Be(com)ing an Eco-Maker – a Pre-Structured Self-Learning Concept for Environmentally-Friendly Product Creation in Makerspaces

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I. Roeder[1], A. Klemichen[2], and R. Stark[3]

[1]Ina Roeder; Industrial Information Technology, Technical University Berlin; e-mail: ina.roeder@tu-berlin.de
[2]Antje Klemichen; Industrial Information Technology, Technical University Berlin; e-mail: antje.klemichen@tu-berlin.de
[3]Prof. Dr. Rainer Stark; Industrial Information Technology, Technical University Berlin; e-mail: rainer.stark@tu-berlin.de

Introduction

Cooperation of educational institutions and makerspaces are still rare in Germany. However, while institutions of higher education have recently begun to explore the potential of makerspaces as educational settings, the makerspaces themselves have become an object of research interest. In the *ecoMaker* project led by TU Berlin an educational unit has been developed that combines the logics of making and self-organized learning to increase the awareness for environmental impacts of production in makerspaces. This educational unit is directed at both, educational institutions and the maker community. Its core method is the *ecoMaker Design Sprint* that offers a structure and tools for the design phase of the eco-oriented product creation process. The educational unit has been tested and altered in three iterations. Additional educational methods and tools have been incorporated to come up with a compact educational unit that has the format of a product-oriented hackathon, based on eco-design principles. As "*ecoMaker Student Training*" the concept has been tested with A-level high school students and students from an apprentices' school. For the maker community it has been evaluated positively as the structuring element of a public hackathon at Fab Lab Berlin.

Identifying a "Behavior Gap" in German Makerspaces

In contrast to the US, German makerspaces have primarily been grassroot initiatives that enable the general consumer to become a producer of own goods and are therefore associated with individualized production and the open movement which is itself closely associated with a positive attitude towards sustainability [1]. Although nowadays makerspaces are increasingly founded by higher education institutions in Germany as well, even those makerspaces remain in part places for exploration and tinkering, having often been established as Fab Labs with some degree of openness to the general public and hosting a variety of fun student projects. At the same time the academic market penetration also creates rippling effects on private makerspaces such as the *ecoMaker* project, led by Technical University Berlin, which seeks to turn public and private makerspaces alike into learning environments for eco-friendly product creation processes.

A Germany-wide survey conducted in 2018 [1] that focused on mapping the "behaviour gap" described by Kohtala [2] as the typical discrepancy between makers' intentions and actions regarding sustainability, showed that this kind of gap cannot be systematically found in German makerspaces. Although the response rate was low (makerspaces were stating that they had been hit by a shear wave of surveys and questionnaires at that time that had led to survey fatigue), it was clear that a missing key factor for the "behaviour gap" was the intention to produce sustainably in the first place. The data showed little consideration of sustainability criteria by German makers as well as lack of knowledge of methods and tools for integrating it. However the majority stated that they were willing to integrate sustainability criteria if it was a simple and low-budget process. As a result, the researchers of the *ecoMaker* project abandoned their original goal of producing academically oriented online courses and an elaborated workshop series. Instead they set out to develop solutions that required low investment, showed quick results and offered unobtrusive learning options along the way. For the setting of co-production the major solution developed was the *ecoMaker Design Sprint*. The *ecoMaker Design Sprint* is a sprint format that integrates design thinking and engineering techniques enriched by simple didactic tools that enable pre-structuring of eco-friendly product design while leaving room for deep learning experiences. The special design of the *ecoMaker Design Sprint* allows it to be applied in situations of product-oriented co-creation, may it be in a distinct educational setting or a typical makerspace event such as hackathons.

The *EcoMaker Design Sprint*

Design sprints are a method that originate from design thinking approaches. They describe a development process usually split in the five phases (1) understand, (2) diverge, (3) converge, (4) prototype, and (5) test [3]. The method has been developed to bring innovative products to market and reduce market risks by including a very broad system level perspective into the product development.

The method has a number of advantages for educational settings. First of all, things need to go fast. There is a strict time-constrain for each phase so that the people involved work very focused and concentrated which helps getting into a state of flow, which again is considered the ideal learning state. Second, they work in teams. Collaborative learning is good for training many soft skills that children ought to

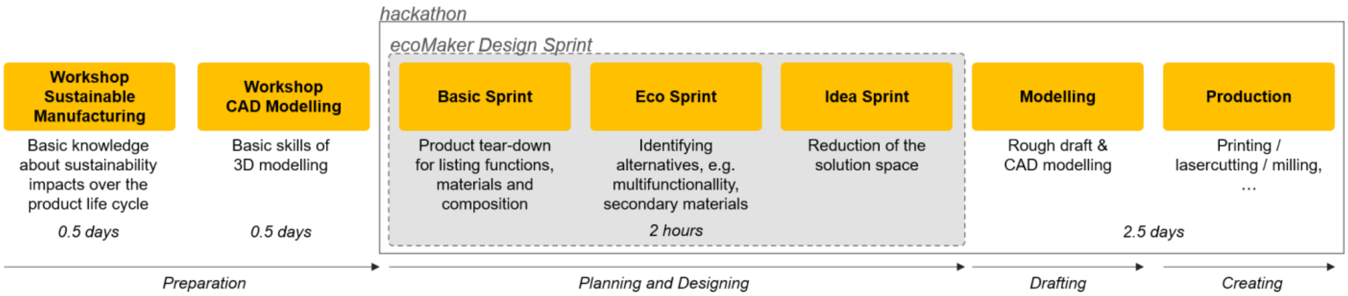

Fig. 1 First draft of the* ecoMaker Student Training *including the* ecoMaker Design Sprint *as a structuring hackathon element

develop and from which adults will also benefit. Third, while working under strict time-constrains, people are encouraged to think out of the box to find innovative solutions. Creative thinking and problem-solving requiring transferring knowledge to new fields are central for design sprints and also best practices in teaching. Fourth, the result is a product which is the materialization of the acquired knowledge. Fifth, the product has actually to be made which requires a considerable amount of learning by doing. The analogies of design sprint basics and best practices in teaching strongly suggest the integration of design sprint elements into educational settings. The *ecoMaker Design Sprint* focuses on eco-friendly product design in the context of education for sustainable development on a beginner's level. Therefore, the system thinking approach appeared too ambitious for participants that have little former knowledge of both, sustainability and market economics. So the design sprint format was adapted to concentrate on the product design only, leaving out broad market considerations and testing phases. The "understand" phase of typical design sprints is represented by the *Basic Sprint* during which participants undertake a product tear-down [4], meaning they define all parts and functions of their targeted product for better understanding the product. The "diverge" phase is represented by the *Eco Sprint* and concentrates on identifying eco-friendly alternatives for each defined part and function to open up the solution space. This space is then narrowed down in the "converge" phase, represented by the *Idea Sprint*. This is when participants choose a number of identified alternatives which they actually want to integrate into their product. This narrowing down of the solution space is equivalent to the cognitive process that has been described as strategic control or synthesis in design thinking [5], [6].

The *ecoMaker Design Sprint* has been designed to be the core of an educational unit that also offers basic knowledge needed for eco-friendly product creation. In the first version, the entire unit consisted of (1) a workshop on sustainable manufacturing, (2) a workshop on CAD modelling, (3) the *ecoMaker Design Sprint*, and (4) a hands-on phase (modelling and production) as shown in Fig. 1.

The phases modelling and production (or "drafting" and "creating" in the terminology of classical product development [7]) were not considered to be part of the design sprint. This means we excluded the classical phases "prototype" and "test" from the design sprint since we wanted to eliminate the time-constrain during this part of the hackathon.

A half day workshop on sustainable manufacturing was implemented in the initial phase of the educational unit to give participants the necessary basic knowledge for the design phase of a product which they had to choose and to design during the *ecoMaker Design Sprint* in order to build it during the 2.5 days hands-on phase. Another half day workshop on CAD modelling was introduced to enable makers to generate their own data files during the hackathon.

Tinkerers have a strong tendency towards self-instructed learning types. As interviews with our practice partners and the survey from 2018 showed, they often prefer to work and learn on their own, often engaging in co-production in an unstructured and unplanned manner. In education, on the other hand, taking responsibility for one's own learning process and outcome is a key educational goal. Respecting the autonomous focus of makers and considering personal responsibility as a learning goal, the design sprint was developed to enable people to go through the entire process of the sprint without an instructor. The major design sprint tool (a canvas) was supposed to lead the maker through the structure of the sub-sprints.

Experts' feedback and repeated testing have led to adaptations of the general structure of the educational unit and to the development of additional guiding tools that ensure self-organized learning. The outcome is a simple but effective open source product for educational purposes in makerspaces, academic and non-academic alike.

Development and Test Field

The *ecoMaker Design Sprint* has evolved via three phases of growth: the development and initial test, changes in the general structure, and adaptations for self-organized learning. This development shall be traced in this section.

The program was developed by an educational scientist and researchers from the field of product design together with three STEM teachers from the project's partner schools. It was originally arranged to fill an entire week. When it came to the testing phase of the concept with 30 students (10th and 12th grade) the schools found it difficult to clear the students' schedules for such a long period. Several students could participate only part-time and missed some essential elements of the unit. Their absence allowed us to treat them as control group and offered important insights in the effects of the different modules of the educational unit.

Those students who had missed the workshop on sustainable manufacturing (about 50 %) showed a lack of consideration of ecological sustainability criteria in their products.

Interestingly, those who had participated in the workshop and incorporated such aspects in their product planning mostly did not refer to the content of the workshop but mainly showed their own line of argumentation. Therefore, it seems that the workshop first of all had a priming effect, activating a working-self within the participants that matched the environmentalist focus of the event.

The working-self is a psychological concept that describes which facets of a person's identity are accessible to that person in a given moment. The facets emphasized in a certain context form our situational working-self. Priming occurs when the awareness for certain identity aspects is raised by a stimulus. This leads a person to interpret subsequent information under the impression of these identity aspects. People interpret situations as identity-congruent or identity-incongruent, depending on which aspects of their personality is particularly active at a certain moment [8]. The recognition of a situation as identity-congruent has strong motivational effects whereas tasks interpreted as identity-incongruent might seem "not worth the effort". Therefore, the question which working-selves are active in learners is important.

It seems that the workshop on sustainable manufacturing had had such a useful priming effect on the participants' self-recognition, emphasizing environmentalist aspects within their working-selves. Thus they were more eco-oriented than the control group even though they did not rely on the specific facts offered during the workshop. Furthermore, it became clear that in order to help students to get into a state of flow and therefore deep learning, theoretical content of the educational unit had to be reduced.

As a consequence, the educational unit was shortened to a three day program (see Fig. 2). The workshop on CAD modelling had not been sufficient enough for some of the students to handle the software on their own during the hackathon (while other students had already been competent in using such programs and had been bored during the workshop). Therefore, it was eliminated from the educational unit. Since the content of the workshop on sustainable manufacturing itself appeared to be less important than its priming function, the workshop was replaced by a storytelling approach [9] that should have a similar priming effect while being much less time-consuming. The method of storytelling has been chosen due to its ability to efficiently convey condensed information within the context of "ongoing cause-and-effect structures of the temporal events" [10] to learners. Furthermore, a very quick tour through the design sprint landscape was added as *Sprint Training* before starting the actual *ecoMaker Design Sprint*.

The educational unit and the design sprint element were also presented, applied and discussed iteratively in three workshops with experts from the educational field. The educational unit was clearly appreciated since it gave educators a methodological approach to cover two difficult topics at once, technology and sustainable development.

Major challenges identified by the experts tackled fundamental aspects of cooperating with makerspaces in general and not so much the method itself. While most educators were happy to let students develop their own projects, some felt irritated imagining that they would give up their role as instructors during the entire educational unit even when there was makerspace staff to assist the learners during the practical phases (learning facilitator is a teachers' role which has hardly entered the practical field in Germany yet [11]). Furthermore, they were worried about security or insurance matters when allowing students to work with comparably big machinery. Another major concern was the accessibility of makerspaces. None of the educators knew if there even was a makerspace in their town, leave alone one that offered student programs.

While it is true that makerspaces are rather rare in some parts of Germany, most medium-sized cities do have such a space which is obviously unknown to the teaching community. Although there are some makerspaces that offer an elaborated curriculum for students, they usually don't cooperate. Public funding of such projects is very limited so that some makerspaces even decide to keep the details of their offers to schools a business secret to prevent other spaces from copying their program. This makes it hard for teachers to identify potential partners and to get a first impression of what to expect when cooperating with a makerspace nearby.

These concerns could not be addressed by the educational unit. However, a brochure is going to be developed by the *ecoMaker* project that will answer the identified concerns of educators and provide a general overview of cooperation opportunities of makerspaces and educational institutions.

The third round of feedback came from practitioners from the maker scene. A major realization was the necessity of guiding tools. A method that found wide acceptance were guiding questions [12] that offer inspiration to the participants during the *Eco Sprint* while giving them a great degree of freedom regarding the definition of the solution space. Obviously, this freedom was a central requirement for makers' acceptance of

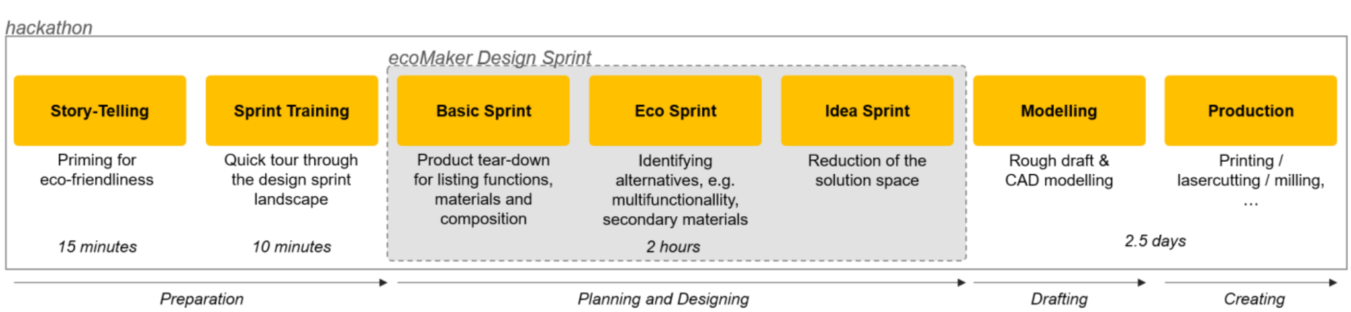

Fig. 2 Final draft of the **ecoMaker Student Training,** *integrating all elements into the hackathon format*

the design sprint method since they rejected other more closed assisting methods or tools. Based on that feedback, additional tools were (re)designed for maximal openness (as described in the next section).
The latest version of the educational unit was tested in a public hackathon “Re:Think Mobility” at Fab Lab Berlin. In a feedback workshop the *ecoMaker Design Sprint* was evaluated as being very useful for structuring the hackathon in general and the design process in particular. Special praise was given to the additional tools that made the method very clear and enabled the teams to work independently. All teams successfully integrated at least some of the eco-friendly alternatives that they had detected during the *Eco Sprint*. Suggestions for improvements touched minor aspects of the tools’ design. Therefore, the *ecoMaker Design Sprint* was defined as ready for market including its assisting tools which shall be described in the next section.

Tool Set of the *EcoMaker Design Sprint*

The main tool of the *ecoMaker Design Sprint* is the working canvas. The canvas shows two concentric circles, representing the *Basic Sprint* and the *Eco Sprint*, as shown in Fig. 3. In the centre a third circle segments the sprints by the impact fields manufacturing, materials, function, end of life and use phase.
During the *Basic Sprint*, the makers use sticky notes to note down as many parts and functions of their product as they can think of and attach them to the respective segments of the *Basic Sprint* circle. For a desk lamp this could be e.g. the function of casting a spot light for which it needs the part “bulb” and electricity during the use phase. It could also refer to the part “plastic stand” usually manufactured through injection moulding which might be difficult to recycle at the end of life.
In the second sub-sprint, the *Eco Sprint*, participants again use sticky notes to note down as many eco-friendly alternatives to common strategies for the specific product as possible, yet not considering feasibility or costs, but simply opening a broad solution space. For the desk lamp this could be an energy saving bulb and a wooden stand.
In order to help participants to deal with the shear amount of aspects that could be considered during the *Eco Sprint*, a cardboard-based tool with guiding questions in a wheel design is offered. This cardboard wheel displays three key fields for potential eco-friendly improvement on the outer rim, naming materials, processes and end of life. Below each key field guiding questions are aligned that encourage own thinking and sometimes some research such as “Where do the raw materials come from?” or “How could energy be saved within this process?”. Those guiding questions are inspired by the “10 Golden Rules in EcoDesign” [13].
To structure the makers’ approach to alternative solutions, a second and smaller disk is attached over the guiding questions with a window leaving open only one key field. Arrows indicate the direction in which the window was to be moved on (so the makers can consider one potential alternative at a time).
During the following *Idea Sprint* the solution space needs to get reduced again. To do so, each possible alternative is revised and checked for its suitability for the targeted product. Alternatives that cannot be realized in the concrete setting are taken out of the circle so that only feasible alternatives remain.
For the *Idea Sprint* the *Logbook* is offered as an assisting tool that helps mastering the sprint in a structured way. The *Logbook* is a ring book that picks up the most commonly stated elimination criteria, namely accessibility, time, and costs on one page each, and adds space for further personal demands such as aesthetics. Participants are encouraged to first define their personal limits for such resource investment. In a second step they are given a colour code to evaluate each potential alternative according to those limits by marking the respective sticky note as “certainly”, “probably” or “never” acceptable. In the case of the lamp this could mean that a

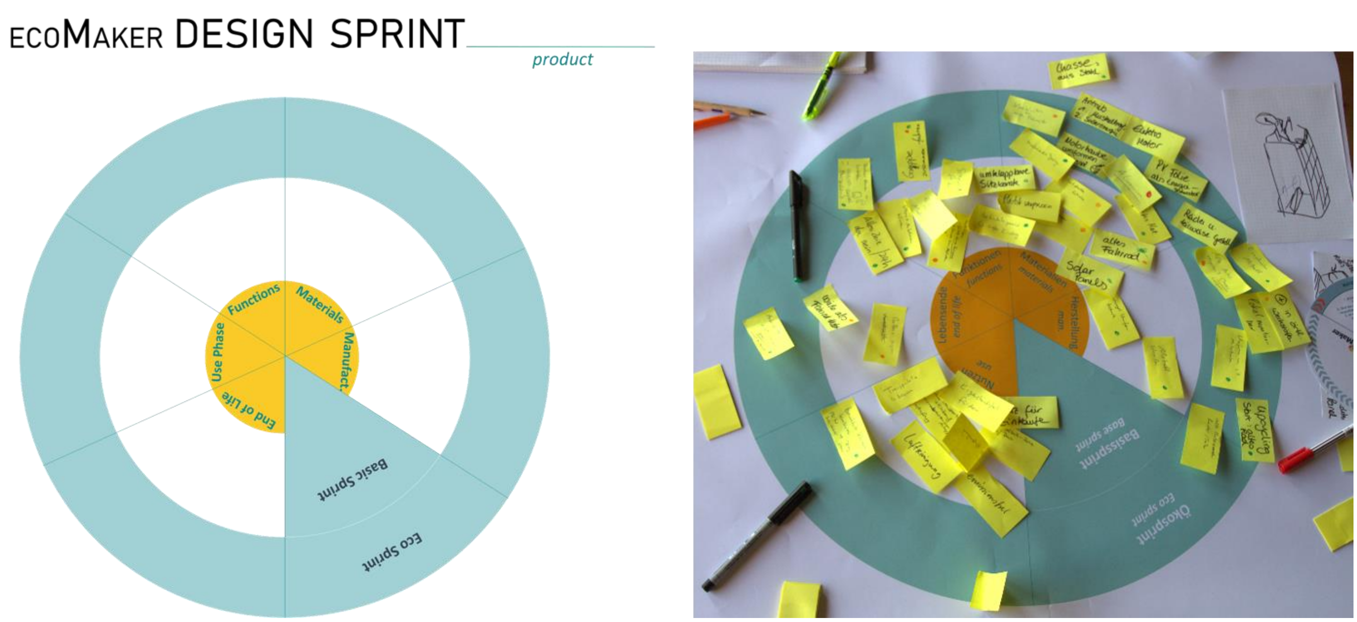

Fig. 3 Final version of the* ecoMaker Design Sprint *canvas as template (left) and in use (right)

certain fast-growing wood that has been taking into consideration, turns out to be not available, to require excessive shipping time or to exceed the financial limit of the participants. It also might not meet their individual demands e.g. with regard to aesthetics due to its special texture. On the last page of the *Logbook* participants are instructed to remove all alternatives that have been allocated with at least one "never" or less than two "certainly" evaluations. The remaining solutions are to be prioritized and revised against their cumulative impact in order to define the cutting line for total investment. All solutions that are ranked above this line can be considered by the participants for they meet the individual demands. Since the ring book pages are laminated and the pens handed out are suitable for overhead transparencies, the ring books can be wiped and re-used after the workshop.

After all this has been done in no more than two hours the canvas shows the strategy which the participants will follow while designing their product. Only now can they enter the drafting stage of the product creation process.

Summary

Although a "behaviour gap" is not evident for users in German makerspaces due to the lacking intention to design and produce sustainably in the first place, the increasing reciprocal effects between makerspaces and higher education allow to integrate eco-design methods in both settings, synthesizing the maker logic with didactics of making. The *ecoMaker Design Sprint* serves as an example of an educational unit that has been developed to meet the requirements of both spheres and that can be integrated in both routines alike. In three sub-sprints, *Basic Sprint*, *Eco Sprint*, and *Idea Sprint*, eco-friendly alternatives to common product compositions are identified and matched with the personal demands of the makers. A canvas displaying the first two sprints, a cardboard wheel with guiding questions, as well as a *Logbook* to define resource limits help the makers to follow a structured approach to their individual eco-friendly product design.

During the testing phase of the method it became apparent that the quality of the participants' working-self during the design sprint decides over the incorporation level of the design sprint goals. A working-self rather congruent with the *ecoMaker Design Sprint* setting turned out to be sensitive to priming. Storytelling has proven to have such a favourable priming effect and therefore constitutes the initial phase of the educational unit.

The *ecoMaker Design Sprint* has been integrated into the general introduction workshops at Fab Lab Berlin and also constitutes the methodological approach of the students' hackathons at the VINN:Lab (the biggest public makerspace around Berlin). All methods and tools developed within the *ecoMaker* project will be made available open source on the *ecoMaker Learning Platform* by April 2020.

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