Design Prototyping for Research Planning and Technological Development

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Abstract Research planning and technological development are part of our ongoing social and cultural development that can be shaped in a user-centred way with prototyping models from design. As an interdisciplinary form of communication, prototyping from design can create a collective understanding of the use of technology and enables the aspirations and requirements of future technology to be determined. This added value for research planning and the development of technology is demonstrated through examples provided in this text. Various prototyping models such as design prototyping, co-prototyping and participatory prototyping are outlined as important indicators for research planning and technological development and are described in terms of their effectiveness. The respective prototyping model determines on the one hand how daily life experts can be integrated into the development process, and on the other it specifies how concretely the given model can be applied to the technology in development. Accordingly, the appropriate prototyping model must be selected for the specific issue in technological development. The detailed description of the parameters and qualities of the prototyping models as well as the graphs and visuals of them should help with these decisions.

1 Introduction

Research and technological development assume a place of particular importance in our society. This is not only the case from an economic point of view, but also because the discoveries and results from both help us to find answers to questions about the future, questions about medical care, future mobility, sustainability and the use of our resources, in short, how we want to live with each other on our planet in the future. Research can provide answers to many of these questions that can be implemented in new technologies for applications. But in all likelihood it is just as probable that

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C. Gengnagel et al. (eds.), *Rethink! Prototyping*,
DOI 10.1007/978-3-319-24439-6_3

concrete proposals from the applied technological developments will not be adopted or accepted by society. There are many reasons for this. In various studies, it has been made clear that the inclusion of people in the implementation process is an important factor. In recent years, various communication models have been developed with different approaches for managing dialogues with society. Design is one discipline that focuses precisely on introducing technology into applications from a user's perspective. Design offers additional methods and procedures for this. One possibility with great potential as a communication and interaction platform is prototyping. Over the last five years, together with the Fraunhofer Center for Responsible Research and Innovation, I have worked on testing and analysing various models of design prototyping in projects for technological development. The discoveries in these processes form the basis for this text and raise the question as to how one can facilitate a user-centred research planning and technological development.

In the research project called "Rethinking Prototyping" where I am part of the "Hybrid prototyping" team, it has become clear that the prototype and the prototyping itself represent a unique possibility for negotiating processes with various disciplines and users. On the basis of prototyping, it was also possible in this project to determine and describe various research approaches in design, architecture, mathematics, computer science and mechanical engineering with their various conceptual models, procedures and decision-making criteria. Prototyping is the word of the hour. After years of intangible and digital concerns, the object itself is once again becoming the centre of attention with the Internet of Things and the new production technologies. Although the prototype is regarded less as an object and more as a process, i.e. prototyping, doing. In the process of prototyping, much has changed through the new possibilities in producing and publishing as well as the new forms of work. Processes in prototyping are more open, collaborative, discursive today, and they will become more accessible and transparent for various disciplines and thus also implementable for social discourse. In this text, the process of prototyping is considered from the design perspective, and three different models of prototyping show how prototyping can integrate the perspective of users into the research plan and technological development. The three models are introduced on the basis of examples from various research projects and are compared in terms of their potential influence for research planning and technological development.

2 Design Prototyping

The term[1] prototype is used by various disciplines to describe a certain state of a project. In design and in engineering disciplines, the term prototype is of central importance and has a comparable, but not identical purpose in both disciplines.

[1]The term consists of the words "protos", from the Greek word for first, and "typos", which means archetype or model in Greek. The prototype is often the first model in series production, but also stands for a concept draft on the basis of which you can check use and acceptance.

While engineers provide proof that a design can be achieved by producing technical prototypes, designers test the future use in the form of design prototypes. The implementation of prototypes in design is characterised by various criteria: The communication and interaction with the interface of the object to be designed and its services are in focus. Aspects of ergonomics, use and experience with the object and service, the feel, form and aesthetic are determined in the design prototypes. This prototype is an object that is being examined with regard to its use.

Engineers and designers can inform themselves about the current status of their respective discipline on the basis of prototypes and learn about important aspects in each case. What does the actual use devised in design prototypes mean for the technology and what does the used technology mean for possible new uses? A dual examination is possible with the prototype since it is more understandable for both sides, a common denominator. The prototype shows options for action irrespective of whether they are from the perspective of users or from a technological perspective. The prototype from design introduces the important parameters of the users' perspective. The design represents the connection between use, technology and aesthetic concerns, whereby aspects of economics, ecology, ergonomics and social developments and expectations are also included. Design acts on the one hand like a discipline by taking knowledge and creative competency from the design, and on the other, in an interdisciplinary way, as a negotiator and translator of the claims and tasks from society and from each of its individual representatives. Prototypes developed by daily life experts, i.e. the future user groups, require the translation of the design just as engineers must translate new discoveries in natural science research into applications so people can understand how they can be used. The focus of design is on the needs and wishes of people and society. Design gives shape to these needs. The more daily life experts are capable of visualising the needs and wishes of people and society on their own and illustrating them in the form of prototypical use scenarios and objects, the more precise the translation to the design will be. Prototyping negotiates not only between the disciplines, but also between society, science and research.

Joint Design Prototyping with Users Prototyping can be a dialogue between a person and an object, between two people or two disciplines—it is, however, also suited for dialogue within groups. A reservation voiced with regard to the joint development of technology with users and daily life experts is the opinion that users can only develop or think of things that are very close to the status quo. Henry Ford is often quoted when someone defends this thesis: "If I had asked my customers what they wanted, they would have said a faster horse"[2]. There is something true in

[2]Henry Ford (1863–1947), founder of the car manufacturer Ford Motor Company, perfected assembly line work in the automotive industry and revolutionised industrial production. He published a lot, partially in books and newspapers, gave numerous interviews and wrote many very controversial anti-Semitic texts. The familiar and polarising quote about customers and the horse has not been proven to this very day. Research by various authors has not discovered any reliable source for this quote. Since it is often cited, the quote has taken on a life of its own in the common vernacular in the meantime, which is why I use it as a conceptual model in this text.

this statement. In our daily lives, we are shaped by the reality surrounding us and cannot simply get over this. The steady flow of information, either through advertisements or reports from research and development laboratories, makes us aware of new products. The well-known refrigerator that goes shopping on its own is an idea that has often been popularised in the media in order to emphasise the added value of the internet of things (IoT) more demonstrably. If you ask users today how the internet will change their daily life in the future, you frequently hear the aforementioned scenario of the autonomously shopping refrigerator offered as an answer, usually accompanied by a shake of the head because the logic of this futuristic idea is doubted. The media has influence on what we should think about our future and makes it difficult to engage in open discourse with users on future wishes and needs. Very few people think explicitly about the more distant future, i.e. beyond their personal concerns. How should they make valuable contributions to the future if they can only think about the existing situation for a maximum of 5 years in advance—something they rarely find a reason to do—and even then, when they are already influenced by the ideas flowing out of research institutions, companies and the media? The example of the refrigerator shows, however, how important the phrasing of the question is: Do we even inquire about the future of the refrigerator or how we should handle cooling or heating in the future, period? By formulating the question in a different, more open and more active way, we gain ideas that do not replicate the status quo. The autonomously-shopping refrigerator is, in some senses, quite similar to the concept of Ford's faster horse. It is not an innovative product and certainly not a new market. The market replicates the status quo and only thinks "faster", or automatically.

While we may accuse those experts of daily life of solely operating in preconceived categories and being incapable of new ideas, we must admit that experts, designers and engineers move in defined fields and formats, too. They do this with greater knowledge of the current developments and a larger repertoire for the development of new combinations and variations of existing ones. These are most important qualities, since the practical knowledge and the adoption of the repertoire require extensive studying and time for independent observations and discoveries, as well as the practical ability to develop something new, such as turning research questions into new discoveries in the respective disciplines. Engineers and designers, however, are also influenced by existing ideas and current discourse, for example, from science fiction and other research and development laboratories. At their core, each new idea has components that are familiar; each designer and developer recombines things, varies and scales them, transfers them to other contexts or uses and can evaluate these ideas in a broader context. The results from basic research, such as more precise measurement methods or smaller mechanics and electronics, offer designers and engineers new options that are not usually available to daily life experts. Therefore, the inclusion of users in development processes requires a method-based procedure that makes it possible to partially and temporarily adopt these specific expert competencies.

Let's return to the idea of the faster horse. It inherently possesses two interesting components that should be examined in more detail with respect to the joint development of technology with daily life experts. If we ask people about their desire for future travel, it is possible for them to consider the *means* (with what type of vehicle) or the question of how. It is possible that the *how*, i.e. the “faster” is a more valuable indicator than the *means*, i.e. the horse. The fact that we can implement the “faster” better with a car than with a horse falls within the decision-making expertise of developers. For researchers and developers, the “weak” component of *how* in the form of the describing adjective is more useful than a “factual” component, such as the word horse. When user groups express themselves orally or in writing regarding the wishes and needs they have for the future, words often prove a limitation, particularly in German-speaking regions. In German, the nominal style[3] is often used in texts—meaning the language is less action-oriented or descriptive, and remains encased in familiar terminology because there is no expression for what does not yet exist. If we made it possible for users to describe their future uses on the basis of prototypical environments, we would gain access to a non-verbal world that could describe more clearly and diversely what a specific use might look like. Factors such as material qualities, size and handling would then be defined since they frequently don’t find any expression on the verbal level. The “faster” is just such a factor in the case of our Ford horse. Consequently, prototyping allows us to discover ways of avoiding the “horse” and to determine the “faster”. It is precisely on the haptic, tactile level that most people are less influenced by preconceived ideas. The process of shaping is accomplished in a steadier, less frenetic and more open manner than in the process of speaking. The process itself is more one of searching and also more descriptive for others. In shaping, people must indirectly answer questions that they have never been asked before. All these are factors that make prototyping with daily life experts expedient and interesting for technological development. Particularly in the areas of aesthetics and shaping, but also when it comes to a description of uses, wishes and needs, people often lack the suitable vocabulary of expression. The vocabulary employed often reflects descriptions from commercials and is limited in terms of aesthetic descriptions. That is explainable because it is unusual for most people to exchange formal and aesthetic criteria or develop their own criteria. Even in public discourse, exchanges of opinion on product design, architecture or fashion are relatively rare. It is possible to attempt to avoid these limitations in language. The action in prototyping represents a possibility of asking for the required information on a non-verbal level that would not have attracted any attention without three-dimensional representation. Interestingly, words are created in the process of prototyping and descriptions are discovered that would not have had any triggering effect without this physical interaction.

[3]The nominal style is a form of expression where nouns (called *Nomen*, or *Substantive* in German) take a larger role than verbs. This style often defines texts re-quiring a precise means of expression, such as scientific and legal texts.

3 Inclusion of User-Centred Design Prototyping in Research Planning and Technological Development

How can one speak about possible uses when one does not even know the technology? Is it not foolhardy to believe that future users' wishes and needs in technological development can be determined ahead of time? Has the history of technology not demonstrated that people will use what technology provides them only when it is present? These questions reflect a popular view in the research landscape that gives technology a head start well before a possible user comes into play. Whether the early integration of user interests can positively influence technology is a matter of debate. If one adheres to the argumentation made in the text, however, formats of prototyping can facilitate this early integration. For prototyping, this entails the following questions:

- How can technology be juxtaposed to possible uses in an early stage of development based on prototyping so that the aspects of use can be taken into account in the development?
- What formats of prototyping are conceivable for this and what benefits do they bring?

In the following, I will introduce three prototyping models[4] derived from design that demonstrate different formats for the inclusion of user perspectives in technological development. The three models differ in terms of their methods and procedures as well as their results in regard to their specific applicability to the technology that must be developed and with respect to the amount of time and content for the inclusion of social requirements and needs:

Design prototyping can have a direct effect on development with regard to a specific field of technology. The parameters for user requirements are specific. The user-specific requirements and needs are included and evaluated by studies and method-based observations.

Co-prototyping should be implemented at an early stage of technological development since it can have a significant influence on the development. User-centred and social requirements and needs are queried by means of co-design processes and evaluated so that specific parameters can be described for the technology, but previously unconsidered fields of development and markets become visible.

[4]The three models were developed in the context of research projects that were worked on with the Fraunhofer Center for Responsible Research and Innovation (Fraunhofer CeRRI) over the last four years. In the three examples, I have been involved as a project partner and accompanied the development of the methodology, the process design and the analysis in the transformation phase. The cases are exemplary for each prototyping model prior to a technological development. For each of the three formats, there are numerous other project examples from research projects at the Fraunhofer CeRRI which cannot be discussed here in full.

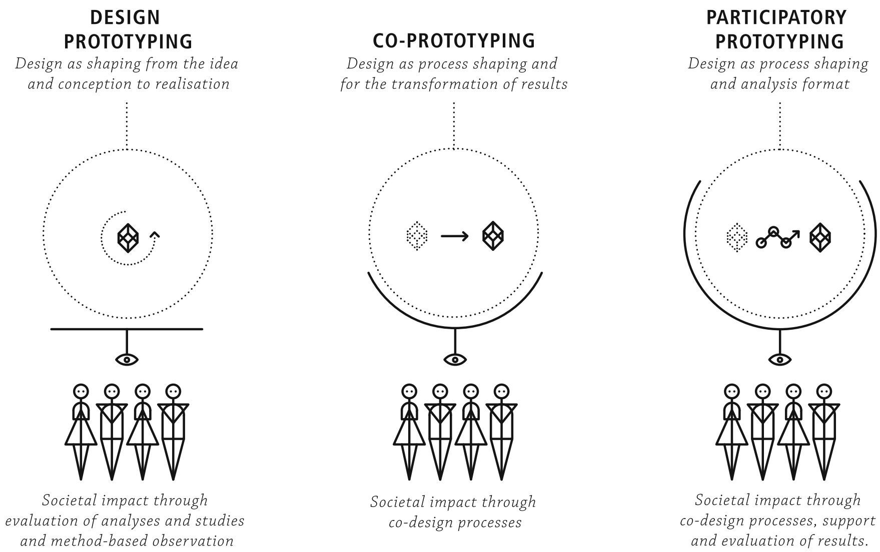

Fig. 1 Models for including a societal impact in design prototyping

Participatory prototyping should be completed prior to the development of the technology and in the research plan. It reveals potential possibilities for new fields of technology and research. Requirements and needs through usage and by society are included through processes of co-design and the supporting evaluation of development.

Figure 1 illustrates the share of the social impact over time in a typical design process. In the decisions, in the design process, socially relevant data is usually included in the form of studies or usability tests. As a rule, this takes place at the beginning of a project and is regularly checked over the course of the project. The co-prototyping accompanies the design process intensively and continuously. Relevant data is collected from users in the process and checked in a feedback loop. The participatory prototyping assumes a prominent place in the drafting process and extends across almost the entire process. The design itself is more for the shaping of the process and for an analysis format.

Design Prototyping Based on the Example of OLED Technology A design study[5] for OLED technology[6] was selected for the example of design prototyping.

[5]The study was prepared in a cooperative project with students in the design area of interface and interaction design at the Berlin University of Arts, the Fraunhofer Center for Responsible Research and Innovation and the Fraunhofer-Verbund Mikroelektronik (Fraunhofer Association of Microelectronics).

[6]The organic light-emitting diode (abbreviated as OLED) is a thin lighting element that consists of multiple layers of organic semi-conductor materials. In comparison to the conventional light-emitting diodes, these OLEDs can be produced less expensively since they can be applied to large areas of space in a special printing process. OLED can be used as an extremely thin panel radiator; the material can be transparent and flexible, produces high-contrast light with high colour

The results of this study were presented at the Plastic Electronics Conference 2011 as part of the SSL Semicon. For the study, a group of design students examined the possible potential of OLED technology and developed about two hundred ideas in an initial workshop on the possible uses of the technology in different markets. Design and technology experts evaluated these ideas in terms of their innovativeness and usefulness. The ideas that received the highest marks were refined in a two-week period for design prototypes. On the basis of the collection of two hundred approaches to using the ideas in various markets, it was possible to carry out an early qualitative and quantitative evaluation of the potential. For some markets, substantially more ideas were developed and were also given higher marks. This concentration of ideas can be considered the first indicator for examining a given market's suitability as a starting place. The two hundred ideas could be analysed in terms of used qualities, e.g. in regard to other material characteristics, shapability and supplementary sensor interfaces. Due to their qualitative information, the ideas transferred to design prototypes could also be evaluated with respect to the useful characteristics of OLED technology for central areas of application. For the field of application called "New forms of visualisation", which was developed in the workshop, the transparency and the flexibility of the material, as well as modular coupling mechanisms with integrated sensors are important, for example. The field of application referred to as "textile interfaces" assumes the generation of electricity on the human body and processing directly in the textile material, while the field of application referred to as "city periphery" is necessary for organic growth, as well as for durable and sustainable material. An example of a particularly innovative application was the self-growing organic OLED display. While the focal point to date in the development of OLEDs from a technological point of view has been the light and its properties, such as brightness, light colour and size of the display, the design perspective made it equally clear that, from an application perspective, it is important that intelligent interaction and communication occur with light. Not large displays but rather light as a means of communication, integrated in the central areas of life, is used. One might be inclined to modify the Ford quote mentioned earlier, namely, "Not larger, but rather modular, intelligent light". This example shows that the main usage characteristics can be identified in design prototyping in a very short period of time and at an early stage of technological development. However, there must be a relevant, qualitatively examinable number of design prototypes, and these can be prepared in an initial study, directly by designers. A specific evaluation tool for the monitoring of design prototypes for certain sectors and fields of technology would be an alternative approach. User groups are not directly included in this process. The results from the design prototyping can be discussed and evaluated with various user groups, which

(Footnote 6 continued)

quality, and the colour can change in the process. The material has a potentially long life and largely consists of environmentally-friendly materials. OLED is mainly used in screens and displays and for large-scale lighting at the present time.

may reflect possible requirements for future product development. The number of design prototypes should fall in a range between five and twenty-five. If fewer than five prototypes emerge in the process, this means that the technology has been developed too specifically, so a range in usage can no longer be developed. Conversely, a number above the upper limit of twenty-five design prototypes indicates that there are no significant differences in our various needs. While single, designer-developed approaches for possible product ideas initiated by individual designers are often gladly dismissed by engineers as non-implementable studies at such an early point in technological development, i.e. prior to the market launch, a larger and broader perspective in a qualitative and quantitative evaluation matrix for interaction and usage offers the possibility of integrating the requirements in the development of the technology at an early time.

Co-prototyping: The Example of Developing an Upper-body Orthosis An example of the co-prototyping format is demonstrated in the "Care-Jack" project, which involved the development of an upper-body orthosis[7] in the form of a jacket to reduce the physical burden on nursing staff in the strenuous nursing processes. This study was undertaken in the "Discover Markets" (cf. Schraudner et al. 2014b) research project.[8] For the study, typical situations in nursing care were re-enacted in a workshop with participants from active nursing care and developers of technology. Based on these detailed scenarios, it was possible to develop solutions for individual movement sequences, required action and communication situations in a co-prototyping process. To this end, scenarios in individual sections were replayed, whereby the participants took turns adopting the roles of patient and nurse. The process of co-prototyping was carried out with a full-body protective suit from a home improvement store, which could be enlarged, labelled and changed with various materials. An accompanying questionnaire also allowed for specific feedback on the requirements for material, interaction, preparation and follow-up action with the orthosis. The participants used the "thinking aloud" method so that all aspects of the patient and the person acting as nurse were recorded. These original recordings, outlines and hand-written instructions as well as the prototypes themselves were evaluated for the study. Extensive information about the desired qualities of use in terms of material properties and interaction applications and communication applications became evident as a result of this evaluation.

One exemplary result of this study, first formulated on the basis of the co-prototyping—the need for a communication interface for upper-body orthosis

[7]An orthosis is a medical appliance or apparatus used to stabilise and guide movable parts and the upper body. The easily attachable, intelligent, active orthosis used here allows nurses reduce their physical burden by providing active support in lifting, carrying and transferring patients.

[8]"Discover Markets" is funded by the German Federal Ministry of Education and Research (BMBF), period 2010–2013 (funding code: 03IO1003). With "Discover Markets", a novel procedural model was designed to support the early identification of potential user groups' wishes and needs and the development of suitable business models for new technologies and product innovations ahead of the research projects. In the "Discover Markets" project, additional comparable co-prototyping studies were conducted.

that was not planned in the previous implementation—stands out in particular. Nurses identified the need to make it possible for the patient to indicate that a certain act by the nurse caused pain by using certain formats of tactile communication on the orthosis, for example. Tactile communication is faster than verbal and also possible for mentally impaired patients. Certain fine-sensor communication points on the orthosis also increase the range of possible uses. The example of co-prototyping demonstrates that, in technological development for specific areas of use and markets, it is possible to conduct studies with future users prior to the development of a product or service, if the co-prototyping is systematically tailored to the area of use (cf. Seewald et al. 2013). Accompanying documentation material that precisely describes the process in the greatest possible detail is important for systematic evaluation. In the process, it is preferable to include user groups that already have advanced knowledge of the process of the application area. The group should be diversified in terms of age, gender, experience and culture and can consist of experts, users and developers. The results of the co-prototyping provide specific information about the requirements in use and in the handling of new technologies in their area of use.

Participatory Prototyping: The Example of "Shaping Future", a Need-based Participatory Foresight Methodology The research project called "Shaping Future" (cf. Schraudner et al. 2014a)[9] was selected as an example for participatory prototyping since it developed methodological access for a participatory process to produce a technology preview that includes prototyping with non-experts (cf. Heidingsfelder et al. 2015). In a series of workshops, technology-interested non-experts are given the opportunity to anticipate possible futures in a method-supported way with the focal point of human-machine cooperation. At the centre is participatory prototyping, outlining the wishes and needs for interfaces in future human-machine cooperation in the form of prototypical implementations. These prototypical objects are not only interesting with respect to their specific recommendations for each case of implementation, but are also examined on a meta level for the technology preview: Which qualities do the used materials exhibit? Which sales paths are preferred? Will the prototype be used jointly and does it belong to anyone alone? Where does the energy come from? Should it be recycled?

In the participatory prototyping process, certain framework conditions are important so that no uncertainty arises with the participants. The environment, the rooms and the materials should encourage collective thinking, discussion and interaction. The materials for the prototyping can be simple: Cardboard and foam, everyday objects that are reused (everyday hacking), but also new prototyping tools such as laser cutters and 3D printers and technically-low-barrier interfaces such as the Arduino microcontroller.

[9]"Shaping Future" develops new methods for a participatory and need-based technology foresight. The results of the participatory workshops are analysed by experts and transferred to specific technology road maps. The project is funded by the German Federal Ministry of Education and Research (BMBF), preparatory phase: 2011–2012 (funding code 16I1630).

The process of participatory prototyping is broken down into individual steps that lead to the implementation of the object. In the form of a narrative integration (when/then, what for, why) of future human-machine cooperation, the first step is contextualisation. The participants then search for material that they want to use for their implementation. In this step, the material is not yet integrated into the object and is therefore more explicit in its statement with regard to the selected qualities. In the prototyping step, the sought material is transferred to an object context that describes the future interaction. The last step of the operating manual describes this narrative object from another perspective.

While the material search and the prototyping of the individual perspectives allow for leeway, the step with the operating manual causes the participants to change perspectives and to describe the use for other people: How does it start, how can it malfunction or be misused, how is the object disposed of? All the steps (the contextualisation, the material search, the prototyping and the reflection level) are evaluated with regard to the new research fields. The evaluation takes place on the basis of the qualitative data from the individual objects and descriptions and the metadata of the objects that can encompass between 20 and 100 objects in this process, and the participants' assessment in the workshop. The group of participants should comprise the greatest possible breadth of society so that the widest range of different backgrounds and perspectives can be included in the process of prototyping. The results of the participatory workshops are analysed by experts and transferred to specific technology road maps. These participatory road maps differ from the classical road maps, for example, due to their integration of previously not-integrated stakeholders and the outlining of new research questions and fields on the basis of requirements formulated by layperson (cf. Schraudner and Wehking 2012). This permits the inclusion of social perspectives in expert discourse. With this procedural model of participatory prototypes, non-experts can be actively integrated into research planning and the development of new technologies.

4 Summary

Potential of Design Prototyping for Future Research Planning and Technological Development Design prototypes reveal a lot about future uses and areas of use and application. If we look at the prototypes from various areas of design over a certain time period and consider them as a whole, we learn a lot about what economic, ecological, cultural, technical and social challenges were connected with them.

What added value does design prototyping provide for research planning and technological development? On the basis of the examples presented in this text, it is possible to demonstrate that design prototyping, co-prototyping and participatory prototyping can be important indicators for research planning and technological development. The respective format must be selected for the specific issue of technological development. In what particular form and under specific what circumstances daily life experts should be included or specific knowledge and shaping skills from design should be relied upon depends on their concreteness and applicability with regard to the technology to be developed.

Design prototyping provides the best results when a technology has been determined, but the user groups are defined as freely as possible. Co-prototyping, by contrast, should be built upon a set technological spectrum (different, but combinable technologies) and be open for various uses with a broad range of fields of application. In turn, participatory prototyping requires the greatest openness; neither technology nor application fields nor user groups should be limited so that an uninfluenced picture of the needs and wishes can arise in the future. These different requirements for each prototyping format also have an impact on the diversity of the results. Design prototypes are already firmly established in terms of their use and interaction proposals, and can be transferred to realisation. Design prototyping produces a picture of a later product by combining technical, use-specific and aesthetic requirements. The results in the co-prototyping provide descriptive and visual information for a technical realisation, but require in general another translation, interpretation and transformation to design prototypes. Only these can translate the various, partially contradictory wishes and ideas into various products and services that are logical, consistent and aesthetically appealing. Participatory prototyping requires not only an open process: This format produces least of all a picture of a later product; the prototype here is only to be understood as a process tool that provides information about future research agendas and technological developments in the concealed information. A translation, interpretation and transformation process in design prototypes is also possible in the process of participatory prototyping, but it requires a lot of feedback loops with the respective groups involved in the process in order to produce a picture of a later product or service.

Figure 2 demonstrates the various possibilities for use and application in each prototyping format.

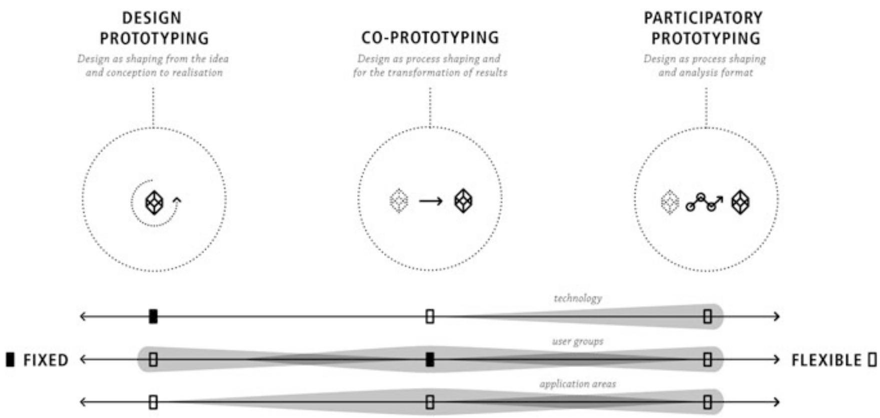

Fig. 2 User-centred prototyping for research planning and technology development

The research planning and technological development is part of the ongoing social and cultural development that can be designed with prototyping. The results from collaborating on research projects with designers, engineers and daily life experts demonstrate what the wishes and needs are for future technology.

As a result, this form of prototyping as an interdisciplinary form of communication can create a collective understanding of technological use. Open source products that offer interfaces for expanded use as open semi-finished objects could be conceivable. This might lead to product development, much in the vein of the open source movement in software development. Products and services would then have a basic configuration that can be expanded independently according to the user's personal wishes and ideas. Prototyping could then become a commonplace form of communication and interaction and become prevalent as a new medium in many areas of daily life, being used as a new form of education and training. This could certainly prove a fascinating challenge for the school of tomorrow if the old subject of "handicraft" enjoyed a renaissance through "prototyping".

Prototyping driven by design facilitates a discussion with respect to options for future actions. Thus, for future research, it is imperative that prototyping formats are defined to take a user's perspective into account as well. Prototyping driven by design can continuously integrate the user perspective into technological research. Consequently, design establishes itself as a discipline, within the technically natural, scientific research context.

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