Fab Lab Education in German Academia

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Abstract

This contribution describes the current state of the ongoing German federal research project 'FAB101' which explores Fab Labs and their role in German academia for three years by way of a real-world, action-oriented research infrastructure of four existing (Fab) Labs at universities. Currently, the results point to infrastructure, collaboration aspects and governance as well as educational concept issues as main factors influencing the more widespread adoption of personal digital fabrication and Fab Labs in German academia. This contribution details these results further and draws some first conclusions as well as recommendations. It also describes FAB101's distributed research infrastructure and methodology and is intended to invite further comments, discussions and input for the project.

Keywords

Fab Lab Education, German Academia, Transdisciplinarity, Digital Fabrication, Governance

1 Introduction

With the growing importance of and activities around personal digital fabrication in academia and other contexts [3, 5] universities are challenged to think about how to best develop teaching and research opportunities in such domains. This is not a trivial process because personal digital fabrication transcends traditional disciplinary boundaries and requires infrastructures as well as skill, competence and organizational structures that are, to an extent, also non-traditional in academic contexts. There is a substantial number of experiments and cases to learn from in practice, though [5, 11]. Certainly, the concept of the Fab Lab Network itself, the 'How to Make Almost Anything' lecture as well as the 'Fab Academy' are the three big, very practical, successful and long-running contexts to draw upon. However, there are also smaller, more local teaching and curricular experiments as well as infrastructural and governance aspects relating to (Fab) Labs as infrastructures in academic contexts that need to be considered. The goal of project FAB101 is to work on such considerations based on a research infrastructure of four (Fab) Labs at German universities. From 2017-2020, the four research groups hosting the Labs will analyze and compare prior experience of 'their' Labs as well as do reviews of the state of the art and carry out empirical work such as the co-development of new, experimental, interdisciplinary and inter-university educational formats in the domain of personal digital fabrication. In a further step, experiences from other (inter-)national Labs will be included into these research and development activities. This contribution describes the project's context, its methodology as well as first findings regarding infrastructure, collaboration, governance and educational concepts.

2 A brief State of the Art

In recent years, Fab Labs, Makerspaces and similar open, community-oriented lab infrastructures have been opened in a variety of contexts, including a number of universities [5, 10]. Within this variety of lab developments, the Fab Lab concept is of special interest to academia because it offers elements of standardization and support structures and has its roots in academia and research infrastructures itself

[3, 9]. With the 'How to Make Almost Anything' lecture as well as the 'Fab Academy' and many more localized projects, there are long-running successful examples of offering students from virtually all disciplines access to Fab Labs within their courses of study.

With regard to learning theories, didactics and pedagogical approaches linked to Fab Labs , there is a substantial body of work on Constructivism [1], Constructionism [4] and, later, more specific considerations about learning models and literacies [6, 8], learning-focused projects [2] curricula [7] and other domains that frames educational work in and with Fab Labs and Makerspaces specifically. [6] evaluated what types of learning are taking place in Fab Labs. They tested whether students gain certain competencies, e.g. in teamwork, communication, design thinking or knowledge sharing when working in Fab Labs. This evaluation took place for a whole semester in fall 2016 and they found that students achieved such competencies successfully.

In Germany, as of the time of writing, there are insular experiments with joining the Fab Academy from a university Fab Lab by way of a research project on 3D printing competences. There are also some locally developed experiments with Fab Lab introduction formats similar to the Fab Academy as well as a generally increasing number of seminars, lectures and other educational activities in the German Fab Lab scene.

There are gaps in the state of work regarding the documentation of and the options for the collaborative development of accessible and safe introductory educational formats to (academic) Fab Labs. Similar gaps can be found regarding documentation and consensus in underlying infrastructural aspects such as organizational and financial models, rules and regulatory aspects as well as (community) management for academic Fab Labs. Further contributions will include more in-depth literature reviews, also including further thematic foci such as international cooperation perspectives that are not part of this publication.

3 Problem Domains

It is our observation that the integration of (personal) digital fabrication in German higher education is still at an early stage and moderated by a variety of open issues. Based on our own long-term experiences in running Fab Labs at universities as well as empirical work centered on understanding these issues, we believe that they broadly relate to the following domains:

- Educational concepts: Safety & competences, transdisciplinarity and didactic requirements.
- Infrastructure: Tools, Machines, Space & Location, contextual /local grounding.
- Collaboration & Sharing: Project- / Community- / Stakeholder-Levels.
- Governance: Organization, safety & regulation, (Community) Management, academic credit.

These domains relate to gaps in the state of work and also represent emerging categories in an on-going (action) research process. This contribution is intended to broadly map them out for discussion and input before implementing and evaluating experimental organizational and educational measures in the FAB101 project consortium and their associated Fab Labs.

4 Methods and Research Context

The FAB101 project consortium consists of four research groups at different German universities. Each group brings long-term experience in setting up, managing and working with (open) interdisciplinary laboratory-infrastructures in academic contexts. The groups' disciplinary backgrounds - and hence, the communities they mainly work with – are diverse and different. All groups have further grounding, collaborations and connections with other labs or communities (e.g. the global Fab Lab network).

Table 1: FAB101 consortium overview

Abbrev.	CSCW	MCG	dimeb	DbT
Name	Computer- supported Group Work & Social Media	Media Computing Group	Digital Media in Education	Design by Technology
Background	Cooperative Systems research with a strong tradition in grounded and participatory design methods, action research, value-driven appraches as well as organizational and public infrastructuring processes	Develop & study new interaction techniques and systems in areas like personal digital fabrication & design, tangible, mobile, and wearable user interfaces, interactive textiles, augmented reality, and visual coding environments	Educational applications in Computer Science and Media Informatics. Digital media and media education within the context of pedagogical didactics	Interdisciplinary and transmedial design, parametric design, animation, experimental fabrication, adaptive materials, modular structures, coding and design
Faculty	Faculty of Economics	Faculty of Engineering	Faculty of Mathematics and Computer Science	Faculty of Design
Courses of Study	Human Computer Interaction, Information Systems, general studies	Computer Science, Media Informatics	Teacher Educations Studies, Media Informatics	Industrial Design, Communication Design, Art
City	Siegen	Aachen	Bremen	Essen

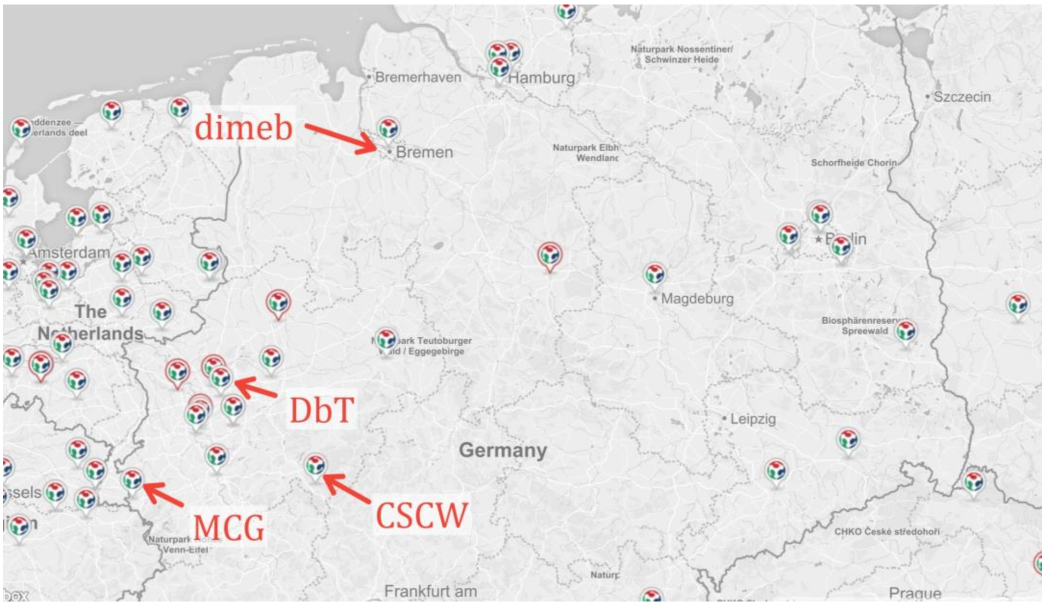

Figure 1: Map of the FAB101 Fab Labs (Image: Modified Screenshot from https://fablabs.io)

This distributed research infrastructure of labs and communities serves as the basis for a three-year, action-oriented project that broadly consists of the following packages:

1. Pre-Study to consolidate prior knowledge and experiences in teaching, governance and other aspects of personal digital fabrication and integration of Fab Labs into academic settings in Germany.
2. Iteration on educational concepts and hosting of experimental courses at each university based on knowledge from pre-study. Focus on integration of experiences from other labs and opening courses to other faculties.
3. Iteration on educational concepts and hosting of joint experimental courses between universities. Development of a cooperative educational format to safely introduce interdisciplinary students to personal digital fabrication.
4. Work on underlying but crucial "infrastructuring" factors, mainly Governance, basic and support infrastructure, community as well as collaboration. Consolidation of knowledge and practices, development of recommendations and demonstrators. Development of a 'booklet' for basic requirements to run Fab Labs in German academia.

The project's main methodological foci are transdisciplinarity (see

Table 1), action-oriented research and Cooperative Systems Perspectives. Research activities explicitly comprise the participatory development and practical evaluation of new educational concepts, the co-development of functional prototypes for support systems and the active involvement of project researchers with 'their' Labs and their communities. Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) bring research perspectives into the process that deal with the analysis and improvement of socio-technical systems. Considering a Fab Lab as such a system, HCI and CSCW methods and perspectives are applicable to achieve an understanding of how labs and their communities work and to help shape management and integration practices for personal digital fabrication in (German) academic contexts. HCI research can be applied to gain an understanding how machines and the lab itself can become more approachable for users. The European conceptualization of CSCW also brings its methodological spotlight on qualitative, ethnographically motivated systems development into the project – the problem domains mentioned above represent emerging categories in a Thematic Analysis inspired and on-going research process that handles existing data from the FAB101 consortium (such as lecture slides, workshop materials, etc.) as well as new empirical work. At the time of writing, the latter consists of multiple interviews between different project partners who teach in and manage Fab Labs, the development of multiple comparison tables (e.g. regarding infrastructure, tools, theses, etc.), observations in the consortium labs, joint workshops and lectures as well as analytical sessions face-to-face on the consortial level. Participatory elements such as co-design workshops about lecture formats together with students also were and are part of the process. A more detailed description of the methods, the data and the coding scheme will be part of future contributions.

5 Results

5.1 Infrastructure

Unsurprisingly, all FAB101-Labs use similar tools and machines. However, there are some specific observations that are of interest: Machines are often sourced differently than advised by the Fab Foundation – an example from our research is purchasing a CNC machine from a local supplier instead of the recommended purchase of a big CNC mill from the US. Besides market-related considerations (especially in the context of publicly funded infrastructure) the local manufacturer also offered additional customization and support which would not have been easily possible with an international order. Hence, the general spirit of the Fab Inventory is preserved but problems down the line (e.g. with software compatibility and sharing projects) can come with this approach. A considerable number of 3D printers is available in all labs (with FDM being most prevalent). 3D printer and laser cutter are also the machines with the highest numbers of users in all partner Fab Labs. The amount of hand tools differs highly. All partners have basics electronics and microcontrollers. Space, location and – crucially – disciplinary traditions and requirements influence machine and tool choices and usages. As an example from our research, the DbT-group has substantially more heavy machinery, woodworking equipment and robots available than all other partners. This is due to DbT working with Industrial Designers, artists and similar disciplines where there are long-standing tradition, budgets and management practices for extensive lab infrastructures – unlike, for example, in the context of project partner CSCW who opened the first ever lab with heavy equipment at the economic faculty of their university.

On the software side, cost and accessibility (e.g. web-based vs. download-based application) are always relevant factors and influence the tool choice substantially, especially for beginners. To get a better understanding of current practices, a comparison matrix between the tools used in the consortial Labs and a selection of tools for the use in a Fab Lab according to the Fab Academy notes of 2017 was developed. There was a certain number of tools that overlap, but especially the requirements for tools for 3D design and scanning are more advanced in the Fab Academy list. The comparison matrix was also used as a conversation-guiding artifact in further interviews in order to understand the practices behind the tool use and will be covered in more detail in future contributions.

Space and Location are general and major factors influencing the infrastructural development of a Fab Lab. In a case from our research, the machines, tools, furniture as well as the space design (and the users) of a very open and public lab in the inner city looks and 'feels' rather different from a smaller on-campus lab a few kilometers away from the city center e.g. in regard to space distribution for social and technical activities. Mobile labs or distributed, smaller 'node' labs associated with a 'mother lab' also were mentioned as space- and location-related considerations because (easy) access to a fully equipped Fab Lab as of now is still moderated significantly by the individual users' place of residence (e.g. rural areas) and mobility options (minors, financially disadvantaged people, etc.).

5.2 Collaboration & Sharing

One of the core results regarding collaboration and sharing was that on the project group level, every lab community seems to have problems with (collaborative) documentation and sharing of data, procedural information, learnings and other aspects about users' projects. Infrastructural, motivational, organizational and other issues as well as a lack of appropriate standard formats and support tools are being mentioned regularly as potential causes for these problems. This problem domain is also being mentioned and discussed regularly in the global Fab Lab and Makerspace communities.

On the community and organizational levels, substantial amounts of collaboration and knowledge sharing are already happening in the open Fab Lab settings themselves (e.g. through ad-hoc over the shoulder learning), in distributed lecture formats such as the Fab Academy as well as conferences, meetups of lab managers and the like. With the current growth of open lab infrastructures, a further increase of collaboration and professional exchange between lab managers (as well as potentially a professionalization of the role itself) are also increasingly being mentioned as open issues – as are practices, organizational models and support tools to balance such a professionalization with the collaborative and participatory elements of (Fab) Labs.

Further preliminary results include that face-to-face communication is seen as most important and effective both in organizational and educational matters. Personal recommendations are trusted most and result in the adoption of practices, procedures and tools. Physical presence plays a major role in joint learning and collaboration in general.

In the academic context, disciplinary boundaries and traditions are also factors moderating collaboration and sharing. Expectations regarding students' independence in project work, project-orientation in teaching, workload, appropriate form and length of documentation and similar factors can vary wildly between disciplines and faculties. Political and, sometimes, personal issues also can influence this problem space significantly.

5.3 Governance

Organizational models: There still seems to be a significant amount of unclarity and local as well as informal agreements about the organizational structure, financial basis, legal and personnel requirements, (open) access as well as other formal aspects of Fab Labs at universities in Germany. Most Fab Labs in academia here have been initiated and are being run by singular entities such as student groups, university chairs or institutes and are only slowly - if at all - being integrated in more strategic academic development. On an administrative level, it might be unclear why and how a Fab Lab relates to traditional academic facilities like e.g. a library. It is, in practice, unclear how Fab Labs relate to traditional central academic services (such as data centers or libraries). For the most part, the labs do not have staff that is employed directly for and in the lab but rather have to cross-finance such roles (if they exist at all). However, the need for such positions in technical, managerial and educational roles have been made explicit numerous times.

Safety, Regulatory and Formal Aspects in Germany: Fab Labs are laboratory spaces with potentially dangerous equipment. As such, an extensive regulatory and legal body as well as local agreements and practices necessarily influence such spaces at German universities. This comprises lab regulatory documents, access, formalized role and responsibility structures, safety introductions as well as the layout and equipment of the actual lab space. With open access for the public and new, interdisciplinary ways of managing and running a lab, Fab Labs also touch on relatively uncharted regulatory issues. We have collected the safety, regulatory and formal documents and agreements from the FAB101 partner labs and will compare and – as far as possible – consolidate them in the next steps. The intended outcome is a basic collection of good practices and broadly acceptable model documents to help create certainty and assurance as well as working materials for (new) German Fab Labs.

Community Management, Awareness and Appropriation: Quite often, a substantial number of potential stakeholders – be they students, lecturers or others - do not even know about the Fab Labs at their universities. The labs themselves can also still often be viewed by the general public as techno-deterministic, elitist and not approachable for 'regular people'. Better, broader and clearer interdisciplinary curricular integration of personal digital fabrication, qualification opportunities for educators as well as a professionalization of the community manager role in Fab Labs are being mentioned as potential solutions. The latter aspect – a focus on community management work – also relates to the substantial amount of hidden work that lab managers seem to invest into community management activities.

Curricular Integration & Academic Credit: All consortial labs offer courses in the Fab Lab that fit into the curriculum of their own courses of study but also are open to participants from other contexts, up to and including external participants not enrolled in the university. In all labs, there is substantial interest in such activities from students from all faculties. However, relatively rigid exam regulations and module combinations can make it hard, if not impossible, to allow all students to get academic credit for their lab work – which is further influenced by the organizational grounding of the Fab Lab in the university (e.g. a

Lab associated with a chair from faculty A might have no way to offer students from faculty B academic credit). More permanent and stable curricular integrations are desirable.

5.4 Education

One of the core requirements for a Fab Lab in German academic contexts is its ability to teach basic and safe Fab Lab usage to students across disciplines. This requires an introductory format including hands-on time with the respective equipment, instruction, supervision and legal documentation. It also seems desirable or even essential to teach some more meta-skills and knowledge such as basic competences with digitized collaboration (e.g. version control, open source as a concept, etc.). A huge problem is how to scale such a course in terms of the number of students attending and the number of advisors. Additionally, the space in the Fab Lab has to be considered, as does the infrastructure (which is not necessarily available for bigger groups). Another aspect is that personal digital fabrication fits into very different areas of study – which leads to widely varying competences, motivations and skills among users – introductory concepts should reflect that and be modular and low-level.

The Fab Academy represents a way of approaching this problem space and is being mentioned frequently in our research. It already is a distributed, introductory lesson format for Fab Labs and there is extensive knowledge about its requirements available, as are students' documentations and many other documentary artifacts. However, it does not (and cannot) consider location-specific legal and other requirements. It also has substantial workload requirements that may be challenging to fit into curricula on a broad basis in Germany and the finance model of students paying for participation is not appropriate for the core European educational market. For appropriation on a broader level, more 'didactic bridges' to the varying disciplinary backgrounds of potential students as well as their individual motivations are also being mentioned frequently as potential success factors. Making the development of such courses open and participatory as well as putting them on open platforms is also viewed as desirable. The co-development of a 'personal fabrication' module based on those learnings is part of the upcoming phases in our project - Figure 1 shows how it might look in practice. This conceptualization (which is a work-in-progress) splits the module in two semester-long courses of 2 lecture hours and 3 practical hours per week with simple 2D and 3D operations, electronics, basic coding and socio-cultural as well as collaboration competences being covered in semester one. Semester two comprises more advanced CNC operations, advanced electronics and IoT, textile and other current research topics. As a first step, we are currently conducting and evaluating a series of experimental shorter guest-lectures, -talks and -workshops centered on topics of the planned personal fabrication module between all consortial labs.

6 Discussion and Outlook

We hope to have presented a useful and broad overview of the state of our research and practice activities as well as our learnings. At this point in the research process, it is too early for a substantial written discussion but there are a few items that should already be discussed:

We welcome input and comments to our general categorization (Infrastructure, Collaboration, Governance) as well as the concrete content of those categories. All sorts of useful documents such as lab regulation documents, information about personnel structure, agreements as to the organizational structure or educational concepts are also more than welcome. As of mid-2018, there is still enough time to integrate such data into our research process as well as the development of experimental educational formats in our consortium – potentially even together with other interested parties. This contribution will be discussed at the FAB14 conference and our categories and learnings are actively being put forward for discussion and comments at gatherings we attend (Maker Faires, scientific conferences, educator and lab-manager meet-ups, etc.).

A booklet, brochure or some other form of concise and clear basic requirements, assurances and model legal documents for establishing and managing Fab Labs in German academia seems necessary. The development of such a medium is one of our long-term goals for the project.

As mentioned, more communication and professionalization between lab managers seems warranted. In 2017, the ViNN-Lab at TH Wildau initiated the first gathering for all German Fab Lab managers (Fab:UNIverse 2017) and after its initial success, project FAB101 will host the event in 2018-2019 and integrate the findings and results in its research process.

Open, democratic access to education in general and – as far as practically possible – to academic education for everybody, even without formal qualifications, is a core value for German universities. These values match well with 'Maker' contexts and personal digital fabrication which are incorporate elements of broad access, openness and explicitly include academic and non-academic users. The same is true for the 'Third Mission' of universities – supporting regional and, ideally, sustainable activities beyond the scope of research and teaching. Personal digital fabrication and Fab Labs mesh well with these values and the labs themselves seem to be able to act as focus points, community spaces, knowledge transfer infrastructures, exhibitions, showcases, coffee corners, meeting points, boundary (negotiating) artifacts and in many other roles associated with increasing cooperation between cities, regions and universities (see also the Fab City project and similar initiatives). Hence, management and regional grounding of open Fab Labs likely can and should not be carried out by a university alone. Other regional stakeholders and organizations need to be involved. On the one hand, this complicates the management and organization, on the other, it also potentially makes a lab more stable and more potent long-term infrastructure. Such considerations will influence our governance recommendations and may result in perspectives for follow-up research projects in the long term.

7 Literature

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