing sustainable interaction between the labs could be attributed to the problems of communicating high tech practice, as the cases also indicates. At the same time the FabLabs seem to reflect a practice of collaboration, engagement approach to communication, which, if it is handled in the right way could inspire the general understanding of how to practice science as an involving process rather than passive reproduction of knowledge.

Garíca-Peñalvo, Garíca de Figuerola and Merlo (2010) describe that in open software communities, open knowledge sharing is based upon open access to the software code. When developing code, the open software community documents while working on the open source code in open innovation processes. This is different from making physical objects where the documentation is not inseparably linked with the development process of a design. So although FabLabs exhibit attempts to share their knowledge opens source and in open innovation processes, the other two characteristics that characterize open access in open software development, namely open contents in education and open science, are missing to some extend (Garíca-Peñalvo et al., 2010, p. 524-526).

Moreover the fact that the sharing and dialogue is already happening across the “conventional” social networks should be an indication for the FabLabs that a virtual or “transportable” dialogue happening in the community. It is “just” a question of understanding how this informal communication among peers can become part of a conscious building of a community and support the expansion of qualities of sharing. It seems that this is also a part of a challenge to re-conquer more space and time for knowledge production.

6 Acknowledgements

This paper presents findings from the project “Open knowledge sharing in the FabLab (OKSIF)” that is part of the research program of the Creative Living Lab at Lucerne University of Applied Sciences and Arts. The authors thank the ITZ Innovationstransfer Zentralschweiz for funding this project as well as Cornelia Wüthrich, Martina Smoljo, Roman Jurt and Marcel Bieri for their collaboration in the OKSIF project. Furthermore, the authors wish to express their gratefulness to Laura Guggiari, Tim Holleman, Christian Röllin, Thomas Spielhofer, André Wismer, Kevin Barnes and Thomas Märki who collected the interview data as part of their project dissertation and inspired the paper very much through their data analysis and conclusion.

7 References

Abel, B. v., Evers, L., Klaassen, R. and Troxler, P. (eds.) (2011). Open Design Now. Why Design Cannot Remain Exclusive. Amsterdam: BIS publishers.

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

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.

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.

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

Dubé, A., Bourhis, A. & Jacob, R. (2006). Towards a Typology of Virtual Communities of Practice. Interdisciplinary Journal of Information, Knowledge, and Management, Volume 1, pp. 69–93.

Edwards, K. (2001), “Epistemic Communities, Situated Learning and Open Source Software Development”, working paper,.

Fab Charter (2007). The Fab Charter. Draft. Retrieved June 15, 2011, from http://fab.cba.mit.edu/about/charter/ (now superseded by Fab Charter 2012; saved version of the 2007 text retrieved December 10, 2013, from http://wiki.fablab.is/wiki/Fab_Charter)

Fab Charter (October 20, 2012). The Fab Charter. Draft. Retrieved December 10, 2013, from http://fab.cba.mit.edu/about/charter/.

Flick, U. (2009). An introduction to qualitative research (4th edn.). London: Sage.

Garíca-Peñalvo, F. J., Garíca de Figuerola, C., & Merlo, J. A. (2010). Open knowledge: Challenges and facts. Online Information Review, 34(4), pp. 520-539.

Gershenfeld, N., (2005). Fab. The Coming Revolution on Your Desktop. From Personal Computers to Personal Fabrication. Cambridge: Basic Books.

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

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., von Hippel, E. (2000), "Profiting from Voluntary Information Spillovers: How Users Benefit from Freely Revealing Their Innovations", MIT Sloan School of Management WP #4125.

Hess, C. & Ostrom, E. (2006). Understanding knowledge as a commons. From theory to practice. Boston: MIT Press.

Holleman, T., Röllin, C., Spielhofer, T., and Wismer, A. (2013). Open Knowledge Sharing at the FabLab – Lucerne and Beyond. Project dissertation. Lucerne: Lucerne University of Applied Sciences and Arts.

Kelty, C.M. (2001), "Free Software/Free Science", First Monday, Vol. 6, No. 12 (December 2001), Retrieved December 23, 2013, from http://www.firstmonday.org/ojs/index.php/fm/article/view/902/811

Kvale, S. (2007). Doing interviews. London: Sage.

Lerner, J., Tirole, J. (2000), "The Simple Economics of Open Source", mimeo, 53p.

Lincoln, Y., & Guba, E. (1985). Naturalistic inquiry. New York: Sage.

Määttä, A. and Troxler, P. (2010). Developing open & distributed tools for FabLab project documentation. Retrieved December 23, 2013, from http://www.academia.edu/1964060/Developing_open_and_distributed_tools_for_Fablab_project_documentation

McConnell, C. R., Brue, S. L., & Flynn, S. M. (2009). Economics: Principles, problems, and policies. McGraw-Hill Irwin.

Mikhak, B., Lyon C., Gorton, T., Gershenfeld N., McEnnis C., & Taylor, J. (2002). FabLab: an alternate model of ICT for development. Retrieved December 10, 2012, from http://cba.mit.edu/events/03.05.FabLab/FabLab-dyd02.pdf.

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

O'Duinn, F. (2012). Tinkers: Maker culture for Librarians. Paper presented at the Computers in Libraries Conference in Washington D.C., United States.

Ostrom, E. (2010). Beyond markets and states: Polycentric governance of complex economic systems. American Economic Review, 100, pp. 641-672.

Polanyi, Michael (1967). The Tacit Dimension, New York: Anchor Books.

Sennett, Richard (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

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

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

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

Troxler, P. and Wolf, P. (2010). Bending the rules: The Fab Lab Innovation Ecology. In Continuous Innovation Network (Eds.): Practicing innovation in times of discontinuity. Proceedings of the 11th International CINet Conference. 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. Paper presented at the 9th International Fab Lab Conference, Fab 9, Yokohama.

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

Wolf, P., Jakob, M. C., & Meissner, J. (2009). Why sharing boundary crossing? Understanding the motivation for knowledge sharing in virtual Communities of Practice. In Collaborative Innovation: Emerging Technologies, Environments and Communities. Proceedings of the 15th International Conference on Concurrent Enterprising.

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.