FAU FabLab: A Fabrication Laboratory for Scientists, Students, Entrepreneurs and the Curious

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We have only named currently active founding members. As of August 2017, 50 volunteers have been supervisors at the FAU FabLab.

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***Abstract*—Creative thinking and interdisciplinary collaboration is encouraged within academic institutions, but often inhibited by resource availability and distribution, as well as interfaces and opportunity for exchange. We—students of the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)—set out to improve this by creating a common open prototyping workspace for researchers, students, staff from all fields and schools as well as unaffiliated entrepreneurs, inventors and the generally curious. In this technical report, we present the origin of the *Fabrication Laboratory* (FabLab) concept and its realization as the *FAU FabLab* [1] in Erlangen.**

I. INTRODUCTION

"FabLabs are a global network of local labs, enabling invention by providing access to tools for digital fabrication" [2]. The concept originates from the Center for Bits and Atoms at the Massachusetts Institute of Technology (MIT), but has spread since 2001 to a global community of over 1,000 FabLabs [3] on all five continents. In "FabLab: Of Machines, Makers and Inventors", Julia Walter-Herrmann and Corinne Büching write: "FabLabs are neither chambers of magic nor mere accumulations of 3D printers and other fabrication devices. FabLabs are places where digital culture and material production merge and enter a new stage" and conclude with "In this sense, FabLabs are globally connected, open workshops, where people can meet, collaborate, interact and exchange ideas, machines, tools, materials and software with the common purpose of making distinctive and digitally designed objects (from scratch) in an easy accessible and cheap way." [4, p. 11f.].

In 2011, a group of students from the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) founded the FAU FabLab, providing access for students to modern computerized machines typically found in prototyping workshops. Such machines were already present at one workshop or another, spread throughout FAU's engineering and natural science faculties, but none were directly available to students. Most often the equipment was not even available to researchers from other groups, departments or fields. In addition to unavailability, direct access was prohibited, as the machines were made available only through work orders, executed by a small number of people. It quickly became clear that not only students, but also research staff faced similar problems. In addition to pure access to manufacturing capabilities, segregation of manufacturing facilities also underpinned the already existing divide between fields. We set out to change this, by creating an open Fabrication Laboratory for all interested parties (students, staff, researchers, even the general public) of all fields with state-of-the-art machines, electrical and mechanical tools. This sparked the formation of a community to utilize and support these new facilities, creation of peer based learning environment and fuels the spirit of interdisciplinary thinking and collaboration across academic fields, professions and age groups.

In Section II, we will go into the concept and origin of FabLabs and their underlying Fab Charter. Section III will cover the translation and implementation of the concept in the context of our university, as well as example use cases that we have seen in science, and the collaboration efforts in support of classes. In Section IV we will shortly describe similar and closely related initiatives, and conclude with an outlook on the potential future of the FAU FabLab in Section V.

II. Concept

The basic idea of a FabLab dates back to 2001, initiated by Neil Gershenfeld with his "How To Make (Almost) Anything" class at MIT [5]. It gave students access to a prototyping-style workshop for any project they could come up with, allowing them to quickly go from conceptual designs to real-world prototypes on many scales (from nanometer-scale electronics to meter-scale wood or metal constructions). This was made possible by the computerization of the fabrication process, enabling quick development cycles and bringing in "design for manufacturing", i.e., designing for manufacturability, from the start. These development processes are only possible, because in a FabLab the user is designer, manufacturer and (often) end-user at the same time, having an in-depth holistic view of the complete product development and life cycle.

Since then, the concept has been polished, focused and formalized by a global community of FabLabs in the *Fab Charter*. This community currently spans 106 countries [3], is supported by the Fab Foundation [6] and other organizations and consists of hundreds of FabLabs around the world. In addition to the Fab Charter, a list of recommended tools, machines and components is provided in order to standardize procedures and capabilities among all FabLabs [7]. This standardization sets a low-threshold for collaboration with and building upon projects from other FabLabs. The standardization is also the basis for the standardized curriculum in the FabAcademy, a global lecture, taught by Prof. Gershenfeld in collaboration with local FabLabs [8].

A. The Fab Charter

The Fab Charter is a written guideline that defines and provides the ground-rules for all workshops considering themselves a FabLab:

What is a FabLab?
: FabLabs are a global network of local labs, enabling invention by providing access to tools for digital fabrication.

What's in a FabLab?
: FabLabs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared.

What does the FabLab network provide?
: Operational, educational, technical, financial, and logistical assistance beyond what's available within one lab.

Who can use a FabLab?
: FabLabs are available as a community resource, offering open access for individuals as well as scheduled access for programs.

What are your responsibilities?
: safety: not hurting people or machines
: operations: assisting with cleaning, maintaining, and improving the lab
: knowledge: contributing to documentation and instruction

Who owns FabLab inventions?
: Designs and processes developed in FabLabs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from.

How can businesses use a FabLab?
: Commercial activities can be prototyped and incubated in a FabLab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success.

(draft: October 20, 2012) [2].

III. Implementation at the FAU

The Fab Charter does not dictate an organizational structure and therefore each FabLab employs a different approach. At the FAU FabLab, we are community-driven and all major decisions are taken in our general assembly in a democratic fashion, allowing newcomers to quickly engage in this grass-roots process, which goes beyond the "What is a FabLab?" in the Fab Charter, see Section II-A.

Anyone may request to become a supervisor, when they show sufficient knowledge and experience with the machines and processes (technical, organizational and social) and pledge to regularly volunteer for the FabLab. Volunteering is typically done on a weekly basis, with a minimum of two hours. This request may be postponed by any supervisor at the general assembly. Supervisor status is granted only for the duration of a semester and may be renewed with a new commitment to volunteer.

Once a supervisor, 24/7 access to the FabLab is given as a compensation but also as a responsibility of the supervisors to allow others to make use of the lab outside regular opening hours.

A. Programming

Most volunteering work is done by offering and supervising the opening hours: OpenLabs, SelfLabs and Workshops. During OpenLabs supervisors are present to support users in their projects and instruct them in the use of the machines. As some equipment may be too complicated to fully teach a novice during such times, the users will accumulate experience in several manufacturing projects and eventually receive the permission to operate the machine on their own. The basis for trainings is how to not harm machines, self and others and how to use the machine for your project. We also encourage experienced users to pass on their knowledge to others, effectively training them on the machines. This is also summarized by "What are your responsibilities?" in the Fab Charter, see Section II-A

During SelfLab opening-hours, only fully trained users may utilize the machines. This allows supervisors to work on their own projects or take care of administrative work.

At workshops, a small group of people works on the same or similar projects, supported by our supervisors. Such events are usually targeted at particular visitors (e.g., pupils) or manufacturing techniques (e.g., soldering of surface-mounted devices). They take place irregularly, since long-term planning of regular events is usually hard for volunteers.

B. Community

In addition to regular hours, supervisors are encouraged to spontaneously make the FabLab available to experienced users while they use the lab on their own. This approach leads to a well knit community of heavy users and supervisors through personal contacts. Sparking new ideas, helping one another and supporting less experienced users are the foundation of the group of volunteers.

Typical for grassroots makerspace initiatives is the formation of a strong community. For such communities the room itself is a place to meet and exchange ideas on science, technology, digital art, engineering and many more. The social interactions are usually the priority of these community gathering places, which in turn leads to the design of such a place to include communal areas. Because of space constraints this was thus far not possible in the FAU FabLab, but a community of supervisors has formed nonetheless.

C. Finances

The initial costs for acquiring the machines and material at the FAU FabLab was covered by the students themselves, through tuition fees. All followup costs, due to the wear and tear on tools and machines, as well as material, is charged to and covered by the appropriate user, including write-offs. We strive to keep the FAU FabLab financially self-sufficient, to be able to maintain the state of currently offered capabilities. Meaning, that even if all financial support from sources other than users (e.g., tuition fees, donations, events and so on) were to cease, we would still be able to maintain the current standard and quality of our machines, tools, materials and infrastructure. Any improvements, however, must rely on donations and other funding sources, to keep the cost for students at the lowest possible level.

D. Equipment and Space

In addition to the organizational structure, programming and financing, a FabLab would not be one without its machines, tools, components and space to use them in. We have tried to follow the recommended FabLab Inventory [7], but have made a few deliberate deviations due to space and availability constraints. E.g., instead of milling circuit boards, we chemically etch them, therefore we do not have a small precision mill but a chemical etching setup. The most significant missing capability, however, is the large format CNC router, due to space constraints.

The FAU FabLab currently occupies two rooms with a total of $51\,m^2$, housing 8 computer workstations (four of which are shared with electronics work places), a lasercutter, a medium-scale CNC mill, a CNC lathe, a chemical workbench, three 3D-printers, a vinyl cutter and a workbench, in addition to a stock of acrylic, electronic components and many other materials and hand tools. A lot of thought has gone into efficient use of the space. By designing our own workbench, tables and investing into small-parts warehouse industrial shelves, we are making the most out of it.

Currently, additional working and storage space, which would have to be provided by the university, is unavailable. Therefore, any new machines acquired have to replace existing ones.

E. Integration in Higher Education

Multiple university level classes use the FAU FabLab as a resource to provide students with access to modern tools.

The *Projektpraktikum* [9] is part of the physics bachelor program and offers students the option to come up with four group projects which touch several areas of the field of physics. The FabLab is one of two workshops that students may use.

In *Praktikum Mechatronische Systeme* [10], student groups from the mechatronics study program have to build robots that can complete a task specified in advance. All groups have to present their robot in a final competition. Each group has a hosting research group and the FAU FabLab provides access to tools that the research groups are unable to provide.

Most importantly, since the winter term 2014, a dedicated class *DIY – Individual Prototyping and Systems Engineering* [11] (previously *DIY: Personal Prototyping* [12, 13]) has been established. Topics revolve around the possibilities offered by FabLabs with an emphasis on the use of realtime and feedback control systems, and it is open to all students with an engineering or science background. The FAU FabLab has been part in the process of defining the curriculum. Each year 16 to 25 students design, realize and document their own project ideas in small groups, ranging from smoke detecting led-lit pipes, their own CNC router to an interactive and self balancing inverted pendulum demonstrator.

Due to space constraints and the number of enrolled students, many classes are unable to make use of the FAU FabLab. We are—nonetheless—always open to integrate more innovative concepts into the FabLab from undergraduate and graduate curriculum.

F. Outreach Events

To support outreach efforts by the university and the FabLab itself, we regularly take part in study program fairs targeted at potential students from high school. The lasercutter and 3D-printers draw a lot of attention and allow us to present projects as well as the practical application of engineering in every-day life.

Twice we have collaborated with the Erlangen public city library, by hosting a “StaBiLab” (City Library Lab) in their facility. Such events give us the possibility to teach and interest people that otherwise would not have come to the FabLab.

In past years, we have also presented the university and FAU FabLab at international computer and technology festivals and conferences in Hamburg and near Berlin.

G. Example Uses in Science

Here we present a few example use cases that illustrate the technical possibilities of a FabLab for science. These examples do not highlight the networking possibilities, which—we believe—to be at the least equally important.

Navid Bonakdar, from the Max Planck Institute for the Science of Light (MPL), built a chamber for the fabrication of giant lipid vesicles as a model system for cell membranes with the help of the FAU FabLab. This allowed researchers from MPL and FAU to evaluate membrane model systems for an overview study under physiological conditions [14].

Martin Schütz et al. introduced a novel, tailor-made UAV-based sensor platform, HeliSAR, that potentially allows interferometric SAR remote sensing based on a bistatic MIMO radarsystem [15]. Many parts of the system were built in the FAU FabLab by Martin Oesterlein [16] during his master's thesis, using the CNC mill, laser cutter, 3D printers, circuit board etching and many more capabilities.

Fabian M. Schaller et al. investigated in their publication the local building blocks of aspherical grain packings found in granular and glassy systems [17]. In order to demonstrate their findings, they made use of the FAU FabLab to produce 3D printed physical representations of local structures, which in turn was part of Robert Weigel's bachelor's thesis [18] in theoretical physics.

Toni Bartsch used the FabLab during his bachelor's thesis, designing a programmable constant and spike free power supply for testing integrated circuits. For safety and practical use in a research and testing environment, a solid aluminum protective shell and an acrylic front cover had to be designed and manufactured [19].

IV. Related Entities

With more than 1.000 FabLabs worldwide and 46 in Germany [3] and many more less clearly defined maker spaces, there are too many variations to cover them all. To put our structure and concept into context, we will very briefly sketch differences and similarities with two other FabLab-like institutions in proximity to Erlangen.

Our closest neighbor is the FabLab Nürnberg [20], which is organized as a non-profit organization, located in the city of Nürnberg. Their FabLab is also run by volunteers, but due to financial constraints they are restricted to more low-cost machines and tools. In comparison to the FAU FabLab, they have more than six times as much space. The founding meeting of the FAU FabLab took place at the FabLab Nürnberg.

Further south-west of our location is the UnternehmerTUM MakerSpace [21], which is based on a collaboration between BMW and the Technical University of Munich (TUM). It is run by paid staff, has equipment that is much more expensive, as well as 20 times as much space. The MakerSpace is embedded in the Center for Innovation and Business Creation at TUM, but does not consider itself a FabLab. Pricing is a major barrier for low threshold entry, with a single-day membership starting at 60 €, with discounted offers for students.

At the Saxon State and University Library Dresden (SLUB), the SLUB Makerspace [22] is operated by library staff and student assistance, has weekly opening hours and low usage fees for their users. It is open to all members of the library, which includes–but is not limited to–all students of the Technische Universität Dresden.

V. Conclusion and Outlook

We have presented the background, concept and example use cases of the FAU FabLab in context of a study and research university. In the last year we have had more than 2,500 visits and accounted for almost 1,500 hours open to the public, all of which has been made possible by nearly 40 volunteers. Theses numbers show, that the FAU FabLab is most likely the highly frequented[1] workshop in the engineering and natural science faculty. It gives access to modern tools and equipment to students, researchers, staff and the general public alike, and provides a space to work and share alongside, exchange experiences and spark interest with a do-it-yourself—as opposed to a let-someone-do-it—approach not typically found in other workshops. The FabLab concept complements already existing classical workshops, by being less specialized and more open.

As two main obstacles for further development we currently see the space constraints and lack of full-time staff. With $51\,\mathrm{m}^2$ and no full-time staff to rely on, larger collaborations with research projects, industry, schools and university classes, as well as regular events–beyond open labs–and workshop classes seem out of reach. Once these obstacles have been overcome, the FAU FabLab will bridge diverse communities of researchers, students, professionals and generally curious, provide the manufacturing and working infrastructure, and support social interactions through events and culture. This makes the FabLab a key enabler for self-driven studies, interdisciplinary research and project work, entrepreneurship, industry collaborations, as well as public outreach.

Appendix A
Purpose of this Document

When using the FAU FabLab for research, please cite this document about the concept and implementation of the FAU FabLab. It describes the state of the FAU FabLab at the time of publication. When significant changes take place an updated version will be released.

Using the citations, we intend to track scientific publications that have benefitted from the FAU FabLab. In addition to citations, we kindly ask to be informed of all science-related uses, such as for publications, bachelor's, master's or doctoral theses, or joint projects with industry. This will help the FAU FabLab in its future endeavors.

Appendix B
Acknowledgment

The FAU FabLab and its volunteers would like to thank the countless people and institutions, who and which have made the FAU FabLab possible through their support, amongst

[1] in terms of visitors, not work hours

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