The Results of Rethinking Prototyping

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Abstract The scientists and academics in the transdisciplinary project called "Rethinking Prototyping" have not only been working on concrete hybrid prototyping approaches in their research, but also on a joint understanding and a general concept of prototyping as well. A differentiated analysis of the terms used in contexts connected with prototyping led to the finding that their application both differs from discipline to discipline and is partially complementary, too. In the transdisciplinary context of complex interrelated developments, it is not expedient to attempt a

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definition that will cover all prototyping concepts. Rather, the prototyping methods and concepts should be placed and described in a multi-dimensional matrix. This article discusses considerations in this regard and presents their reflection in the "layer cake" publication format.

1 Introduction

The hybrid prototyping approaches in the sub-projects of the main research project called "Rethinking Prototyping" arose from a particular multi-perspective constellation that has survived all-too-rarely in the long run: the engineering disciplines at the Technische Universität Berlin (TU Berlin) and the artistic-design disciplines at the Berlin University of the Arts (UdK Berlin) worked together to jointly develop new prototyping concepts from the very outset.

In the three-year project, scientists and academics addressed the latest prototyping concepts in order to perform an experiment that involved the creation of a general, transdisciplinary concept of prototyping. They reflected on their own methods and approaches, considered new ones and determined similarities and differences in the areas of use, complexity, materiality and the objectives of the distinct prototypes and prototyping processes.

The experimental aspect of the "Rethinking Prototyping" project was considered in the practice of collaboration in the sub-projects; all the participants engaged in a continuous exchange on a joint level in various formats for three years in the guise of colloquia, retreats, workshops and review conferences that provided opportunities for productive transdisciplinary exchanges (cf. Eichmann and Nagy in this volume). In the summary of the latest developments in each case, it was possible to find starting points that opened up theoretical discourse on the one hand, but also led to cooperation with practical results on the other. This cooperation, for example, enabled a research team from "Hybrid Prototyping" and "Blended Prototyping" to create a prototyping app for smartphones. The app lets users find suitable prototyping processes for their development tasks and to do so in accordance with their particular stage of development and the desired function of the prototype. The information for the design of the app's content was provided by the findings from the project-accompanying discourse on prototyping, which defined the intensive, three-year collaboration between the participants. How the search for an overarching definition of prototyping was designed and what results it brought are presented in the following.

2 Explanation of Terms: Model Versus Prototype, Design Prototype Versus Technological Prototype

Prototyping of technical and digital systems, products and design artefacts or components is one of the core disciplines in design and engineering. Nevertheless, major differences exist with respect to the motivation, use, function and goal of prototyping, as well as the degree of rigour in planning, executing and reflecting prototypes, which eventually represent the output of prototyping. In the project, it was possible to question the actual way prototyping is applied in the different disciplines.

This diversity of prototyping concepts was also reflected in the project by the diversity of terms that the representatives from complementary disciplines used. The research group recognised the need to define the terms at the outset in order to precisely describe the prototyping concepts. This was followed by the need for exchange based on concrete examples where the relevant characteristics for the differentiation of the terms are manifested. A portion of the discourse therefore shifted to practice and was reflected in the hybrid prototyping concepts of the partial projects.

In the theoretical discourse on prototyping, two complementary main forms of prototypes have been differentiated and described. They are called the *design prototype* and the *technological prototype*, a distinction that is generally made across disciplines. The differentiation of their content in individual fields is not identical, however, and it is not possible to clearly assign these two forms to specific disciplines. At the start of the project, the two forms were juxtaposed on the basis of the main functional areas of prototypes that were identified in the discussions and in the joint prototyping processes. These main functional areas of prototypes can be divided into four categories: (1) generating ideas and externalisation, (2) determining user perspective and expectations, (3) validation and testing and (4) communication. In these categories, one can identify numerous individual functions that are comprehensively outlined in the chapter entitled "Perspectives on Future Prototyping—Results from an Expert Discussion" in this volume and in the conference paper bearing the title of "A transdisciplinary perspective on prototyping" (Exner et al. 2015). Some examples of these functions of prototypes are:

A prototype

- visualises mental ideas;
- supports the comprehension of complexity;
- enables communication, thus removing cultural and linguistic barriers;
- always contains a specific question and is limited due to given constraints;
- tests functionalities and requirements;
- creates a basis for common understanding of the idea that should be realized;
- localises users' interests and/or
- allows analysing users' interaction with the object.

To begin with, the two main forms of prototypes can be described on the basis of the categories and their associated functions as follows:

Design Prototype At the beginning of a development process, a design prototype serves to externalise an idea, determine the target horizon and define the problem. In later development phases, a design prototype also primarily involves functionality, but the aspects of use, interaction and communication take precedence here. Questions about the acceptance and the needs of users as well as the complexity and sequence of actions should be answered on the basis of the prototype. Adjustments and the consideration of alternative design proposals can be easily included since a wide spectrum of design and layout options remain available in this stage of development. Lastly, design prototypes also answer aesthetic questions.

Technological/Functional Prototypes An essential aspect of technological and functional prototypes is to prove the functionality and the implementation of the planned and developed product. This usually occurs in the late development phases. Only a few options for alteration in the specifications remain at this stage of development, since the effort and costs of adjustments rise disproportionately. The main objectives of functional prototypes in today's engineering approach are to evaluate the results of the development process and to ensure preparation for serial production of a product. However, in tomorrow's engineering approach the interplay of interdisciplinary teams need new types of functional prototypes early on the engineering process. Currently, such new functional prototypes are under research and development.

To summarise, it is not possible to assign a specific prototype to only one discipline. In this context, it was essential to research the interrelation between the different types of prototyping within the involved disciplines. By addressing precisely these issues, "Rethinking Prototyping" started where these traditional dichotomies of the two complementary prototype concepts can no longer hold sway and their merging in hybrid processes is necessary. Today, for example, development tasks in design are solved generatively and individually, which can give rise in principle to an endless number of prototypes that may also simultaneously be understood as a product. At the interface between the algorithmically-generated design and traditional design, the sub-project called "Beyond Prototyping" pursued research related to quick production possibilities in the creation of individualised products. Since the functions of a product can increasingly be scaled and modularised, a demonstration with a technological functional prototype is no longer expedient. The sub-project called "Blended Prototyping" examined how iterative user tests with prototypes can help to build a bridge between different levels of complexity in development. Increasingly, product development involves holistic systems with manufacturing and service components, infrastructure and business models. The "Hybrid Prototyping" sub-project answered the question of how these systems can be tested in a user-centred way. All three sub-projects sought hybrid prototyping approaches in areas in which no longer the complementary use of the technological and design prototype, but rather their merging could lead to a holistic solution.

The jointly undertaken attempt to differentiate between model and prototype also confirms the blurred boundary between the previously co-existing terms. According to the traditional point of view, the model was upheld as a simplified or reduced, but primarily theoretical and abstract replica of a complex reality, yet one which represents, in its objectified form, a fluid transition to the prototype. Above all, this applies to the generative models of designers that approach the complexity of reality in constant change and thus become prototypes. By contrast, the prototype represents a higher degree of complexity (in regard to the specific issue), which is why it can fulfil concrete demands, be tested, validated, verified and evaluated.

From the point of view of the engineering sciences, models and prototypes traditionally do not embody the degree of abstraction that is present in the generation of ideas, but rather a degree of maturity with respect to the realised draft in the sense of an analytical consideration aimed at a pre-defined goal. The levels of development in this sense trace the course of idea-model-demonstrator-prototype-product, with the model understood as the very general first materialisation of the idea. In common parlance, the prototype is considered proof of the correctness of an idea or objective, and can be understood as the first archetype of the product. This project has showed that not only a flowing transition, but rather also jumps are seen in this area: A model (even "just" a sketched-out idea) turns into a prototype by means of rapid prototyping, which can directly be the finished product as the "Beyond Prototyping" sub-research project showed. Quick production methods and algorithmically-generative and digital tools allow an approach to areas of engineering and artistic-design disciplines that initially think and operate in a complementary way.

At the end of the clarification processes for the terms, all the participants were in agreement that the role of the prototype as medium would be recorded as the smallest common denominator among the prototyping concepts. In terms of specific issues, a prototype is a mediating element between the actors involved in it. Prototyping processes are therefore at the core of communication processes.

3 From Static Prototypes to Dynamic Prototyping

The considerations on discernible dichotomies and the attempts at defining a prototype led to the following discovery: A view of the prototype that statically reflects a specific stage of development is not expedient in a holistic consideration of development processes in which the actors must fulfil systematic requirements in a multi-competent team. Therefore, the research group conducted prototyping processes in mixed groups in a prototyping workshop, and dedicated themselves to the analysis of development processes. Multiple development tasks from distinct fields were addressed jointly and documented on different levels (e.g. procedural and terminological). In the subsequent evaluation of the work and communication processes, it was possible to develop a discipline-overarching description of the prototyping process (see Fig. 1).

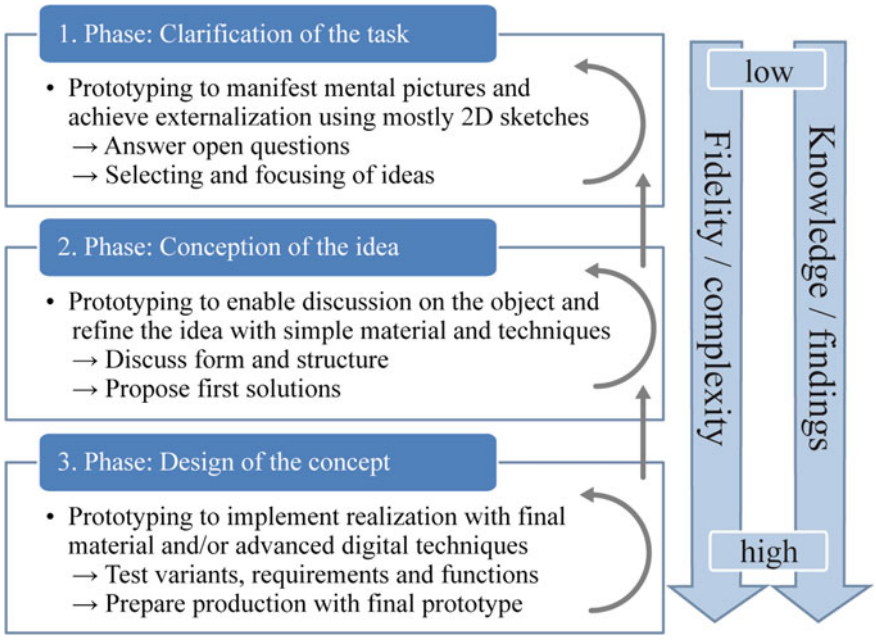

Fig. 1 Prototyping process (Exner et al. 2015)

The combination in this description was by no means trivial since nine disciplines (Digital Design, Industrial Engineering, Mechanical Engineering, Architecture, Automotive Engineering, Interaction Design, Computer Science, Cultural Science and Physics) were involved in the process and they brought greatly diverging views and focal points along with them (Exner et al. 2015). This abstract description of the prototyping process is integrative and represents a basis for communication in transdisciplinary development teams. The integration of distinct dimensions into the abstraction of an ideal-typical prototyping process helped achieve greater penetration than has been seen in the conventional, very generic attempts at definition.

Another step was the attempt to derive a collective prototyping definition from the workshop results. Although the distinctly used terms such as drawing, mock up, draft, simulation, model, etc. could ultimately be identified as partial aspects of a holistically observed prototyping term, a definitive, collective definition was ultimately not possible. Instead, this attempt raised the question of whether a complete description of applicable characteristics of prototyping across disciplines in the form of a definition is expedient. The research group considered it more sensible to describe the individual prototyping approaches according to their functional focal points (communication, validation, determining user perspective and generating ideas) and to position them in a multi-dimensional matrix. This facilitates a differentiated description of prototyping processes across disciplines and thus communication on their diverse potential and the resulting possibilities for use in

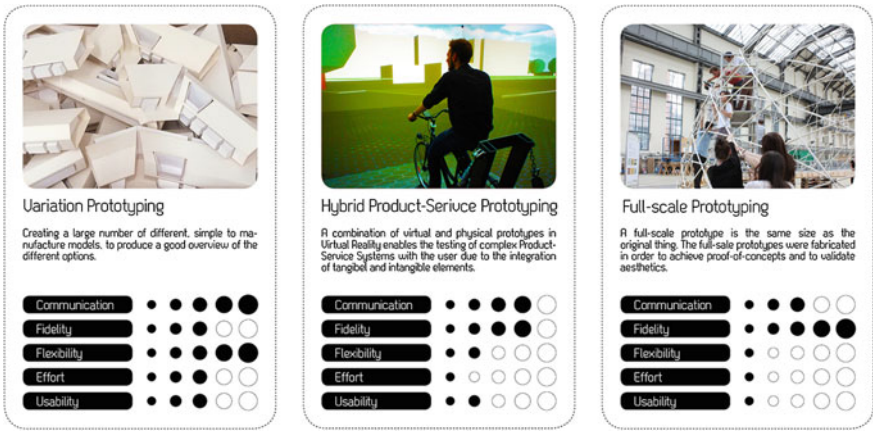

Fig. 2 Prototyping methods/prototyping quartet

interdisciplinary teams. The dimensions of the created matrix are the aspects of prototyping known to all the disciplines involved in the project: effort, fidelity, flexibility, usability and communication (Fig. 2).

The prototyping workshop, where these considerations and discoveries were addressed, was a valuable format for this project in order to question one's own perspective and to enrich the discipline-specific ways of thinking and procedures by obtaining ideas from other disciplines. The findings in the workshop, particularly the idea of a clear positioning and integrating individual prototyping concepts in a matrix, were practically implemented in the prototyping app for smartphones and in the prototyping quartet (Fig. 2). Both are elements of the expanded final publication for this project, the *layer cake*.

4 Layer Cake

In the three-year research process, the sub-projects developed the hybrid prototyping concepts that were presented in the preceding chapters of this anthology. The research group's objective was also to depict the research results in an integrative form that corresponds to the research principle of transdisciplinarity rather than to arrange them additively alongside each other in a standard collection (cf. Eichmann and Nagy in this volume). In addition to the prototypical self-reflecting, self-optimising project, an appropriate format was developed that reflects the character of the research. It is a package that includes this book and other artefacts layered one on top of the other. These layers transport the findings according to the principle of understanding by doing, which reflected a central aspect alongside the theoretical considerations in this research project. This form of publication offers access to research contents on multiple levels, so-called *layers*, and therefore

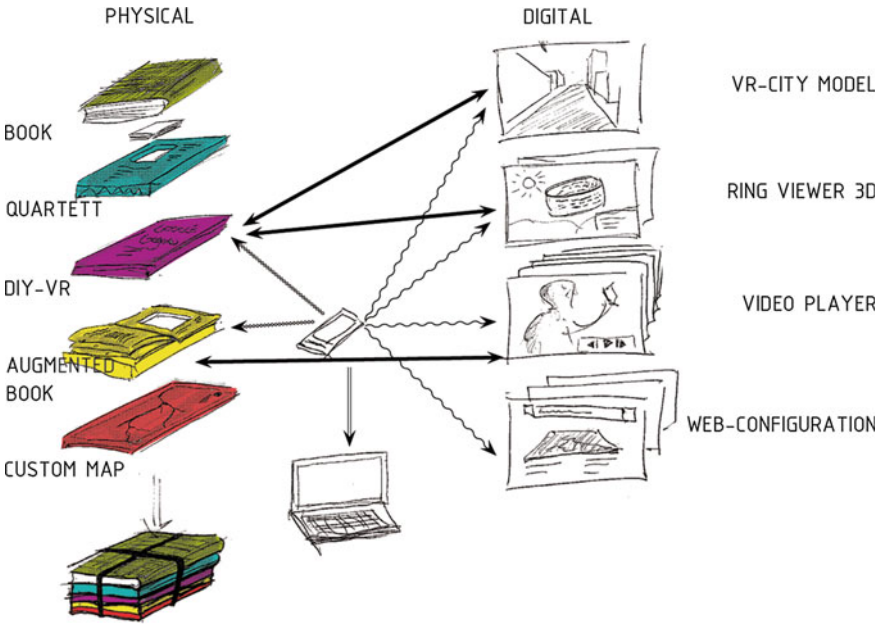

Fig. 3 Structure of the layer cake

abandons the framework and linearity of a book. The analogue and digital elements of this so-called *layer cake* impart knowledge from the considerations on the joint understanding of prototyping in a playful, appealing and generally understandable way. Figure 3 illustrates the structure and the concept of the publication of all the research results, which the research group understands as a prototype of a transdisciplinary publication.

The book, as the top layer, contains all of the scientific and academic findings from the individual sub-projects, the overall project and the projects accompanying this transdisciplinary project. The design of the cover reflects the increasing relevance of individualisation in product development: The regular pattern provides a scaffold for the owner of the book to customise its message. The cover of the book is inspired by random international's work in the early 2000s (http://random-international.com/work/tape/).

Quartet and Prototyping App The prototyping quartet card game and the prototyping app, as already described above, playfully reflect the results of the discussions on prototypes and prototyping in the search for a general understanding of prototyping. Prototyping quartet consists of 25 cards that show prototyping methods and the evaluation of prototyping properties. The description of the methods is carried out with the help of five categories (effort, fidelity, flexibility, usability, communication). Each category can be evaluated with a maximum of five points. The ratings can help in selecting the right prototyping methods. Comparing and displaying the quartet cards will amusingly introduce a player introduced to the

topic of prototyping. The contents are compiled by all project participants and are also used for the prototyping app, which is part of the applications within the augmented book. The prototyping app allows a development team to select suitable prototyping methods at different phases of the development process. Its interface also makes it possible to evaluate distinct factors such as expenses or communication. Finally, the app recommends multiple prototyping processes in a list. In addition, the user receives information and examples on how to proceed. The interface also offers the option of including additional prototyping processes in the app, along with their advantages and disadvantages, and thus places them at the disposal of users. The app thereby supports the search for new prototyping possibilities and makes it easier to try out different procedures.

Do it Yourself Virtual Reality For a better understanding of what virtual reality is and why immersion, interactivity and the human imagination are so important, we have built a simple prototype based on the Google Cardboard project. Google Cardboard is a simple HMD (head mounted display) consisting of a cardboard, two wide-angled lenses and a smartphone. Our approach is to empower the reader to build his or her own HMD prototype. For this reason, the project team prepared a cardboard and one virtual reality application, which is a ready-to-use smartphone. Following the instructions, the reader is able to build, see and understand how virtual reality and HMD displays work: The application makes it possible to place aspects of individual sub-projects at the disposal of users in an exploratory way. Accordingly, digital models from "Hybrid Prototyping", such as the digital city model of Berlin or the Pedelec product are visualised and explored by the user (cf. Exner et al. in this volume). Additionally, "Beyond Prototyping" enables a virtual previewing of an instance of the *Ciphering* (cf. Ängeslevä et al. "Beyond Prototyping" in this volume), enabling the user to align the model to decode the hardcoded message in the ring. Besides an additional display of the project results, which cannot be explained in a book, the complexity of virtual reality is reduced and thus made possible for the user to experience in a playful way, which is one of the main characteristics of prototyping.

Augmented Book The layer-augmented book creates a self-made book that integrates physical book pages with interactive content on mobile devices, inspired by the Kickstarter project "Little Magic Books". The book uses a mobile device that is attached on top of the last page. Through cutout areas in the other pages, a reader/user can see and interact with the device's display. After a specific app is installed on the device, it automatically detects which page the reader opened. This is done with small metal feelers that are integrated on the backside of the pages and trigger touch commands on the device display.

In this way, the device can provide content to the user that is related to the specific physical book pages. For such content, we use videos, 3D models, diagrams, photo galleries and a special medium—a film about the entire "Rethinking Prototyping" project. Furthermore, with touch gestures that bridge the space between the physical page and device display, the user can make references from the content printed on the page to the app installed on the device.

Custom Map Locatable is leveraging the social context that tables can provide and bringing meaningful and aesthetic customisation to "the table" (cf. Ängeslevä et al. "Beyond Prototyping" in this volume). As a layer cake component, a whole table is not feasible, and therefore an instance of locatable is produced that is ambiguous in its use. The chosen area of the map depicts the partners in the "Rethinking Prototyping" project, potentially serving as a talking point for the partners involved in the project.

5 Conclusion

The openness to questions and results in the project made it possible to flexibly circumvent the initially set goal of a collective definition of prototyping. The project's first results from comprehensive discourse raised the question of the extent to which a joint and holistic definition of prototyping can and should be sought at all. It was determined that it would be more expedient to work out fundamental factors that are applicable across disciplines and which, when transferred to a matrix, allow for a clear positioning and description of individual methods and concepts. Finally, it is important to note that the findings from the joint work on an overarching understanding of prototyping that produced the matrix concept, may only be preliminary at the present time. Nevertheless, they are also ground-breaking. The individual dimensions that are used to identify the various prototyping concepts across disciplines by their position in the matrix present an opportunity for future research that will theoretically justify and describe these in greater detail.

In addition to the theoretical findings, the individual sub-research demonstrated interfaces between the different disciplines and their concepts, which were subsequently used as a starting point for the development of concrete hybrid prototyping concepts. The differentiating, but also integrating consideration of prototyping in the theoretical discourse as well as the development and testing of hybrid prototyping concepts in practice facilitated the productive, transdisciplinary work on the research subject matter. With respect to the methods, processes, functions, areas of application and the objectives of the prototyping and prototypes, it was possible to achieve a more in-depth mutual understanding between the individual disciplines. On the basis of the experiences and findings in the project, such an understanding on a broader level can also be understood as a general prerequisite for the holistic development of new products and complex, interactive systems.

Reference

Exner, K., Ängleslevä, J., Bähr, B., Nagy, E., Lindow, K., & Stark, R. (2015) A transdisciplinary perspective on prototyping. In *International conference on engineering, technology and innovation* (Belfast, Ireland, 2015). Institute of Electrical and Electronics Engineers (in press).