Design as Open-Ended Inquiry

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Abstract: While it seems quite obvious that collaborative design is a creative process, its relation to knowledge creation is far less obvious and indeed not trivial. Design as knowledge creation is a pedagogical model which aims at creating knowledge in design processes rather than solely designing and implementing products. Roughly speaking, design as knowledge creation entails at least the following elements: 1) creation of a local theory of the problem at stake, 2) deriving a working hypotheses (the designed product or services) that might overcome the problem in line with the local theory, and 3) evaluation of the developmental aspects of use and viability of the proposed solution. The designed product and service working as a hypothesis also serves as a means to explore the problem and design space more deeply, creating a refined working theory. This paper provides an understanding of design as knowledge creation and defines a pedagogical model for design education. Its implementation is shown in a scenario.

1 Introduction

The fact that many products and systems are utilized differently from the designers' intentions and expectations has been recognized widely and led to an ongoing discussion about the interrelation of design and use (e.g. Béguin, 2003; Carroll, 2004), both entailing developmental aspects (Bødker & Petersen, 2001). Nevertheless, there is little agreement neither on the processes that shape the adoption and utilization of new products by the user nor on how these could be reflected in the design process itself so far. For example Béguin (2003) lists three main interpretations, ranging from insufficient knowledge of the designer with regard to users' needs, over situational circumstances and contingencies, to the productive and developmental nature of human activity itself. Even though there is more and more agreement that the active appropriation of products by the user is not the designers fault, current process models for engineering design as well as models for design education hardly take into account situated and productive nature of human activity. Consequently engineering and design are still often seen and taught as an instrumental process aimed to solve some more or less distinct problem. We belief that in order to create "better" products which respond to users' needs and overarching issues such as sustainability and inclusiveness we have to come to terms with the relationship between design and use as well as to develop new models for design and design education.

1.1 Motivation

The model of design as knowledge creation proposed in this paper also arose from a problem we face and investigate in design and engineering education. In design processes students poorly explore the problem space and hardly question the initially stated problem, but concentrate on listing requirements which already entail a solution, stating that the solution will work without validating the statement and being able to form a respective argument. They focus on implementing and finalizing a product from an early stage on. Problematizing ones' own and peers' design decisions and solutions as well as explicating and problematizing underlying rationales/assumptions/premises/implications seldom takes place (e.g. assuming users needs and practices, mechanisms). As they do not explore the problem space deeply, they are hardly able to argument and question their solution. Students normally do not utilize design options and solutions as helpful tools to explore the problem space more deeply. The pedagogical model of design as knowledge creation is developed to meet these challenges.

1.2 Objectives

Against this background the aim of this paper will be twofold. Building on cultural-historical activity theory (Leont'ev, 1978, Engeström, 1999) as well as the knowledge-creation metaphor of learning (Paavola, Lipponen, & Hakkarainen, 2004) we conceptualize design as a particular kind of knowledge creation activity. Emphasizing the productive nature of human activity, we argue that the designed artefact can be understood as a working hypothesis, which is tested when the product is put into use. It works as a means of progressive and open ended inquiry. The design hypothesis itself thereby is a result of abductive reasoning based on local assumptions on potential users' needs and practices. Evaluation of the designed artifact (product/service) in use and its appropriation provides the basic input for the revision of the local assumptions as well as the working hypotheses, i.e. the product, system or intervention as a designed and "materialized/symbolized" hypothesis.

Furthermore, the paper provides a pedagogical model to support design as knowledge creation in design education. The model of design explained above has been applied in a cornerstone course in the study program „Communication and Knowledge Media" at the University of Applied Sciences Upper Austria. In this course students are asked to conceptualize, implement, evaluate, and revise a personal learning environment built from off-the-shelf software applications. Pedagogical means to foster design as knowledge creation include techniques of conceptualizing the design space for explicating students' design assumptions and hypothesis as well as enforced breakdowns by regular peer-to-peer reviews. The basic aim of our work is to develop and test new models and methods for design education emphasizing design as a particular kind of open ended inquiry. The intent of our educational interventions is to support innovative (knowledge) practices among engineering and design students.

The approach of design as knowledge creation is different from research in design where specific research methods are developed to be used in design processes (e.g. Lunenfeld & Laurel, 2004). Whereas deepening understanding is usually assigned to research and producing artifacts to design, design as knowledge creation is concerned with inquiry and conceptualization in local context.

2 Design as Knowledge Creation

While it seems quite obvious that collaborative design is a creative process, its relation to knowledge creation is far less obvious and indeed not trivial. Therefore we think it is important to explicate our understanding of design as knowledge creation first. We use the term design in a broad sense including the development, realization (, and use) of both products as well as services. This also comprises the design of multimedia-products as well as instructional designs and interventions.

2.1 Design Theory: Design Artifact as Hypothesis

Maldonado (2007) elaborates on Defoe's The Life and Strange Surprising Adventure of Robinson Crusoe of York, Mariner (1719), stating that Robinson, living in the projecting age, had to build a cottage and to decide on its physical configuration despite being in a cognitive distress. Just having arrived on the island he did not have knowledge on the severity and frequency of local environmental strengths and conditions. Thus, according to our approach of design as knowledge creation, the design solution (the cottage Robinson built) was no more than a working hypothesis about the unknown natural environment. The hypothesis needed to be revised when the cottage was damaged by unexpected strong winds etc: Robinson most likely will have revised the design and also will have conceptualized on the environmental conditions in a local context and the appropriateness of his design solution. According to Maldonado (ibid), Defoe located Robinson in an extraordinary situation as he deprivated him from society (except his own cultural background) in a purely natural environment. When doing design in social context, designers are confronted with more complex and ill-structured situations as well as with norms and values. Design problems are wicked, the context is not stable and design artefacts work as interventions mediating social practices, transforming human activity systems and context, and are appropriated and thus further developed in use. Defining the artifact as hypothesis (generated by abductive reasoning) means that we understand design and engineering not as applied sciences. The model of design which design as knowledge creation refers to is not the artifact as theorem (deducing the artifact from a set of statements), nor the artifact as theory (producing the artifact by a process of induction from a set of requirements) (cp. Coyne, 1988).

Design as knowledge creation aims at creating knowledge in design processes rather than soleyly designing and implementing products. Thus, the outcome of design is knowledge and products. Of course it might be argued that the outcomes of the design process (product or service) "embody" or "objectify" the implicit and explicit assumptions and insights of its developers and hence the outcome produced is the knowledge created. Even though we agree that the products or services created reflect the assumptions and insights of its developers we think that it is too simplistic to equate the product or services with the knowledge created. To our understanding the artefact (designed objects such as products or services) constitute a working hypothesis of the designers, which is tested when the designed outcome is put into use. Given the wicked nature of design problems putting the designed solution into use is most often the only way to check the viability of the proposed solution and it is by this test, which compares the envisioned and observed effects, that we are able to create knowledge. Roughly speaking, design as knowledge creation entails at least the following elements: 1) creation of a local theory of the problem at stake, 2) deriving a working hypothesis (the designed product or services) that might overcome the problem in line with the local theory, and 3) evaluation of the viability of the proposed solution.

Whereas usually research is concerned with deepening understanding, design is expected to come up with a product/service/artifact. Design as knowledge creation is concerned with both as the designed artifact as hypothesis works as a means to explore and conceptualize the design space more deeply, creating a refined working theory. The object of activity is design and conceptual understanding. The kind of knowledge to be created in this process is aimed to provide answers to the question on what works for whom, how, and under which conditions (in this sense design is also aimed at a particular kind of knowledge which is different from those to be created by scientific inquiry and organizational learning).

2.2 Activity Theory in Design

Activity Theory (Leont'ev, 1978) as a framework for designing artifacts, policies, services, organizational structures, user interfaces and systems as well as for explaining the transformation of practices when introducing innovative artifacts from a cultural-historical perspective (Engeström, 1999) and for understanding the developmental aspects of use in appropriation is known in design literature (e.g. Bødker, 1990; Bødker & Petersen, 2001; Uden, 2007; Béguin & Rabardel, 2000). It allows explaining the mediating role of artifacts in community's practices. The designed artifact does not determine the way it is used rather it mediates the practices within a socio-cultural context in an unforeseen way (Engeström, 1990). Engeström introduces the framework of a human activity system to describe practices, assuming that all elements of the system are mutually interdependent. The change of the one means the transformation of the others and thus the entire system.

Building on activity theory in this paper is twofold: Beyond understanding design and use of artifacts based on this framework, we harvest on activity theory to propose a pedagogical model for design education and to plan educational interventions. At a first glance this is a self-referential adventure. Teaching students to understand design and use through an activity theoretical perspective and on the same time, planning pedagogical interventions according to activity theory. But to grasp the planning of pedagogical interventions as design makes this likely. Learning is not seen as individual information processing but as a socio-cultural and trialogical activity (Hakkarainen & Paavola, in press) of students deepening their understanding and transforming knowledge in collaboratively developing and manipulating an artifact. Depending on whether the (epistemic) object of activity is the local theory or the design to be created the tool and expected outcome of the learning process is different (figure 1).

3 Pedagogical Models

In our research activities we investigate design practices of students and identify their design tactics. Interactions of students and clients are analysed systematically using qualitative research methods (discourse analytic approach) and tactics are identified (productive and unproductive interactions such as: "unarticulated expectations regarding each others roles and responsibilities" and "solution based requirements validation") and collected in order to make them available to reflection. An important objective of educational intervention is to transform design practices and knowledge creation practices. In order to plan pedagogical scenarios we conceptualized a pedagogical model based on the approach of design as knowledge creation. The overall foci of the pedagogical model are:

- Design as inquiry and open-ended problem solving
- Design as knowledge creation as co-evolution of product and conceptual understanding
- Dynamic interrelation of product (addressing user needs) and process (open ended inquiry).

The pedagogical model we outline includes three main components, a general notion of design as knowledge creation, a list of propositions and a heuristic model of design-based learning. The following describes the components in a nutshell. But first of all the pedagogical model is integrated in a broader context.

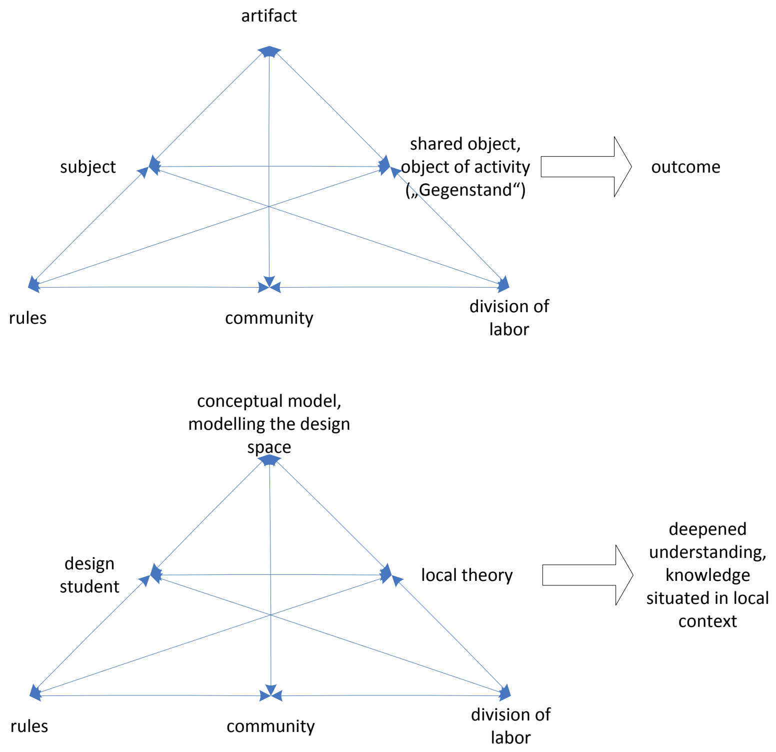

Figure 1: The human activity system (Engeström, 1990) used here to describe different objects of activity in design

3.1 The Pedagogical Model in Context

This section briefly explicates our understanding of a pedagogical model before providing a concrete scenario (case). Figure 2 is an attempt to depict the relationship between learning theories, the approach of “learning as knowledge creation” (Paavola & Hakkarainen, 2004), pedagogical models such as “design as knowledge creation” and “progressive inquiry learning”, scenarios, patterns and cases. This helps to clarify the distinction and relation between learning theories (a descriptive theory about how information processing, knowledge creation etc. works), domain theories, normative commitments, and a pedagogical model (about what should be done). According to that, educational interventions and a pedagogical model is not applied learning theory but entails normative commitments and intentional decisions such as empowerment and the ideal of Bildung (Klafki, 1996). We understand a pedagogical model as the general conceptualization about how a pedagogical approach can be applied in a certain domain or field of activity. For example “design as knowledge creation” is a pedagogical model that aims to apply the approach of “learning as knowledge creation" and learning as open ended inquiry to the context of design and product development. If this approach is introduced to different context, it focuses on different objects of inquiry (conceptual artefacts (PI), products or services (design as knowledge creation) or social practices (practice transformation)). Consequently a pedagogical model would go "beyond" the approach of "learning as knowledge creation" as it has to take into account domain-specific theoretical foundations (e.g. philosophy of technology and design theory).

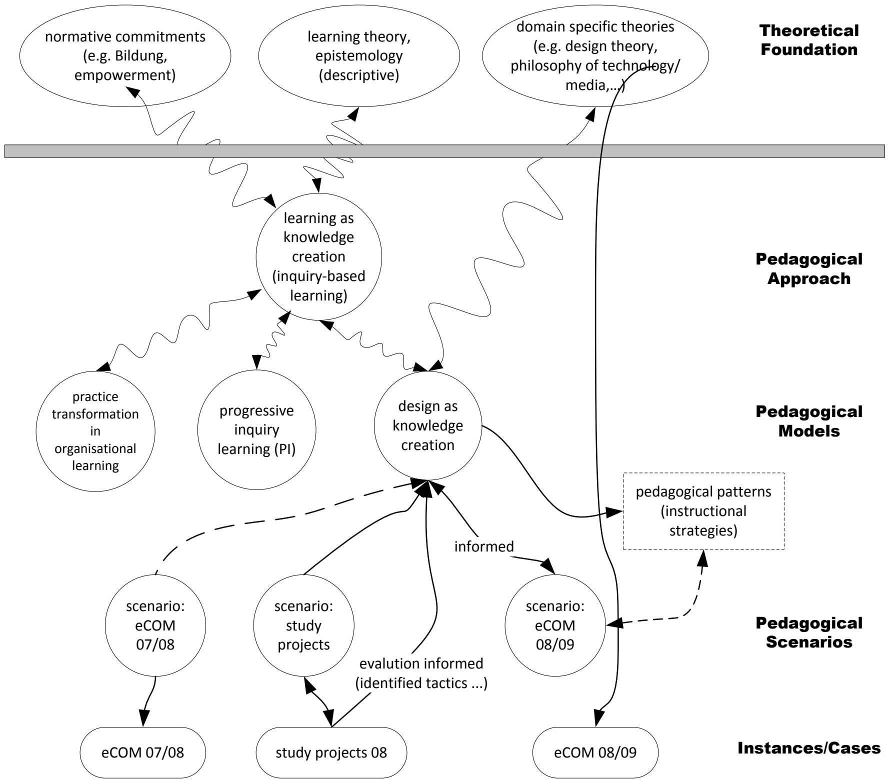

Figure 2: Pedagogical model in relation to the pedagogical approach and pedagogical scenario

The approach of learning as knowledge creation is referred to as one of three metaphors of learning (Paavola & Hakkarainen, 2004). Beyond the metaphors of learning as knowledge acquisition and learning as participation where an individual acquires knowledge which is assumed to be transferable and becomes a member of a community by adopting the communities' knowledge, rules and routines, the third metaphor of learning describes learning as collaborative knowledge construction. In a so called trialogical activity learners collaboratively develop and transform artifacts (such as conceptual artifacts, practices, products) and thereby create knowledge regarding the shared object within a respective domain (Hakkarainen & Paavola, 2008). Whereas the pedagogical approach of "progressive inquiry learning" (Muukkonen, Lakkala, & Hakkarainen, 2005) concentrates on constructing conceptual and epistemic artifacts, design as knowledge creation focuses on designing products (material and symbolic artifacts, including usable products in engineering and media). The approach of learning as knowledge creation and both pedagogical models, progressive inquiry learning and design as knowledge creation, highlight pragmatic and socio-cultural aspects of inquiry, building on cultural-historical activity theory (Leont'ev, 1978, Engeström, 1999) and thus go beyond purely cognitively oriented models of knowledge generation such as knowledge building (Scardamalia & Bereiter, 2003). The outcome of the learning process is transformed knowledge and design practices.

On the other hand we also would make a distinction between a pedagogical model and a pedagogical scenario and a case. While a pedagogical model is still generic and can be applied to different settings and contexts, a pedagogical scenario takes into account contextual constraints and requirements. Finally, we think that a pedagogical scenario also builds on what has been called pedagogical patterns in the sense of instructional strategies that proved to be successful. To our understanding these pedagogical patterns are important to be explicated and investigated, as they can be used in other context, but they should not be mixed up with the pedagogical model as they can be used independently of the pedagogical model chosen.

3.2 Propositions

The following are assumptions and propositions which we regard as important in the pedagogical model of design as knowledge creation. (1) Design as cyclic process of knowledge creation with the design artifact as a working hypothesis. (2) Material/symbolic artifacts play a prominent role in idea generation and design, transforming and creating knowledge regarding a shared object. (3) The focus is on creating knowledge by design and not learning how to design. (4) Focus is on exploration, innovation, and risk taking, rather than strict processes and final solutions; the evaluation of use, provoking problematizing moves, forcing failure and break down as an integral part of the design process. (5) All requirements evolve in time, are shaped by culture and social negotiation, they are not objective. (6) Introducing conceptual artefacts, co-conceptualizing of problem space and solution (co-evolution), which means that strictly separating the phase of analyses from synthesis is obsolete; modelling the design space is an ongoing and epistemic activity for creating the local theory of the problem and generating the working hypothesis. (7) Allowing for co-creation - the user as a produser, sharing responsibility. (8) Exploring and evaluating design-options as a means to explore the problem-space more deeply. (9) Design is retrieved by abductive reasoning ("informed guesses"). (10) Design decisions entail normative commitments and intentions which the designer takes responsibility of.

The pedagogical model conceptualizes design as a particular kind of knowledge creation activity and open ended inquiry. Emphasizing the productive nature of human activity, the designed artefact can be understood as a design hypothesis, which is tested when the product is put into use. The design hypothesis itself thereby is a result of abductive reasoning based on local assumptions on potential users' needs and practices. Evaluation of the product in use and especially its appropriation provides the basic input for the revision of the local assumptions as well as the design hypotheses, i.e. the product, system or intervention. The pedagogical model enforces the evaluation of use (by regular peer-to-peer reviews and actual use) in order to allow for break downs which initiate reflection and further inquiry as well as support conceptualizing the design space. Second, pedagogical means to foster design as knowledge creation include techniques of modelling the design space for explicating the students design assumptions and hypothesis. Thus conceptualization is a trialogical and epistemic activity, beyond purely implementing the working product.

Third, an heuristic model of design-based learning explicates design as a cyclical process which can be broken down into a set of activities resembling typical stages of ill-structured problem-solving or design-based research (figure 3).

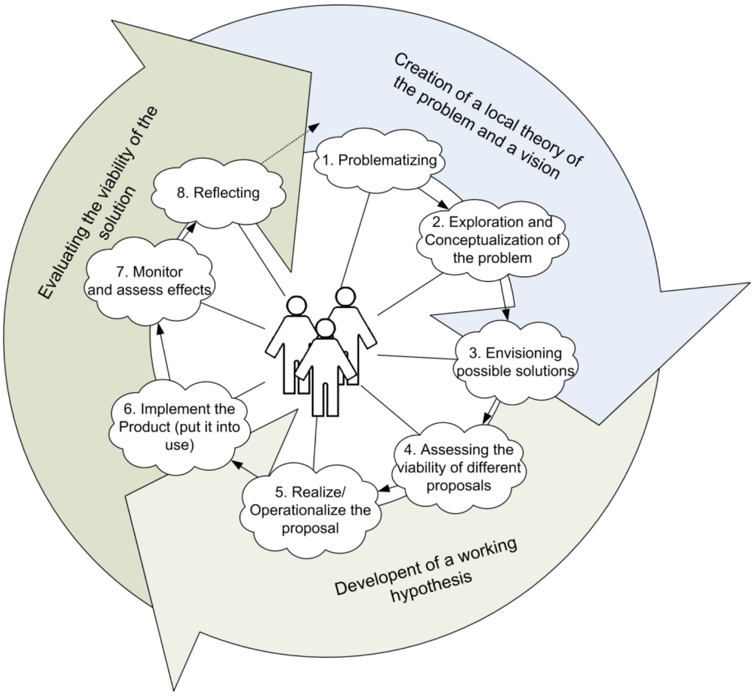

Figure 3: Heuristic model of design-based learning.

3.3 Heuristic Model of Design-Based Learning

Figure 3 provides an overview of the main activities constituting essential elements the design teams have to go through, although the relative importance of these elements, their order, content and methods employed might vary across courses or projects. The objective is not to follow the elements mechanically, but to provide a conceptual tool to make explicit the strategies and activities crucial in design-based learning.

The core activities can roughly be characterized as follows. Problematizing: The aim of problematizing is to develop an idea about the actual/performative needs the design project is going to address. This activity also entails to question and scrutinize the current state of affairs, including the wishes and instrumental needs proclaimed by the client or customer. Exploration and conceptualization of the problem: The aim is to develop a local theory of what constitutes the problem, the mechanisms that trigger the needs identified and a potential vision for the design project. Due to the complexity of most design-problems there might be multiple theories about the problems as well as the potential aims the design is heading for. Hence as substantial task here is to handle and eventually integrate multiple perspectives on the problem at stake. Envisioning possible solutions: Drawing on the local theories developed so far, the aim of this activity is to generate possible solutions suitable to overcome the problems. This is a highly creative process which might result in a diversity of proposals. The status of these proposals and the artifact (designed product) is that of a hypothesis. Assessing the viability of different proposals: As design-proposals are associated with different strength and weaknesses it is important to assess their potential viability against the local theory articulated. The assessment itself might also give rise to the formulation of new proposals. Realize/operationalize the proposal: The aim of this activity is to translate the proposal selected into a working product. This activity resembles core development activities such as system design, technical development, and strategy creation. Implement the product: Following its realization the product needs to be put into use. The implementation of the product (artifact) might also include things like field trials or more controlled forms of experimentation. Monitor and assess the effect: The main aim of this activity is to collect information on the product's performance and to check whether these meet the designers' expectations. Reflecting: Reflecting finally refers to the review of insights gained on the product's performance and viability against the local theory articulated. The reflection might result in a revision of the proposed performative needs, conceptualized problem, and envisioned solution and thus in an update or revision of the local theory itself.

3.4 Pedagogical Scenario

The context for implementing the pedagogical model of design as knowledge creation is a design course in winterterm 2008/09 (eCOM 08/09). Students are asked to design their personal learning environment (PLE) using social media (doing bricolage with of-the-shelf software tools). The PLE has to address three global requirements: it has to support (1) individual learning, (2) team and group collaboration, and (3) networking within a community. In order to achieve the overall objectives and to cope with the problems and constraints described above, the following measures are foreseen in the pedagogical scenario:

Using a scalable design task: The task should allow students to adapt their design activities to their own background knowledge and skills. Thus, an easily scalable but realistic design task has been chosen. The assignment for the project teams was to design and realize a *personal learning/information environment* which they can use to organize and carry out their study-related activities both individually as well as collaboratively. Thereby they do not have to develop any new technologies but can draw on any existing tools they find suitable for this purpose. To define the scope of the design task is already part of the students' assignment.

Fostering conceptual thinking in design problem solving: Students are asked to develop and continuously refine a visual (conceptual) model of the design space, explicating the proposed solution, the analysed problem space, the assumed mechanisms, and the local theories. Conceptualizing the design space is a means for generating the working hypothesis. Furthermore, students are supported to bring the artifact into use within the community (awaiting the response). Conceptual models are seen as epistemic objects rather than tools for documentation (Visual Model Editor: KP-Lab Shared Space: http://2d.mobile.evtek.fi/shared-space/). A simple modeling language has been defined to scaffold the needs and problem analysis. The so called "Problem Analyses Language" allows modeling by using the following factors and relations: Resource, specified factor, constraint, goal, action, unspecified factor, link, affects, causal influence, inverse causal influence. We expected is the students' taking up the modeling of the design space throughout the entire design process and using it as epistemic object.

Enforcing problematizing moves: To test the usability of proposed solutions students call for a peer review, i.e. they announce a call at the end of the lesson and prepare the review of their (preliminary) design product to be carried out next lesson. Minimum one peer review is required and thus break downs are allowed for. In order to make the scenario work it was important to define a task within the activity systems of students, so that they can fully rely on their own competences and decision-making authority. Nevertheless, the task was authentic as it changed students' practices and practices within the educational organization.

4 Discussion

Conceptualizing design as knowledge creation is not something genuinely new as authors in different disciplines made at least similar proposals (e.g. Zamenopoulos & Alexiou, 2007, Lawson et al., 2003, Floyd, 1992). Nevertheless, it seems important to become clear about this issue as this perspective is at odds with the prevailing perspective on design in higher education. According to this position design basically makes use of existing knowledge in order to solve a given problem. The knowledge required includes knowledge about the domain as well as the processes apt to derive a design solution. According to this position, the design solution itself can be understood as the successful application of pre-existing knowledge. This position parallels the vision on engineering which according to Buccarielli (2003) is characteristic for engineering education: "Engineering is an instrumental process requiring the application of established, rational scientific theory in the development of new products and systems for the benefit of humankind. Different engineering disciplines rest upon different paradigmatic sciences." (p. 296). Making use of existing knowledge in design often is an underlying assumption of study programs in engineering which claim that basic lectures must be given before providing project-based courses.

4.1 Related Approaches from a Knowledge Creation Perspective

Design- and project-based learning approaches to engineering education have been proposed for many years and applied on various levels of granularities, ranging from learning units over courses to entire study programs across the globe (cp. Dym, et al. 2005). Therefore it seems necessary to depict what we gain from looking at design- or project-based learning from a knowledge creation perspective and explicate some of those points where we think the understanding differs.

Knowledge creation vs. skill and competency development: A first difference relates to the learning objectives pursued. While design- or project-based learning in engineering education is often seen as a means for skill and competency development (e.g. Dym, et al. 2005, Wijnen, 1999, Kolodner, 1995) the emphasis of design as knowledge creation is on knowledge creation. While traditionally the insights gained and solutions produced in the course of design- and project- based learning are only of secondary importance they are at the forefront in our pedagogical model. Or to put it differently, the focus is on creating knowledge by design and not on learning how to design. Design products as hypothesis vs. design products as final results: According to the understanding of design as knowledge creation the design product is not a final or concluding result but only a hypothesis to be tested when the designed product is put into use. From this perspective many design- or project-based learning arrangements fall short in that they end with the delivery of the product to the client or even worth with a specification of the product without its implementation (for an overview on engineering design process models see Howard, Culley & Dekoninck, 2008 e.g.). Design as an iterative, hardly predictable, and unique process vs. design as a well structured endeavor: With its focus on skill development and learning how to design, many design- or project-based learning arrangements come along with a rather strictly defined sequencing of activities often reflecting a particular process-model common to design or engineering. Even though these process models might be useful to scaffold students' activity it might at the same time impair the knowledge creation process as it might prevent adopting the most suitable process or method. Problems and requirements as socially constructed vs. objective entities: Even though the ill-structured nature of design problems is acknowledged by many practitioners and scientists in the domain, the fact that requirements evolve in time, are shaped by culture and arise in a process of social negotiation is often ignored or marginalized in design- or project-based learning arrangements. In contrast to approaches which assume (implicitly or explicitly) that the problem to be addressed can be defined (at least in principle) objectively, it follows from the idea of design as knowledge creation that the problem to be solved is inevitably socially constructed. As a consequence there is not a single correct interpretation of the problem but design is always multiperspective (cp. Floyd, 1992). Appreciation of failures vs. striving for the "perfect" solution: Seeing design as knowledge creation also implies that new insights might evolve from viable as well as faulty design solutions. Hence learning is at least partly independent of the quality of the designed object. Rather than producing "perfect" solutions it seems more important to push forward those designs which might lend itself to deeper insights but which are at higher risk to fail. Or as Davidson (2004) puts it, a project which is at not risk of failing is hardly worth evaluating. The list of differences given here is only a very first proposal and clearly more work is needed towards this end.

4.2 Further Work

In our further work and the evaluation of the above described scenario, we plan to answer the following research questions: How do product development and conceptual understanding go together in students design processes? How do appropriate methods look like? What are critical events in the lifecycle of a design project from a knowledge creation point of view? What is the role of breakdowns? Under which conditions do they result in productive interactions? How can they be provoked and used systematically? What is the role of shared artefacts, such as models, reports, sketches in design as knowledge creation? What are the affordances these artefacts and respective tools should provide in order to foster reflection? From a methodological point of view we are concerned with questions such as: How to track and analyse collaborative design processes? How to track and analyse the development of artefacts as well their role in design processes?

Understanding the relation of design and knowledge creation as well as design and research is an relevant issue as design theory is interested in exploring its own epistemology (Cross, 2007; Jonas, 2007) and research is increasingly confronted with solving complex problems in local context (Jonas, 2007). Furthermore, researchers are confronted with design as today some research questions can only be answered by designing instruments. Design as knowledge creation implies bringing an intervention into a human activity system (the designed artefact mediating practices within a socio-cultural context) and is thus different from design research methods typically used for research in design (Lunenfeld & Laurel, 2004) such as participant observation (e.g. ethnography) where the impact of observation is about to be minimized. Building on activity theory we further work to address this issue.

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