A Possible Ubiquitous Way of Learning within a Fab Lab
The Combination of Blended Learning and Implementation-oriented Learning

Aleksandra Konopek, Lukas Hellwig and Michael Schäfer
Institute of Informatics, Hochschule Ruhr West, Lützowstrasse 5, Bottrop, Germany

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Abstract: This report describes a possible peak of blended learning and implementation-oriented learning within a special training concept which can easily lead to a ubiquitous learning attitude. The associated field report characterizes a special ratio between self-learning methods and active support through an instructor, turning the combination of blended learning and implementation-oriented learning into a ubiquitous way of learning proposed to be called mushroom strategy. The idea of a fab lab exemplifies open workshops. Its growing influence on the educational landscape is specified, highlighting questions and difficulties regarding the integration of this very special ubiquitous way of learning into a daily routine of a fab lab. An exploration of this learning strategy leads to a proposal for a learner-mentoring-process.

1 INTRODUCTION

Many different educational offerings characterize the educational landscape. They may have different goals. Attending a school, for example, implies graduating, going on to vocational training and university with the aim of employment. Skill enhancement offers a range of higher qualifications with the prospect of better income or competitiveness. But there are also training courses one needs to complete to be allowed to do something like drive a car or work for the voluntary fire brigade or be an exercise instructor.

All these training courses have one thing in common: They offer entrance qualifications. The associated assessment criteria focus on the human-being as a learning individual.

Currently, a new kind of diverse educational institution is spreading rapidly, like open workshops, repair cafés, hacker spaces and others. Learning skills simply on one's own initiative without any prospect of certification is one aim of these institutions (Makerspaces 2014-2018). Questions of motivation arise: curiosity or social contacts? The implementation of one's own ideas is definitely a key motivation (Keller 2010). Learning skills and their instant implementation into a desired project or product can be seen as a powerful stimulus. Below, the concept of a fab lab will be briefly described and exemplifies open workshops. Fab lab users can learn how to implement their own projects or product ideas with the assistance of fab lab staff by using computational methods and CNC machines.

2 OPEN WORKSHOPS

"Open-access workshops are member-lead organisations that provide access to affordable space, tools and workshop facilities." (Corbin and Lynch n.d.) The following chapters describe functionality, aim and relevance of fab labs as an example for open workshops.

2.1 Fab Lab Overview

The concept of a fab lab was invented and developed by MIT's Center for Bits and Atoms in 2001. It is mainly based on the idea of institutionalizing the "maker movement" – an open-source transdisciplinary and transcultural knowledge transfer using the Internet as a communication channel (Gershenfeld 2012, p.47/48). Fab labs focus on providing machines to the public for digital fabrication and computation as a technical prototyping platform. One claim they make is serving as a node for a local community of learners, educators, technologists, researchers, makers and innovators acting globally in a global network of fab labs around the world. All fab labs should provide

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and share common tools and processes to be able to easily exchange and support each other (What is a Fab Lab 2016).

Besides providing workshop spaces, tools and high-tech machines, the main mission of this concept is to enable penetrability and transferability of digital fabrication and computation knowledge to the public. The main focus of attention is the key word "open source". It is the idea of picking up and using the enormous unfiltered knowledge and energy, available for free on the Internet (Hüttenegger 2016), and creating a "constructivist learning environment" in terms of individual perceptions und responsibilities (Pörksen 2014).

Yet there are no prescribed studying techniques, only an internal charter defining a desired behaviour within fab labs (Fab Central - MIT Center for Bits and Atoms n.d.). One of the charter items defines fab labs as educational institutes providing "…operational, educational, technical, financial, and logistical assistance…".

Why educational? The crux of the concept is: "Users learn by designing and creating objects of personal interest or import" (What is a Fab Lab 2016). Ideally, a fab lab user comes with a product idea and leaves with a self-fabricated prototype or final product. Nonetheless, it is equally valid if people just want to learn to use a software tool, realize personal projects or develop prototypes as entrepreneurs. They must learn how to do it by themselves and fab employees only assist with the learning processes. That means that there is no longer a classic teacher-student relationship, but rather a sharing of knowledge and skills without any hierarchy. In the best case, fab lab users learn from each other.

2.2 Fab Lab Facilities

Typical well-equipped fab labs provide (Fab Lab Inventory 2016):

- Digital fabrication: 3D printer, laser engraving and cutting machine, small CNC portal milling machine, precision milling machine for PCB milling and soldering furnace, 3D milling machine, large CNC portal milling machine, vinyl cutter for smaller objects and for stronger materials like copper foil, digital sewing machine, …
- Computation: designing and modeling software, music- and film cutting tools, if possible open source and tools for VR (virtual reality) /AR (augmented reality) …
- Computer and color printer are mandatory
- Conventional fabrication: lathe, band-saw, circular saw, grinding well, drilling machine, vacuum or thermoforming machine, press, Styrocut …
- Tools: as in every workshop you need a standard tool kit incl. hammer, screwdriver, ruler, saw … as well as soldering tools…
- Consumable materials: wood plates, paper, acrylic glass, leather, screws, etc., electronic components such as wires, resonators, LEDs, microchips, breadboards, servomotors…
- …

2.3 Relevance of Workshops like Fab Labs in the Educational Landscape

"In 1998 we tried teaching "How To Make (almost) Anything" for the first time…" (Gershenfeld 2005). The first fab lab was launched in 2001 at the MIT Media Lab in Boston/USA by Center for Bits and Atoms and Grassroots Invention Group. Only the following year the first fab lab was established outside MIT, in Costa Rica (Costa Rica Institute of Technology TEC) (Mikhak and Gershenfeld, 2002).

In September 2017 there were already 1,183 fab labs registered on fablabs.io (a communication interface for all fab labs and members) spread all over the world. Two months later, in November, there were 1,201 registered fab labs (fablabs.io n.d.).

The number of fab labs has increased exponentially in recent years. They now exist as independent institutions or integrated in universities or schools. As such, they are having a growing influence on our educational landscape worldwide, but at the same time reflect a social need. They are becoming relevant within the educational landscape.

Beside the labs, the huge number of community workshops with similar goals should be mentioned: hacker spaces, repair cafés, makerspaces, workshops that help people to help themselves, and others.

3 LEARNING METHODS

Yet as workshops like fab labs are becoming ever more relevant, a very important question is arising: What kind of knowledge is being conveyed and, above all, how is learning taking place in these workshops?

One indication is that "users learn by designing and creating objects" (What is a Fab Lab 2016). This defines learning as "implementation-oriented

learning" in contrast to "knowledge-oriented learning", which takes place at most of our schools and universities.

3.1 Learning Strategies in Open Workshops

Open workshops are also self-qualifying (Sabel 2002) environments. Even if implementation of one´s own ideas is one powerful key stimulus for learning, providing learning strategies within these workshops are quite helpful for the learning process. Still, main focus of implementation oriented learning is the final product. The following chapter introduces a learning strategy for this kind of request. Starting point and central aspect will be the learner´s own responsibility and a ubiquitous attitude regarding the learner´s environment as potential educational material.

3.2 The Mushroom Strategy: A Ubiquitous Way of Learning

In addition to current definitions of ubiquitous learning arising from the definition of mobile learning and purely based on ubiquitous technology (Specht and Ebner 2011), there is a different way of ubiquitous learning possible within fab labs. The difference is the perspective. While the current definition of ubiquitous learning is mainly described from the perspective of the technical environment, the mushroom strategy flips the perspective to the student. This change leads to a demand-oriented view. Thus, potentially everything, a conversation with colleagues, neighbors, family, can be part of the learning process, or just the bare observation of the environment or situations can give useful hints. It depends on the student's current requirements, interest and receptivity.

The mushroom strategy is interesting for simultaneous learning to reach the goal of a finished product or project within a certain period of time, similar to Integrated Design Engineering (Vajna 2014). It is a strict and high-pressure way of achieving educational goals focusing on the final product all the time. Thus it is also a ubiquitous way of learning. This learning method is mainly a self-learning method. Some of the learning material is given through links, for example, but the students absolutely have to conduct their own research depending on the subject they are focusing on. They have to become a specialist in their individual projects.

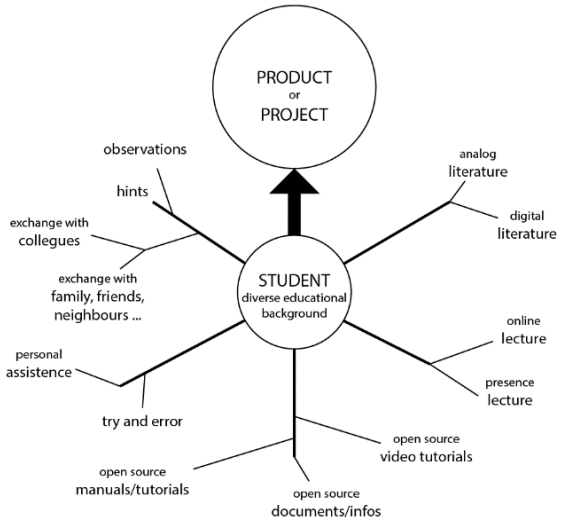

Figure 1: The mushroom strategy as a ubiquitous way of learning.

The figure above shows the relationship between student/environment/final product. The focus is always on the product idea. Meanwhile the technical and natural environment serves as a potential information and learning source. Even so, a strong willingness for one's own research and alliances is standard. The student determinates the flow of information, mainly. The educational background is the foundation from which to choose learning tools and ask the right questions. The student assimilates and cross-links all information instantly with a view to the product idea. Only learning material which is necessary for a better understanding of the problem exceeds the focus and will be transformed into the product more indirectly. This learning strategy is highly individual and mostly self-organized. The terms in figure 1 are exemplary and can be extended.

The student's attitude, focusing on a successful implementation of the project idea, defines the environment as a ubiquitous information source. The goal is omnipresent during the studies.

3.3 How the Mushroom Strategy Works – A Field Report in a Situation of an Advanced Training Course

The above attitude is encouraged by the Fab Academy's course structure (Fab Academy Course Structure 2017).

3.3.1 What Is a Fab Academy

The Fab Academy offers a combination of blended

learning and implementation-oriented learning over a period of 5 month. It is a special training concept for fab lab managers developed by the Center for Bits and Atoms and headed by Professor Neil Gershenfeld and can be seen as a possible peak of "blended learning" (Erpenbeck et al., 2015) in combination with "implementation-oriented learning" (Martinez and Stager 2013).

Meanwhile, there are as many as 11 university fab labs that accredit Fab Academy training courses or are working on accreditation systems for it (Accreditations 2017).

The aim of this educational concept is to train fab lab managers who are able to establish and run fab labs. For this special requirement pre-qualifications are necessary in at least one of the fields of mechanical engineering or mechanics, informatics, electronics or industrial design, etc. Within six months students get involved in a wide range of digital and conventional fabrication techniques, various computational, design and modeling tools and in robotics, including circuit board development and embedded programming.

3.3.2 Short Introduction into the Fab Academy Process

The teaching and learning program is being constantly enhanced, but the main structure is clearly organized:

- Basically, all topics are structured within a weekly rhythm.
- The professor gives an online lecture once a week, a local instructor assists the weekly learning process and a supervising tutor called a "guru" supports various fab labs in a particular catchment area.
- Learning tools vary between online tutorials, online lectures, presence lectures, personal assistance, online research on open-source examples and solutions, direct implementation, exchange between students.
- Studying techniques are influenced by the instructor. If the instructor wishes to control the learning process, study will be less self-determined. The other extreme is complete withdrawal. This will almost certainly lead to failure.
- The topics of the Fab Academy's lectures build on one another, in part, but it often seems they lack continuity. For instance, one week of PCB design is followed by one week of 3D modeling. This makes sense. A weekly rhythm is strict and fast. A thematic break allows students to fill in or make corrections to the previous assignments outside of the actual topic. Why does it work out? Given students' pre-qualifications some weeks are relatively easy and assignments quick to solve, depending on their individual knowledge background. For example, an industrial designer will find it easier to design and model a product than to develop a circuit board.
- Weekly reviews, mostly online, give early feedback on assignments.
- A final project running over several weeks should integrate a number of topics. It checks the skills learned.

Even if the topics are fairly interesting, the most thrilling part is the studying technique, the combination of blended learning and pure implementation-oriented learning, which can easily result in a ubiquitous way of learning.

3.3.3 Field Report

The following field report by a 2017 Fab Academy student (Konopek 2017) shows how mushroom strategy takes place in a very special situation, when the instructor's or guru's support is reduced to the bare minimum and a learning week of about 60 hours+ becomes the norm.

It should be emphasized in advance that the assignment of tasks was one of the main success factors.

The Fab Academy's assignments all have a similar structure throughout:

After a short weekly review, the student attends a 90-minute lecture on the upcoming topic and its sub-items. The lecture provides an intense overview of state-of-the-art science and technology including a huge representative range of products and working methods. Some of the products are analyzed and highlighted, such as 2D or 3D design tools, CNC machines, etc., followed by best practice or successful examples.

Now, the student must come up with a project or product idea and choose and explore one or more working methods of realizing that idea. Research and workflow must be recorded online in the Fab Academy's archive. The documentation should take the form of instructions or guidelines.

3.3.4 The Workflow

The weekly topic generates a focus on one purpose: realizing the idea and completing the assignment.

1. After brief research on working methods, software and the fab lab's equipment, the preferred working method must be chosen depending on the project requirements.

2. A near-simultaneous learning and implementation process starts:

- Make sketches on constructional features of the project.
- Research similar open-source projects in the Fab Academy's archive and online.
- Search for online handbooks, manuals and video tutorials.
- Communication with fellow students and neighbors and request for hints.
- Download software tools required for realizing the project.
- Research retailers and buy missing tools, accessories and molding material needed.
- Literature research for additional and continuing studies (good for bedtime reading).
- Read instruction manuals (if required) or obtain operating instructions from the local instructor.
- Design, planning and realization of the project by trial and error.
- Take notes and pictures of the process.
- Instructor or guru assists only where necessary.

3. Write an online documentation with the help of the recorded notes and pictures.

4. Local review/global review. Lecture, with next topic.

3.3.5 Thoughts on Assistance during the Fab Academy Training

Although the mushroom strategy is a highly self-motivated and self-learning strategy, there are important factors keeping the student focused. The weekly rhythm is one of them. It divides the training course into clearly set-out learning units. Combined with the educational orientation of the course structure, it helps systematically increase knowledge and skills with a view to the final product. The ubiquitous technology as well as freely accessible online tutorials, videos, open-source tools and information facilitate research, learning and implementation processes. However, sometimes progress is difficult without any personal assistance. Lectures should be given to communicate important structures and links between relevant information that cannot be easily found on the Internet or in literature. Sometimes, the guru's or instructor's direct intervention is unavoidable. Yet this point is highly sensitive. Too much assistance makes students passive and the learning effect falls. No assistance can easily cause failure, because of two possible factors: First, the student may lose focus. The instructor's duty is to remedy this. Second, insurmountable obstacles may cause the student to discontinue the training course. Obstacles could be missing equipment or a permanent failure of the breadboard. The instructor's duty is to organize and supplement the standard equipment or help the student to do so and to support him/her with difficult problems or find an easier way to solve them together with the student. The right amount of help will increase the knowledge of and empower the student.

3.4 Feasibility of the Mushroom Strategy for New Fab Lab Users Particularly Individuals and Companies

Set up on the above report the main task is to customize and integrate the mushroom strategy into more open and self-qualifying projects within workshops without any assessments and evaluations. Based feature of this task is the idea that only a ubiquitous attitude in combination with one´s own project can lead to the mushroom strategy. A missing attitude cut off this strategy. This very important point has to be imparted.

The experiences of various groups of new fab lab users show similar problems. First off all, new learning individuals and groups are overcharged because of the huge range of options this kind of workshops offer. Too many unknown machines and software tools. Even if they already have a project idea, they don´t know how and where to start. On the internet one can find nearly all kinds of manuals for machines or tutorials for software tools and well described projects, but the new fab lab users aren´t able to rank this information. This mostly leads to frustration and unproductivity. Even a simple reference to information, tutorials, manuals for machines, software tools and projects in internet is helpful but not enough. An implementation oriented perspective is still missing, the behavior is more passive, waiting for input from an instructor or teacher. But for applying the mushroom strategy one needs a ubiquitous attitude to be able to implement and learn in the same time without any pressure and evaluation. On the other hand, too much assistance

of an instructor reduces the time for implementing the project idea but also the learning effect. It keeps the learners passive and nearly untaught. Indeed, if they implement their projects by themselves, they understand how it works and are able to repeat or improve their projects, again. This should be recognized.

Mentoring is therefore necessary before a project starts and during the development process. By this the self-qualifying process can take place with more satisfaction and a sense of self-empowerment.

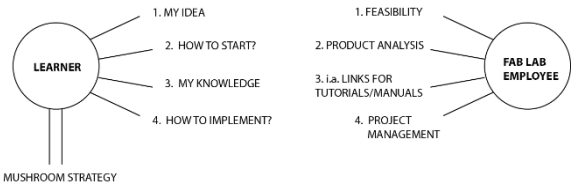

Figure 2: Learner – Mentoring Process. Preparing learners for the mushroom method as a self-qualifying technique.

According to different kind of instructions our fab lab seminars for students, individuals and companies show different behavior of patterns. In predefined lessons participants become more passive. They have more difficulties to create own project ideas, compared to open lab days, where participants come up with ideas first and want to implement them.

3.4.1 Limit of the Mushroom Method

The success of this ubiquitous way of learning depends on two factors. First, the quality and quantity of given support during the learning and implementation process. Second, the learner should adopt a ubiquitous attitude to be able to focus the aim during learning and research processes. Without any support the projects often end in demotivation caused by information overload. Too much support makes the student more passive and tends to result in the old student-teacher-relationship which isn´t effective for this type of learning environment. There is a thin line between too much and too little support during the ubiquitous learning process, as it should be completely self-motivated. Influencing factors which define a range of helpful support have to be explored to make this ubiquitous self-learning strategy successful. As well as a suitable amount and quality of support for building up and keeping a ubiquitous attitude.

3.5 Resulting Questions and Research Aspects

- What is the quality of the knowledge gained? Can it match Schelhowe`s sustainable knowledge (2013) in terms of applicability in different situations?
- Which personal attributes, skills and abilities are required and/or will be developed through this mushroom learning method?
- Does this ubiquitous way of learning within a training program transferred and adapted to the daily routine of a fab lab – maintains the same learning quality without any pressure from a supervisory authority?
- Is it possible to integrate this learning and implementation method into other given organizations or companies as a co-operative self-qualifying concept (Heidack 2001)?
- Developing a vivid and well-thought-out net of carefully-presented knowledge is one aim. The missing links for switching learning levels in present fab labs which are criticized by Katterfeld (2013) should be easily bridged by the combination of this net and the mushroom learning method.

4 CONCLUSION

A fab lab, exemplary for open workshops, is an institution where people are free to come and learn and develop things without any pressure or expectations as regards certification. After a brief explanation of functionality and goals of a fab lab, a mainly self-learning method proposed to be called mushroom strategy is outlined. A field report of a student specifies how the mushroom strategy is taking place within an ambitious training and certification program, executed in fab labs. Its learning method combines blended learning with implementation-oriented learning and provides a basis for a particular and extreme learning situation. It led the student expand the learning method into a ubiquitous kind of learning in the most consistent meaning of the term. In view of the mushroom strategy and the aims of a fab lab or open workshop, the report highlights the idea of and thoughts on integration of a free mushroom-strategy learning environment within open spaces. A proposal for a learner-mentoring-process is described. Basic principles for applying the mushroom method are a ubiquitous learning attitude and the right amount and quality of mentoring.

First indications in seminars and workshops show, that mushroom strategy can be an effective extension to present learning concepts, particularly regarding heterogeneous and hierarchical mixed groups and should be explored more detailed.

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