Fab Lab Research Papers. From Experiment to Expression

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Abstract

Starting with a quick and dirty trial at Fab8 in Wellington, New Zeeland, the Fab Lab community has produced a considerable body of research over the past seven years. Together with colleagues Betty Barrett, Tomas Diez and Cindy Kohtala I've been carefully developing this endeavour to collect and present research that has been done at FabLabs, with FabLabs, through FabLabs, and for FabLabs.

In this paper I recount how the research papers stream developed, I track the topics and how they evolved over time, I present some of my personal highlights, and I try to relate them to the themes of the Third Digital Revolution.

Keywords

Research, fab lab, digital revolution.

1 Background

When I started my PhD in 1993 I had just completed a € 1.3 million project hooking up an industrial robot to a CNC lathe at a Swiss subsidiary of GEC Alsthom and I was about to start a similar, almost €2 million project that would involve a larger robot and a CNC milling machine. I was fluent in projecting the return on investment of such automation projects. I also had learnt, for my master's degree, that designing industrial systems should be approached from a socio-technical perspective {reference}. And while I had the tools to technically and financially assess and evaluate a design, I did not have the tools assess the social or human aspects of a design.

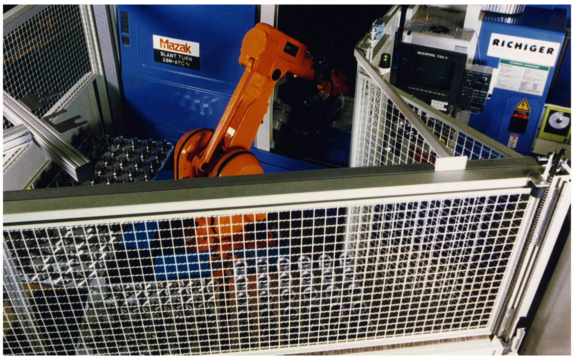

Figure 1: From robot and CNC lathe to FabLab Zurich

The psychologists' socio-technical instruments were good for studying existing, already built and operating industrial systems, and that is how they were used: to fix problems that had been introduced at the design stage. Psychology operated as a "repair science", not a design science. In my PhD, I wanted to change that (Peter Troxler, 1999) – and it has been my endeavour ever since to design systems which are inhabitable, liveable for humans.

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For doing my PhD I left GEC Alsthom – all the interesting projects were done, and I was not particularly keen on a corporate career. I worked in consultancy, academia and the arts – particularly the community-based, critical, and social practices – before coming back to manufacturing. Yet that was in a completely different kind of manufacturing thank I was used to: I was made the project manager of FabLab Amsterdam at Waag with the assignment to turn it from a one-year project into a lasting something (barely eschewing the term "institution" as I write that down).

As someone who had, industrially, grown up with Dubbel (1983), the FabLab situation with its "ready, fire, aim" attitude was quite a surprise – but for my arts background it wasn't. And even industrially, "just in time" had become the mantra in logistics supposed to replace an outdated "just in case" mentality (Ohno & Mito, 1988). I enjoyed the systems-breaking contraptions (as illustrated in Zydac's "Duplo Brick"). Combining that with the human liveable systems endeavour it was for me love at first sight with FabLab as a self-inflicted social experiment (P. Troxler, 2015, p. 75). Becoming a FabLab entrepreneur after two years at Waag I started to set up FabLabs as an occupation which would not last for as I truly do not have the stamina to go through the setting up a FabLab process more than three times.

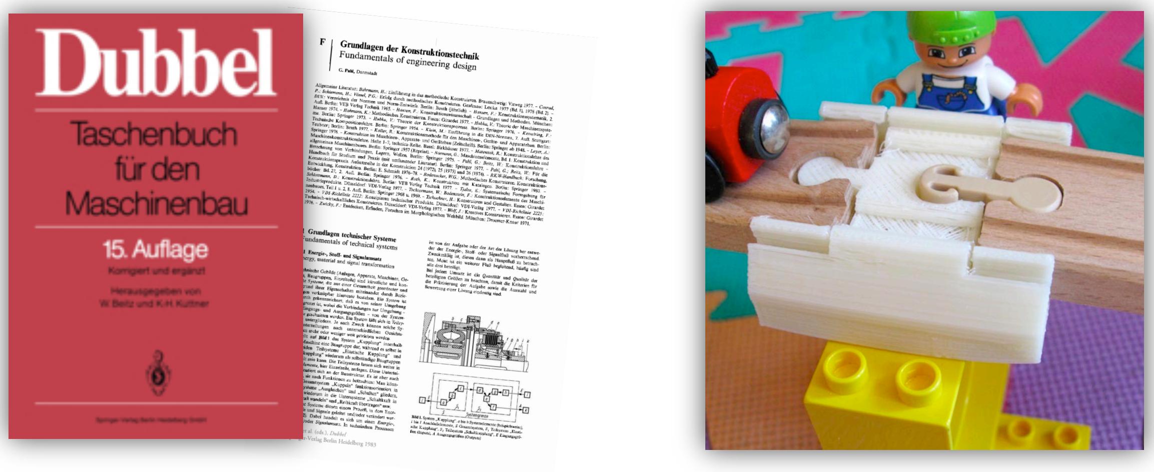

Figure 2: From Dubbel (1983) to Duplo Brick by Zydac (2010)

Still I pride myself of setting up the first FabLab in Switzerland, thanks to visionary professor Simone Schweikert who saw the potential of a FabLab long before most of her colleagues. And I was the business model architect for FabLab Zurich that never asked for subsidies, started in 2011 and opened in 2012 with twelve businessmen (literally) putting their own time and money on the line to establish a lab that still runs profitably. Starting the FabLab at Rotterdam University of Applied Sciences, also in 2011, eventually landed me a job as a research professor as of 2012. The same year, 2012, we started to think – no: act – on FabLab research papers.

2 The streams at the Fab conferences

The idea of facilitating research that happens in, through and on FabLabs at the annual FabLab workshop and symposium emerged somewhere in late spring 2012 – way too late to actually facilitate a proper call for papers with double blind reviewing of abstracts and full papers. So, we set out for a "just in time" experience, having four papers which we discussed in a small group of collocated and online participants. I remember myself clinging to the MCU for what felt like an infinite time trying to follow discussions in Wellington at 6am in the morning as I was due to report on a high-level ICT project with a major logistics company in Switzerland later that day.

Fab9 in Yokohama was the first time FabLab papers were properly established, and there was an impressive amount of FabLab research. The contributions and their breadth of scope pretty much established the breadth of the FabLab research papers stream: Technical? Yes. Empirical? Yes. Ethnographic? Yes. Conceptual? Yes. Speculative? Yes. Completed research? Yes. First draft? Yes. We had a packed session at the Fab Lounge, with probably way too many presentations shoehorned into a timeslot of just three hours. The papers covered studies on how FabLabs develop in different regions, FabLabs and education, open source approaches, various projects, and social fabrication.

Next on was Fab10 in Barcelona. By any means this was the conference that attracted the most interest in the research papers stream with 135 submissions. About one third of the papers were invited for presentation, and another twenty were presented as posters; papers were divided along the themes of the main conference, digital fabrication, productive cities, and emergent communities.

Fab11, Fab12 and Fab13 were smaller in volume, but not less interesting, important and diverse in content.

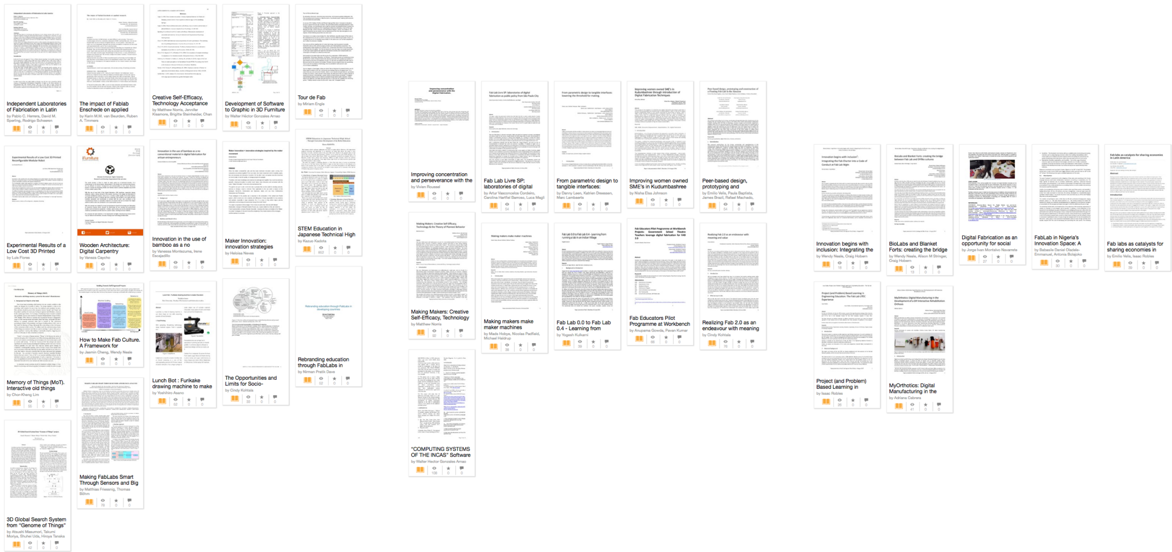

Figure 3: Papers at Fab11, Fab12, Fab13

Across the 7 past Fab conferences, there were four main areas of interest which the papers covered. These were education, technical projects, analyses of local, national and regional FabLab networks, and the social aspects of digital fabrication. Occasionally, other topics emerged, such as architecture, open source and the sharing economy (see table 1).

Table 1: Topics covered at the Fab conferences

Fab8$_{2012}$	**Fab9**$_{2013}$	**Fab10**$_{2014}$	**Fab11**$_{2015}$	**Fab12**$_{2016}$	**Fab13**$_{2017}$	**Fab14**$_{2018}$
	social facrication	emergent communi-tities	fab culture		code of conduct	fab and economy
satellite labs	regions	productive cities	regions	India	Nigeria	developing countries
open source 3D printer	projects	digital fabrication	technical	design, machines	health, bio	projects
Lab in education	education		education	educators	education	education
archi-tecture	*open source*		*archi-tecture*		*sharing economy*	

3 Highlights

In the following, I'd like to highlight some of the papers we have seen in the past Fab conferences. With a very few exceptions they are all available through the website of http://fablabinternational.org

3.1 Education

Lassiter and colleagues (2013) were looking at the increasing demand in the USA for digital fabrication in the classroom as a consequence of an increasing focus on STEM education. In the context of the "Teaching Institute for Excellence in STEM (TIES)" and drawing from a few examples, they proposed a framework of seven categories of knowledge educators would need to master. These categories were (p. 3):

- Four technical categories: Digital design and fabrication techniques, engineering fundamentals, application of the design process, and project design and management;
- Two educational categories: Strategies to align student learning to benchmarks and to leverage standards for assessment, and partnership and asset building and alignment;
- An overarching category they called "The BIG Picture": The larger context of digital fabrication in the making, tinkering, and fabbing communities as well as the interests of industry and national economy.

In that paper, Lassiter and colleagues laid the conceptual foundation for the development of educational resources in the FabLab network in programmes such as FabEd and more recently SCOPES-DF.

Two empirical, survey-based studies from FabLab Tulsa were investigating the effect of working in a lab on perceived self-efficacy of people. Dubriwny et al. (2014) studied 156 youth aged 8 to 15. They looked at how confident the participants felt with technology and engineering (efficacy), the attitude towards technology and engineering, both before and after spending time on a project at the lab (4 or 12 weeks). They measured the impact of the lab on the participants' perception of technology and engineering, the skills learnt, and children's hope in terms of pathways and agencies. They found that particularly efficacy increased significantly. Significantly correlated with increased efficacy were a positive change in attitude, the impact of the lab and the skills learnt. Also, hope was significantly correlated with efficacy and attitude change, impact and skills.

Norris (2016) was testing the hypothesis that perceived behavioural control, creative self-efficacy and the usefulness of making technology would increase the intention to return to make. In total, 96 surveys were collected from adults aged 30 to 49, 81 % male. The study found a strong correlation between perceived behavioural control and intention to return to make but could not confirm the other correlations. Based on the data, Norris suggests that social interactions and creative behaviour (creative role identity, openness to experience and creative self-efficacy) are antecedents to perceived behavioural control. He suggests specific actions that labs could take to influence these variables, e.g. highlighting member projects, recognizing creativity, offering and encouraging cross training om machines and software and positioning the lab as a hub of various activities and interests.

3.2 Technology

Regularly we received and accepted technical presentations on many aspects of digital fabrication – CAD (Gonzales Arnao, 2014), self-assembling materials (Akiyoshi, 2014; Mitsui & Tanaka, 2014), new machines (Asano, 2015; Hoybe, Padfield, & Haldrup, 2016). Here I would like to highlight two projects that both in their own right made a technical contribution to their respective community.

The first project is GitFab, a system to share and fork "daily notes" about how to make things. The original concept of GitFab was presented in Yokohama (Akatsuka & Tanaka, 2013). The authors went on and implemented a working prototype of the system (Akatsuka, 2014; Tanaka et al., 2014). Although the system has now been retired, this was one of the early and at the time most promising attempt at proposing a system for sharing documentation.

Figure 3: GitFab (Akatsuka & Tanaka, 2013) and egg incubator (Kulkarni & Gadhe, 2013)

The second project is the solar egg incubator developed and presented by Kulkarni and Gahde (2013) in India. Over a period of three years, the students at the FabLab at Vigyan Ashram in Pabal developed, built and tested an egg incubator with a capacity of up to 1.000 eggs that was cheaper than equivalent products on the market and consumed less energy. Gahde went on to start Future Innovative Systems in Pune, India, where he manufactures egg incubators of various sizes.

3.3 Labs and Local Culture

FabLabs have proven to connect to local cultures on various occasions. The egg incubator is just one example coming out of Vigyan Ashram. Kulkarni (2016) described the journey of this very first FabLab from its inception in 2002, its educational activities and its projects – both completed and unfinished, and he detailed which equipment was most useful in which applications in the local context. He concludes that a FabLab is a setup to overcome the weaknesses of appropriate technologies in rural regions – such as inferior technology, skills and workmanship required and the low replicability of solutions. Humbly, after 13 years of existence and at a moment when the FabLab community was gearing up to Fab 2.0 (the topic of the Shenzhen Fab12 conference), he titled his contribution “Fab Lab 0.0 to Fab Lab 0.4”.

Two other projects appear worth mentioning. The first is the Ethioplug-in developed by Bedala (2014), a library of parametric architectural 2D and 3D models based on traditional Ethiopian architecture, furniture and ornaments that allows architects and designers to integrate those traditional elements into their actual work.

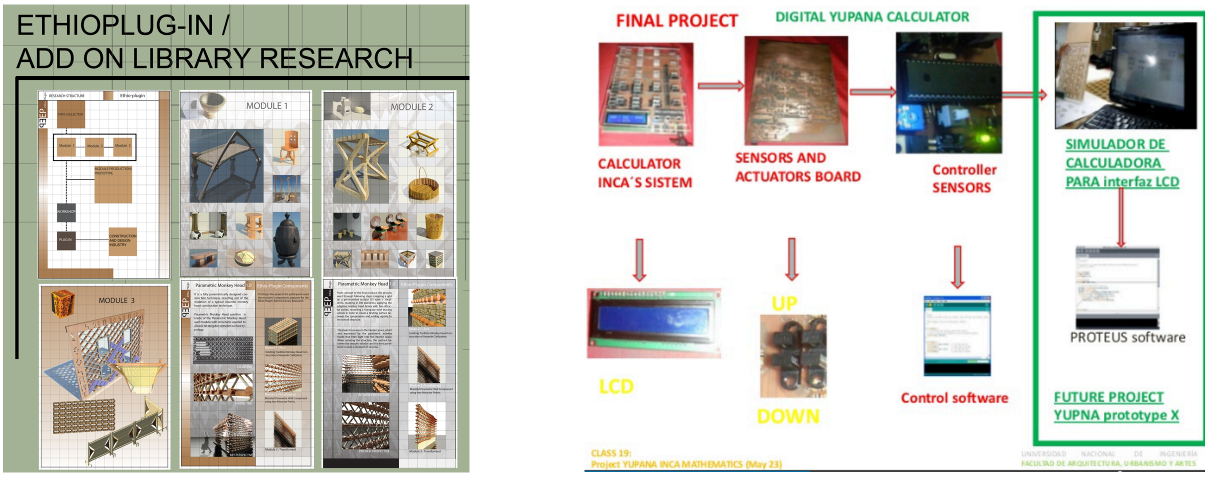

Figure 4: Ethioplug-in (Bedada, 2014) and digital Yupana (Gonzales Arnao, 2016)

The second project I’d like to mention was on the computing systems of the Incas. Gonzales Arnao (2016) studied the ancient Inca calculating tablet, the Yupana, and recreated it as a digital software and hardware system with the purpose to teach math to primary school children while at the same time reconnecting education to traditional Andean culture and counteract or at least balance dominant Western influence in education.

3.4 Country and region profiles

Regular contributions to the FabLab research papers were studying the state of development and role of FabLabs in countries – such as Japan (Krebs, 2013), Russia (Smith, 2013), Ghana and Kenya (Waldman-Brown, Obeng, Adu-Gyamfi, Langevin, & Adam, 2013), Nigeria (Oladele-Emmanuel, Bolajoko Akinola, & Redlich, 2017), Egypt (El-Zanfaly, 2014) – and regions: Latin America (Herrera & Juárez, 2013; Herrera, Sperling, & Scheeren, 2015; Velis & Robles, 2017) and Europe (Engle, 2015).

These papers were of course all just a snapshot of the "state of Fab" at one given moment in time in one place on the planet. They describe the particular struggles and successes of the growing FabLab phenomenon across the world and provide a glimpse of the variety of its manifestation in different socio-economic contexts. The three papers on Latin America are particularly interesting as they follow the development of the Fab Lab network in the region.

3.5 Looking at Labs Differently

In 2013, I postulated that "[r]esearch will have to be participative, not purely observational" that "a multiplicity of views are important" and I was calling for "research action" (Troxler, 2013, p. 193). The FabLab research papers regularly contributed to this endeavour when social researchers visited labs and contributed through a rather interpretative than engineering way to make sense of what FabLabs are about.

Bosqué (2013) introduced this type of research to the community in Yokohama when she started looking at "[t]he high/low tech forms that are created in collective Labs" (p. 7) from an anthropologist's perspective interested in learning about the social and political relations, which she would later develop into a PhD thesis (Bosqué, 2016). Neves (2015) was particularly searching for innovation strategies in FabLabs that are based around "making" rather than "thinking" only and involve collaboration, agility and low cost prototyping – the concept of "maker innovation" she developed in her PhD thesis (Neves, 2014). Kohtala (2015) showed an interest in the socio-environmental sustainability in FabLabs.

3.6 Fab Culture

Expanding on her research on sustainability, Kohtala (2016) shared her observations on "ideology" in FabLabs and how It materially could be seen in the artefacts – but also how ideology in a FabLab was dependent on the lab's situatedness. She underlined the necessity that FabLab founders needed consciously and explicitly to address the question "what is this Fab Lab for?" (p. 8) so they were able to explicate the strategic direction of e.g. empowerment: why, how, and who.

Cheng and Neale (2015) directly addressed this question of "Fab Culture" when they analysed collaborative learning during Fab Academy 2015 at the lab in Wellington. They analysed the role of global instructors, local instructors and students in (respectively) establishing trust, creating bonds and developing reciprocity as learning activity moves from controlled assignments to self-organized projects.

Neale and Hobern (2017) expanded on this analysis and offered their answer to Kohtala's (2016) questions when they described how Fab Lab Wgtn interpreted the Fab Charter in a meaningful way by developing a local Code of Conduct using decolonizing methodologies. This allowed them to create "human engagement and multi-disciplinary learning within an ostensibly 'machine focused' space" (p. 4) where "innovation begins with inclusion" (p. 1) and participation was based on being welcoming, considerate, respectful, careful in the words that one chose, and on understanding why one disagreed ("Code of Conduct," n.d.).

Indeed, already at Fab9 in Yokohama, Aizu and Kumon (2013) argued rather than digital or personal fabrication the term "social fabrication" was more appropriate. They based their argument on the concept of InfoSocionomics that postulates that the third industrial revolution coincides with the first information revolution, the former creating new industries, the latter creating new lifestyles (p. 9). Thus, they argue, that "the social dimension of 'universal fabrication' will become the main source of the next major change for our society as a whole" (p. 14).

4 Themes of the third digital revolution

The Fab Lab research papers have covered a wide range of topics and came from a diversity of fields of academic studies. Kohtala (2017) developed a “research mindmap” identifying the most prominent areas and typical journals where corresponding research on FabLabs and on other “materialist grass roots activism and DIY makers” has been published (see Figure 4). As of now, the FabLab research papers stream were the only places where transdisciplinary encounters were systematically curated and taking place.

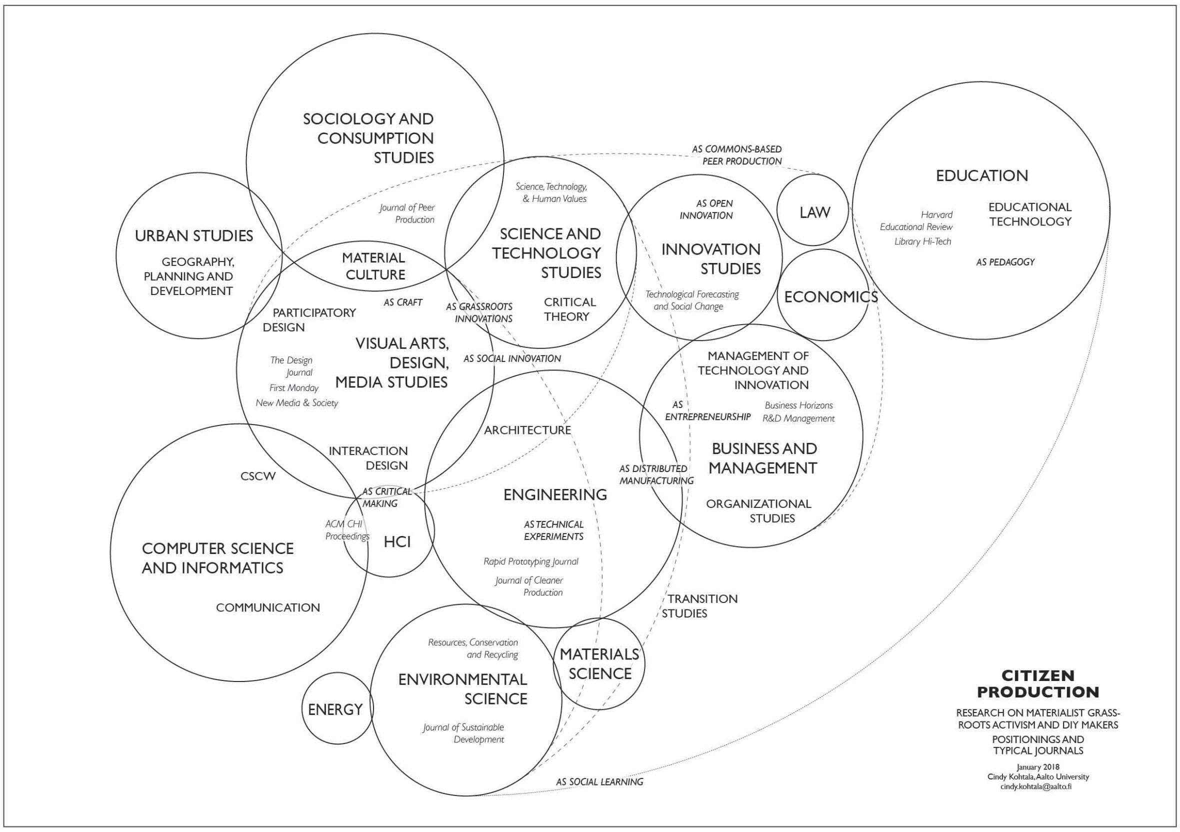

Figure 4: Mindmap of research on citizen production (Kohtala, 2017)

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