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THE ROLE OF DESIGN MODELS IN DESIGN THINKING

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ABSTRACT

In this paper we identify the role of models in design thinking (DT) to bridge the gap between design and engineering. Models as artifacts help cross the boundaries from designers to other disciplines like engineering. We introduce our approach (*mDT*, *multidisciplinary Design Thinking*) by describing its methods including the steps showing how to carry out them in a design project. We show how the results of a DT process can be handed over to others. We focus on the characteristics of the artifacts DT induce. We introduce the notion of *design models* in this context consisting of use, systems and interaction models. We illustrate our *mDT* by giving some examples from a previous DT project before concluding the paper.

KEYWORDS

Design Thinking, Models, User-Centered Design, Innovation

1. INTRODUCTION

More and more "radical innovations" are needed "in our connectivity infrastructure" (Weiser and Brown, 1996). This is because of the imbedding, invisibility and the ease-of-use requirements to technologies that we use in our everyday life. Several theories like sociotechnical systems (Cherns, 1976), actor network (Callon, 1987), activity (Engeström et al., 1999; Nardi, 1995) or other methodology centered ones like participatory (Bodker et al., 2004), user-centered (Cooper et al., 2007) or contextual design (Beyer and Holtzblatt, 1998) try to bring user, use and context issues into the design and development of systems. They inform software engineering about user needs, user capabilities and use context restrictions and affordances. Creativity and innovation were subject to art and economy related disciplines. The increase of technology use everywhere in the last years made it essential to invest more into innovation and creativity in product and service management. At this point, design thinking (DT) became an interesting approach as a new way of thinking. Facilitating innovation and idea generation was originally motivated by economic factors. It was studied to create new forms of managing business. It enables improvements in innovation management, but it is still unclear to many managers which DT approach is most useful and effective for their business (Tschimmel, 2012).

It is for sure that creativity-supporting environments are needed to design and develop interactive computer systems of future. Such environments enable foster, promote, improve, and increase creative experiences, processes, products, or services. To create and maintain such environments is still a challenge for most companies, especially if there are several teams working on different parts in a design and production workflow. In most cases, innovatively created new ideas need to be handed over to engineering teams. Interaction between designers and engineers must be smooth and continuous by avoiding misunderstandings and disagreements that would have impact on the quality of the product-in-development or on the production process as a whole. Besides cultural differences the language, the artifacts and the representations of work differ in design and engineering teams. Conflicts that occur because of these differences can create big problems during the entire process, which might be the reason for a failure at the end. This is exactly the challenge we are dealing with in our research.

In this paper we address this critical link between design thinking (DT) and software engineering in product and service development. We introduce our approach (*mDT, multidisciplinary Design Thinking*) by describing the methods as well as their relation to each other in a time line. The focus of *mDT* is providing means to improve the communication among stakeholders involved in a design project by creating and maintaining common understanding among all. It applies well-known and -established artifacts like models for the mediation and exchange, which is scientifically and empirically well informed by our investigations so far. Furthermore, *mDT* systemizes models based on their purpose and content to express the areas of communication like use aspects, system properties and functions as well as interaction mechanisms. This is the main difference of *mDT* to other DT approaches known so far that mainly focus on economic factors.

After the introduction of the *mDT* we show how the results of DT process can be handed over to engineering teams. We focus on the characteristics of the artifacts DT induce. We suggest ways to create a smooth transition from design to engineering, especially by creating three different types of models: use, systems and interaction models. We illustrate our *mDT* by giving some examples from a previous DT project before concluding the paper.

2. RELATED WORK

User participation has been explored and further developed in computer science for a very long time (Bodker et al., 2004). By means of principles user participation in a project can be defined and kept throughout a process as well as the nature and content of outcomes. Besides being a mutual learning process, active genuine user participation increases the potential of visions produced by a project and then of the systems to be used according to their intentions.

The principle of firsthand experience can be realized especially during the in-depth analysis phase of a project. It builds on the proposition that to understand any phenomenon one needs to experience it firsthand. This can be done by qualitative methods, like observation, shadowing, in situ interviews, and thinking-aloud experiments, followed by systematic analysis and presentation of the gathered information. Models are very powerful tools for the representation of work, for the presentation of ideas and for the articulation of activities (Tellioğlu, 2013; Schmidt et al., 2009). Finally, anchoring vision involves informing target group about the project's goals, visions, and plans, and again getting their feedback.

Besides ethnographic qualitative methods (like participatory observations, in-depth open interviews, data analysis) several innovative methods have been established in participatory IT design, partly stemming from other disciplines: cultural probes (to understand the cultural context of users), provocative requisites (to achieve provocation, ambiguity, inspiration in context) (Dahley et al., 1998), design games (as a playful way to gain design ideas) (Brandt, 2006; Pedersen and Buur, 2000), narrative posters (to tell the whole story on one sheet) (Sandelowski, 1991), design workshops (to be creative and explore ideas in a team), technology probes (to get a hint about real life interaction). These methods can be applied to facilitate participatory explorative design by involving users, also from other disciplines. They at the same time guarantee that solutions developed fit to users' skills, environments and requirements.

DT was introduced as a cognitive process of designers two decades ago (Cross et al., 1992; Eastman et al., 2001). The goal was to understand design creativity and to improve design-thinking abilities. Today, DT is defined as "a complex thinking process of conceiving new realities, expressing the introduction of design culture and its methods into fields such as business innovation" (Tschimmel, 2012, p.2). The most popular DT models are: the 3 I Model (Inspiration, Ideation, Implementation) by IDEO (2001) (Brown and Wyatt, 2010, 33ff); the HCD Model (Hearing, Creating and Delivering) again by IDEO; the model of Understand, Observe, Point of View, Ideate, Prototype and Test by Hasso-Plattner Institute (Thoring and Müller, 2011); the 4 D or Double Diamond design process model (Discover, Define, Develop, Deliver) by British Design Council (2005); the Service Design Thinking Model (Exploration, Creation, Reflection, Implementation) by Stickdorn and Schneider (2010).

Seen from actor network theory point of view (Callon, 1987), intermediaries created by applying DT impact the setting in which they evolve so they influence the design process as such. Being part of the network, intermediaries are related to activities or actors. Activity theory (Engeström et al., 1999) "focuses on practice, which obviates the need to distinguish 'applied' from 'pure' science – understanding everyday practice in the real world is the very objective of scientific practice. … The object of activity theory is to understand the unity of consciousness and activity." (Nardi, 1995). Besides involving users in design processes we believe that DT is a very helpful approach to design sociotechnical systems. "Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success." (Tim Brown, IDEO).

The exploration of the role and potential of DT within organizations has changed the original objective of this research (Brown, 2009; Martin, 2009). So, "DT is not only a cognitive process or a mindset, but has become an effective toolkit for any innovation process, connecting the creative design approach to traditional business thinking, based on planning and rational problem solving" (Tschimmel, 2012, p.2). This shifted DT from design disciplines more and more to the fields of management and marketing. In this paper, we want to investigate DT again in the context of design of systems, products or services, especially in the field of systems design and development. If we take DT as an approach seriously and apply (all) its methods thoroughly throughout the whole design process, we can easily follow the goal of understanding of the everyday practice and its actors. This would lead us furthermore to design of systems that consider the context of use, user experiences, and the needed technology support. Our objective in designing systems is being innovative and improving user experience. We think this can be done only by understanding the actors, their actions, their use context, and of course by including them as experts into the design process.

3. *Multidisciplinary Design Thinking – mDT*

Our research group has created and established a special version of design thinking approach to enable design among designers, students, and companies for a decade now. We call it *Multidisciplinary Design Thinking* (*mDT*). The design process we have established so far is iterative and user-centered by supporting creativity and innovation. *mDT* not only shows how to design to provide user experience it also involves users in the entire design process. We see *mDT* as a summary of several design methods (for details see Table 1) accompanying a design process from the idea creation, through shaping and detailing design parameters, to the exact configuration and description of the properties of a system that has to be finally engineered. The methods shown in Table 1 are mainly carried out in a design team of at least of 4-5 persons and presented in a chronological order of their execution, whereas some of the design-evaluate-redesign methods are applied repeatedly in several iterations of the ideation and implementation process. Steps listed in the table for each method are supposed to be a guideline for designers. Depending on the type of the (design) project or characteristics of the design idea, some steps can be skipped sometimes. Furthermore, the type of the project or idea might make some of the methods obsolete or useless. It is up to designers to find out which methods with which steps are more relevant and fruitful for a specific project or not.

Table 1. Design thinking methods applied in *mDT* (*media.tuwien.ac.at/designthinking*)

Method	**Steps**
The Very First Idea *Description*: Brainstorming the very first associations and impressions in team *Goal*: Gather all associations and possible ideas based on images, texts, artifacts, and impressions *Type*: Idea generation *Example of use*: Very early stages of idea generation or orientation, by explicitly exchanging ideas/considerations/options within the design team	1. After a discussion in the design team, create associations to the subject 2. Brainstorm (brainwrite and brainsketch) different ideas, also by using images or impressions from media as well as other artifacts 3. Map all results in a shared representation of ideas and associations and visualize it 4. Start thinking further on ideas following up the collected associations and impressions 5. Document all relevant data for further reference
Literature Review *Description*: Effective evaluation of selected digital, analog, scientific, or non-scientific documents on a research topic *Goal*: Assure that the idea is relevant and unique within the use context considered *Type*: Data inquiry and knowledge generation *Example of use*: Early stages of idea generation or orientation	1. Prepare: setup a due date, create a precise focused question to base the review on, create select criteria, consider synonyms and translations as well, define the scope of the literature to review, identify the sources of literature 2. Search on identified sources by using the select criteria 3. Select the most relevant documents from the result list, repeat 2 and 3 as long as necessary 4. Procure the selected documents 5. Document the most relevant data from the literature reviewed
Expert Interviews *Description*: Gathering data from experts *Goal*: Consider experts' knowledge to the very first idea and research alternatives *Type*: Qualitative knowledge inquiry *Example of use*: Ethnographic field work	1. Prepare an interview guideline by formulating questions based on hypothesis developed so far 2. Locate and contact experts of interest 3. Carry out semi-structured or in-depth open interviews and, if possible, record the interviews, make notes 4. Transcribe the interviews, analyze them in relation to questions and hypothesis, write down the analysis results

Observations with Video Analysis *Description*: Creating (video) views of real scenarios *Goal*: Observe and understand the context, use, or other aspects of design; analyze interaction, requirements, evaluation, usability; document or illustrate *Type*: Data inquiry and recording *Example of use*: Workplace studies	1. Find the place and/or people for the observation 2. Setup the video equipment 3. Carry out the observation and recording, if needed, repeat it several times or change the location and time of recording 4. Analyze the material qualitative and quantitative, select relevant parts, and create a short video to visualize the most relevant observations that are expected to be very useful for further design decisions
Cultural Probes *Description*: Understanding the cultural context of future users in their own home or work environment *Goal*: Create qualitative approach to understand the user, inspire the design functionally and aesthetically, evoke creative reaction of (potential) users, support the creation of design material *Type*: Experimental research *Example of use*: Early stages of user-centered design processes	1. Define data to inquire via the probe 2. Design probe elements, consider corporate identity, visuals, sounds, tangible elements, and texts 3. Create a cultural probe package for distribution 4. Identify and recruit users 5. Distribute the probe to users 6. Analyze the data gathered in probes: qualitative, ask for clarification if needed, compare, extract particular occurrences including emotions, ideas, and inspirations 7. Document the analysis and comparison without interpretation
Provocative Requisites *Description*: Provocation, ambiguity, inspiration in use context *Goal*: Represent a design idea creative and playful, question and discuss the design ideas by letting them experienced in use context, create inspiration for design *Type*: Experimental research *Example of use*: Dealing with ambiguity and dubiety of the idea	1. Define a situation, a scenario, or a context for the requisite 2. Design the requisite, populate it with data, play it or set it up 3. Observe the requisite in action 4. Document the scenario, the observation, the interaction with the requisite (preferably with a video recording) 5. Analyze and explain the observed occurrences in relation to the design idea
Design Games *Description*: Playful way to gain design ideas based on a game containing elements of the design idea or some of the not yet decided components *Goal*: Generate design ideas, concretize a design idea in form a party game, play different options of interaction, experiment with use and functionality of design elements *Type*: Design creation *Example of use*: Create playful elements of a design idea	1. Define the goal of a design game 2. Document the process of the creation of the design game, also the dismissed ideas 3. Describe the game with all of its elements (props, content, rules, etc.) 4. Play with the design game several times and let others play with it 5. Document the games played, describe how it was perceived by the players 6. Adapt the game if necessary 7. Analyze the game, its components, the interaction, problems occurred, etc. 8. Document the analysis and extract issues for the design idea
Scenarios *Description*: Scenarios of use context with personas and actions/tasks *Goal*: Identify use scenarios related to the design-idea-in-development; identify personas	1. Define the goal, context, prerequisites, actors, interactions, and processes of a use scenario 2. Start with a rough scenario 3. Observe and play the scenario, analyze, and refine it

and anti-personas; describe the scenarios including the application of the design idea; identify problems and search for solutions in certain settings; provoke ideas *Type*: Experimental research *Example of use*: Product design, interaction design	4. Create a positive scenario: Adapt the scenario as long as it does not contain any negative aspect any more 5. Create a negative scenario: Adapt the scenario as long as it does not contain any positive aspect any more 6. Analyze the results and their impact onto the design idea 7. Document all actions and results 8. Repeat 1-7 for all other relevant use scenarios identified so far
Design Workshops *Description*: Being creative and exploring design ideas in team, or exploring options for systems design *Goal*: Communicate different views to the design idea in a group, generate new ideas in a team, discuss different perspectives to the design-on-table in a group, explore different options for systems design based on a decided idea at a later stage of a design process *Type*: Design in team *Example of use*: Create common understanding of a (rather complex) design idea in a team, e.g., in product design	1. Define the goal of the design workshop 2. Select the participants of the workshop and define their role 3. Set up a place, date, and process for the workshop 4. Prepare the necessary material like models, plans, creative material, etc. as well as devices for audio/video recording and photos 5. Carry out the workshop: introduction of participants and process, brainstorming related to the defined goal, working on different ideas, discussion and refinement of ideas come up during the workshop 6. Identify and document results of the workshop
Sketches *Description*: From the idea to the first low fidelity design artifacts *Goal*: Sketching the design ideas for an overview but also for details *Type*: Design generation and evaluation *Example of use*: User-centered design projects, prototyping	1. Create sketches of interaction, with different details meaning that some show an overview of the system and some the very details of a single system element 2. Compare and update sketches, explain their use 3. Evaluate critical sketches with users 4. Document the evaluation results
Wireframes *Description*: From sketches to more linked organized design artifacts as a base for prototypes *Goal*: Design structures, control elements, contents, and navigation as a blue print *Type*: Design generation and evaluation *Example of use*: User-centered design projects, prototyping	1. Create wireframes to cover all parts of the system 2. Link all parts of the system with the wireframes, including the navigation 3. Evaluate the wireframes with users 4. Document the evaluation results 5. Update the wireframes based on the evaluation results
(Video-)Mockups *Description*: From wireframes to the first prototypical systems *Goal*: Create look and feel of the interactive design with visual and audio elements *Type*: Design generation and evaluation *Example of use*: User-centered design projects, prototyping	1. Create mockups to visualize the look and feel of the interaction with the system 2. Use video and audio elements if needed 3. Evaluate the (video) mockups with users 4. Document the evaluation results 5. Update the mockups based on the evaluation results and repeat the steps 2-5 if necessary

Technology Probes *Description*: Getting a hint about real life interaction by applying real technology *Goal*: Examine and experiment a challenging technology implementation as a possible solution to the design idea to provide the functionality considered or planned so far in the design *Type*: Experimental technology application in field *Example of use*: User-centered design projects	1. Select a relevant technology for the system-in-development 2. Select an interaction aspect of the system-in-development 3. Set up the technology infrastructure and implement the selected interaction 4. Evaluate the technology probe with users 5. Document the evaluation results by stressing out the pros and cons of the technology selected for evaluation 6. Analyze the evaluation results and decide for the technology in use to create the prototype
Prototypes *Description*: The first impression of the last design step in an interactive piece of technology solution *Goal*: Create 2D, 3D, or executable prototypes to illustrate the idea as an interactive artifact *Type*: Executable design generation and evaluation *Example of use*: Product design	1. Gather all positively evaluated design ideas 2. Define the most important functions of the system-in-development 3. Implement a prototype by focusing on the selected functions, applying look and feel from the positively evaluated mockup, and using the technology chosen after the analysis of technology probes 4. Evaluate the prototype and update it 5. Describe the final prototype
Product and Design of Corporate Identity *Description*: Designing the whole story as a (final) product including the corporate design *Goal*: Define and present the product as a result of the whole design process *Type*: Product and context definition *Example of use*: Product design	1. Define all interactions, functions, and interrelated systems, including hard facts like costs and target users 2. Finalize the visual and technical design of all product components 3. Describe the use and administration of the product with a guide or handbook 4. Design a corporate identity for the product, apply it for its presentation 5. Create a product folder with all data relevant for target stakeholders
Narrative Posters *Description*: Telling the whole story of the design idea and its implementation on one sheet *Goal*: Tell a general or specific story about the design, its use, and context; visualize the design process and its elements to reflect on in form of a poster to provide an overview *Type*: Experimental narrative *Example of use*: Visualize design elements and process for reflection	1. Sort and organize the design material including all relevant artifacts and intermediaries created so far in the design process 2. Construct a story based on the material gathered 3. Visualize the story in form of a poster

To summarize, *mDT* can be presented as a road map from a very initial idea to a product that is ready for engineering and deployment. Figure 1 shows an overview of *mDT*. It consists of two parts: ideation & implementation and engineering, which are carried out by different communities of practice (by designers and engineers). The goal is to create and deliver the final product engineered and developed by basing its design, user interface, navigation, aesthetics, and technical components on the user-centered iterative design (thinking) process.

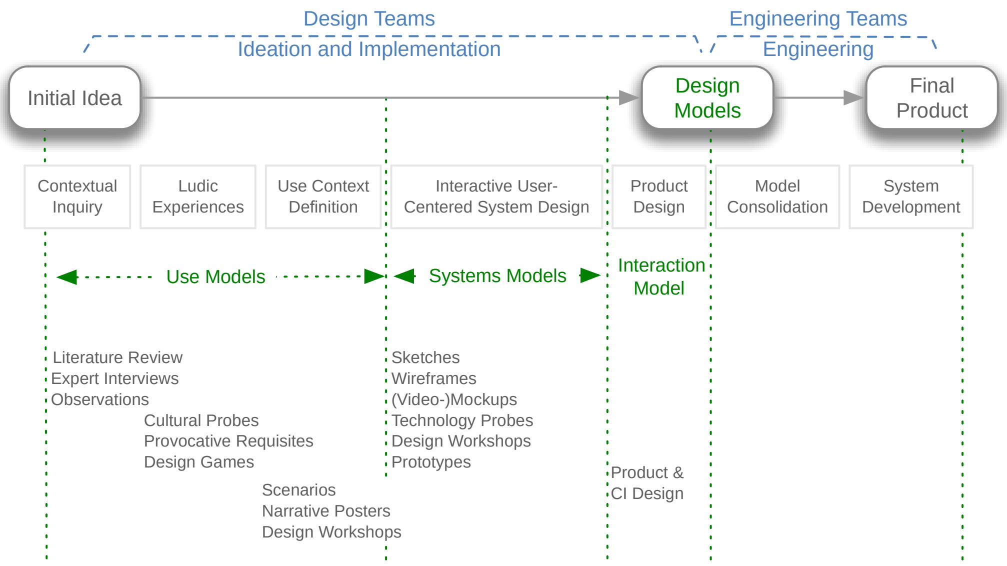

Figure 1. Overview of *mDT* containing the threefold design models for representing use, systems, and interaction elements of the design-to-develop

The results that are sent as the design-to-develop to engineering teams are in form of, as we call them, *design models*. We found that there are three types of design models:

Use models – Use models represent the use aspect of the design: who is the target group; what are the characteristics of the potential users, their habit, computer literacy, and expectations; what is the use scenario, are there restrictions, givens, and other circumstances that should be considered (in the design); are there dependencies between tasks needed for use, etc. So, use models contain then personas, scenarios, use cases, flow models, storyboards, narrative posters, mainly presented as models and descriptions, e.g., by using a standard modeling language like UML (Unified Modeling Language). The aim of these models is to detail and describe the design to make its parameters and elements communicable within the design team and understandable for others who are not involved in the design process but related to its results.

Systems models – Systems models represent the system mainly from functional, structural, and interfaces point of view: how are the user interfaces and interaction mechanisms look like; what are the interfaces between system components; what is the technological architecture and the implementation; how can users interact with the systems, etc. So system models are interface and interaction visualizations, technology probes as well as (hi-fidelity) executable 2D or 3D prototypes showing how the original idea looks like in action in the envisioned context. It does not necessarily mean that the technologies used to create the prototypes must be the ones that build the final product used by engineering teams who are in charge for the system development. In most cases the engineering team changes the platform completely.

Interaction models – Interaction models represent the product as a whole: what is the branding, form, content, functionality, and architecture of the product; how is its use and administration and configuration carried out; how much does it cost; what are the services provided around the product, etc. Interaction models are product descriptions and presentations with final corporate identity elements, demonstrating the use and features of the product, pricing, and measures for dissemination. They show the idea of the final product or service, by referring to its technology features, interfaces, architectural elements, or its real time use.

In this section we presented our *mDT* as a set of methods to guide and facilitate innovation and creativity in design teams, to document the intermediaries developed, and to create artifacts to bridge boundaries to other communities of practice, like engineering teams. In the next section we will discuss some relevant aspects for a successful implementation of the design thinking approach in software projects.

4. DISCUSSION

Designing for use requires an intensive user involvement in design processes. We need to be aware of that users are not designers but experts in using the artifacts designers create. Nevertheless, users contribute to the design in two ways: First of all, they communicate their requirements to the systems-in-design and their use context including the restrictions and conditions that might have impact on several properties of the system. Second, they evaluate the intermediaries created during a design process and give their feedback to the features, interactions, and interfaces of the system. Timing of the user involvement and the ways of gathering the user experience during a design process must be planned and managed properly. Methods applied must be selected and compiled carefully to make the best use of the gathered contextual data.

Software engineering deals with several problems of requirement gathering and analysis, design and development issues. But, its primary focus does not lie on the idea creation at the first place and continuous adaption during the design process based on user feedback and use context considerations. While software engineering deals with engineering methods and technologies, DT tackles the challenges before the prospect software is engineered.

Since two decades our group has been studying several design and engineering teams, their obstacles, communication problems not only within their project teams but also with externals, and all the effort that was in vain because it was based on false assumptions, lack of communication and misinterpretations. In this paper, we introduced and showed our design methods (used in *mDT*) to describe how design thinking might look like and be integrated in software projects. *Design models* help translate the design ideas into the language of engineers by avoiding information gaps and misunderstandings.

mDT integrates user involvement into its methods and through this into the whole design process. *mDT* is based on important principles of sociotechnical approaches. Considering the sociotechnical design principles defined by Cherns (1976), we found out that *mDT* is in line with the principles of sociotechnical systems, especially with the ones that are related to processes: compatibility, minimal critical specification, design and human values, and incompletion. By considering these principles in design and development of systems we believe that we move the engineering process further into the direction of a process that produces more innovative and usable systems for the anticipated target group.

Compatibility – Design thinking facilitates a process, which is compatible with its objectives (Tellioğlu et al., 2012). For instance, if the design objective is a playful system, the process needs to be playful by facilitating playful working and playful intermediaries. If the objective is the highest degree of usability, the process must be opened for users and their evaluation of single design artifacts, just from the beginning of the project to its very end.

Minimal critical specification – This principle says that no more should be specified than is absolutely essential. In the context of DT, this means the design process must be kept open and flexible as long as possible. Options should be not closed; each design decision should be challenged; and it should be possible to offer and consider alternatives throughout the whole process. Design thinking supports this principle completely.

Design and human values – This principle defines that the design process as well as its results must put human values to the center. Design thinking offers a complete model how to design and what its principles and outcomes are, which makes designing sociotechnical systems possible. Its goal is to improve the quality of users' life and this is in accordance to this principle.

Incompletion – Finally, designing is a reiterative process. As soon as design (intermediaries) is implemented, its consequences indicate the need for redesign. "The multifunctional, multilevel, multidisciplinary team required for design is needed for its evaluation and review" (Cherns, 1976, p.791). This is exactly how design thinking sees the design process. The methods described in the previous section illustrate the different facets of the DT process and the need of approaching the design process from different perspectives. This can only be done if the design process is seen as an on-going incomplete open process.

mDT fulfills the above listed principles, and furthermore it communicates its results by using design models. To illustrate how diverse the artifacts, as instantiations of these design models, look like depending on the idea that the design process was based on, we present some examples from one student project carried out two years ago. It is about enabling free speech and democracy and the ways to create a public space in which citizens can stress their thoughts to a given common subject. A group of five students[1] applied *mDT* throughout two semesters in their media informatics study. The goal was to create and evaluate a new idea to support practicing democracy in the society. After the first semester the team ended up with the design idea that supports the expression of one's (political) opinion in a public space. After the second semester, a product – the so-called *Meinungsbilder*, meaning *images of opinion* or *opinion former* – was created.

[1] Michael Dichtl, Markus Hametner, Janis Meißner, Rafael Mitterlehner, Gözde Taskaya

Figure 2. *Use models*: Contextual inquiry with a publicly placed cultural probe (upper left), ludic experience with a design game to express one's political opinion (upper right), narrative poster illustrating the use context and the functionality to be achieved if one wants to communicate a publicly relevant opinion with others (bottom)

Figure 2 shows some example artifacts or intermediaries that we see as *use models* to hand over from design to engineering. They are results of contextual inquiry, e.g., a publicly placed cultural probe (upper left), and results of the ludic experience phase, e.g., a design game to express one's political opinion (upper right). A narrative poster illustrates the use context and the functionality to be achieved if one wants to communicate a publicly relevant opinion with others (bottom). Figure 3 shows some of the *systems models* created during the project: iterative user-centered system design with sketches; wireframes and models of the product (in this example a mushroom-shaped kiosk to stress one's own opinion to a common subject) showing different details explicitly.

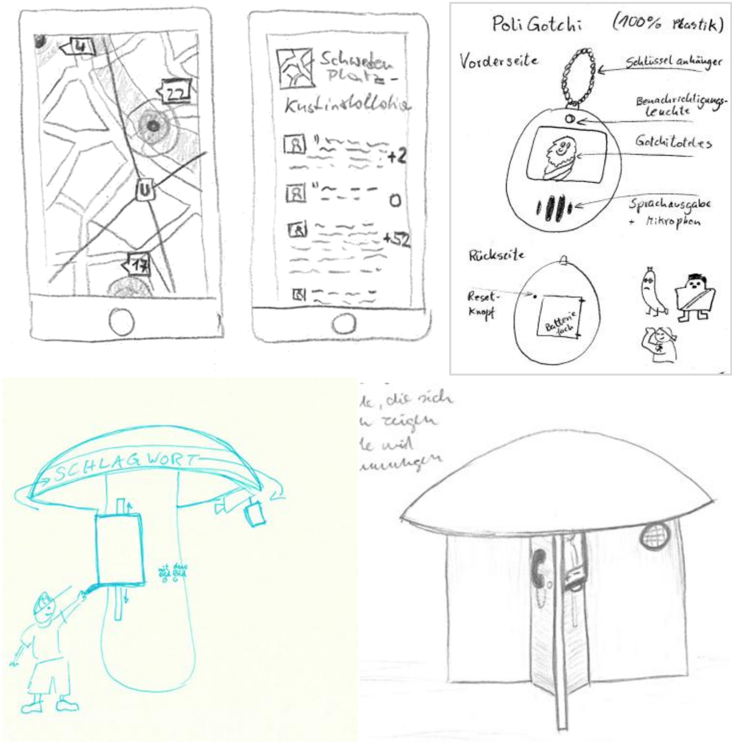

Figure 3. *Systems models*: Iterative user-centered system design with sketches, wireframes and models of the product showing different details (in this example a mushroom-shaped kiosk to stress one's own opinion to a common subject)

The first ideas were withdrawn during the course of the design process, based on the evaluation and feedback given by users. Figure 4 shows the final *interaction models* of the project: (upper left) the model of the product with concrete measures for production (in this case the mushroom-shaped kiosk), (upper middle) the computer model to visualize the entire shape of the mushroom, (upper right) interfaces implemented in four compartments of the mushroom showing the interaction possibilities for users, and finally (bottom) the logo and corporate identity of the product. This example tries to represent the introduced design models that *mDT* delivers to help understand, use, and further develop in engineering teams.

5. CONCLUSION

We succeeded in several industrial as well as educational projects by considering design thinking as a holistic approach to design sociotechnical innovative systems. We contributed to DT research by proposing *design models* as an interface and communication channel to cross the boundaries to other disciplines like engineering, management, or marketing. Nevertheless, our development of DT methods and processes are ongoing. Next, we plan to describe best practice examples to provide more insights to design teams. We are currently developing measures for the evaluation of *mDT* in design projects what we plan to present in our future work. However, we are aware of the difficulty to evaluate this approach in a real context.

Figure 4. *Interaction models*: Model of the product with concrete measures for production (in this case the mushroom-shaped kiosk) (upper left), computer model to visualize the entire shape of the mushroom (upper middle), interfaces implemented in four compartments of the mushroom showing the interaction possibilities for users (upper right), the logo and corporate identity of the product (*Meinungsbilder*) (bottom)

Our goal is not addressing managers to offer an easy access of several DT tools and methods by providing a guideline how to do this. Our objective is rather to contribute to the integration of DT driven design processes with the following engineering and final production and deployment processes by explicitly determining the interfaces facilitated mainly by model-based artifacts, like we put them into the categories use models, systems models, and interaction models. We think the only way to achieve the goal of an innovative design and development process is a holistic integrated approach to design and engineering what, we think, can be implemented by means of models and DT process we introduced in this paper.

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