Brief Report

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Potential and Challenges of Prototyping in Product Development and Innovation

Insights from an Expert Discussion Among Researchers and Practitioners

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Prototyping represents an established, essential method of product development and innovation, widely accepted across the industry. Obviously, the use of prototypes, i. e., simple representations of a product in development, in order to explore, communicate and evaluate the product idea, can provide many benefits. From a business perspective, a central advantage lies in cost-efficient testing. Consequently, the idea to "fail early", and to continuously rethink and optimize design decisions before cost-consuming implementations, lies at the heart of prototyping. Still, taking a closer look at prototyping in practice, many organizations do not live up to this ideal. In fact, there are several typical misunderstandings and unsatisfying outcomes regarding the effective use of prototypes (e. g. Christoforakos & Diefenbach [3]; Diefenbach, Chien, Lenz, & Hassenzahl [4]). For example, although prominent literature repeatedly underlines the importance of the fit between a prototyping method or tool and its underlying research question and purpose (e. g. Schneider [7]), practitioners often seem to lack reflection and structure regarding their choice of prototyping approaches. Instead, the used prototypes often simply rest on organizational routines. As a result, prototypes can fail their purpose and might not contribute to the initial research question or aim of prototyping. Furthermore, the varying interests of different stakeholders within the prototyping process are often not considered with much detail either. According to Blomkvist and Holmlid [1], stakeholders of prototyping can be broadly categorized in colleagues (i. e. team members involved in the process of product development), clients (i. e. clients, whom the product is being developed for or potential new clients to be acquired) users (i. e. potential users of the final product). Each of these stakeholders employ different purposes of prototyping due to their distinct responsibilities within the process of product development. Moreover, they can hold different expectations regarding the prototyping process, and thus, have different preferences for certain methods or tools. Yet, the substantial role of stakeholders in the appropriate choice of prototyping approach and methods is often overlooked.

The interdisciplinary BMBF funded research project ProFI (*Zielgerichtetes Prototyping für gesteigerte Innovation; FKZ: 01IS16015*) addresses such challenges and focuses on goal-oriented prototyping for innovation. The present paper reports central findings from an expert discussion among researchers and practitioners concerned with prototyping. In total, representatives of three companies (IXDS GmbH: Sven-Anwar Bibi, Nina Volkanova; Micromata GmbH: Moritz Fröhner, Tobias Marx; Neuland-Medien GmbH & Co. KG: Nadine Pfeiffer-Leßmann, Thies Pfeiffer) and two universities (Hochschule Mannheim: Kirstin Kohler, Dominick Madden; Ludwig-Maximilans-Universität München (LMU): Lara Christoforakos, Sarah

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Figure 1: The expert discussion among researchers and practitioners at Micromata GmbH in Kassel, Germany.

Diefenbach, Stefan Tretter) took part in the discussion. IXDS GmbH is an agency based in Berlin and Munich, focusing on the design and technical development of innovative product-service ecosystems and connected hardware. Micromata GmbH focuses on developing customized software solutions for companies in the fields of logistics, automotive, pharmaceuticals, medical technology, energy and raw material extraction. Neuland-Medien GmbH & Co. KG is an agency providing new media solutions and a specialist in mixed reality, prototyping, and IOT. The discussion was led by the three researchers from LMU and focused on the awareness of prototyping in practice, the appropriate choice of approach and methods, the role of stakeholders in this process and general benefits of goal-oriented prototyping within organizations. Furthermore, reflecting on two years of experimenting with different, more systematic prototyping approaches in context of the research project ProFI, participants reflected on the specific developments regarding prototyping within their organizations. In sum, the primary goal of the expert discussion was to identify common challenges of prototyping in practice within different branches as well as potential benefits that a systematic use could provide for all kinds of organizations. Based on those practical considerations we seek to identify universally applicable ways to choose prototyping methods systematically in an appropriate manner. Therefore, reported insights are relevant for both practitioners of various domains as well as HCI researchers, who want to establish systematic, goal-oriented prototyping for various product concepts.

In the remainder of this paper, we cover goal-oriented prototyping and its application in practice, focusing on central topics of the expert discussion, such as the systematic choice of prototyping approaches and methods, the role of stakeholders and benefits of prototyping on organizational components. Finally, the last section reflects on the generalizability of our results and implications for prototyping in practice.

1 Insights from an Expert Discussion: Potential and Challenges of Prototyping in Practice

ST: *Let's begin with a general reflection on the routines of prototyping in practice. At the beginning of our research project, about two years ago, we conducted focus groups on this issue within each of your companies. Can you still recall your practical perspective on prototyping at that time?*

MF: At the beginning of the project, when it came to developing a prototype, we mainly focused on the time frame set by our organization as well as methods and materials that were easily accessible and could support the efficient development of a prototype. Thus, we were often driven by routines or current circumstances, when deciding on the prototyping method and tool. But we rarely reflected on the underlying research question and the most suitable, yet at the same time cost- and time-efficient way to answer such.

1.1 Awareness of a Systematic Choice of Prototyping Methods Regarding Design Phases

LC: *Starting the research project, you critically remarked that prototyping approaches and methods were mainly chosen in accordance with organizational routines rather than with regard to the particular product's design. How is your*

Figure 2: Virtual AR-Prototype on Gear VR (ExProtoVAR) coupled with prototype for IoT devices (C-Blocks) and integrated web-app to assist users finding the correct wine.

organization handling this today? How far have you challenged this approach?

MF: Oh yes, this has definitely changed. Meanwhile, the choice of prototyping methods and tools has become way less habitual. We take our time to reflect and challenge our quick decisions – will this method answer the initial question that motivated us to prototype this concept idea? Are we aware of the concrete research question?

In additional statements, the experts highlighted a certain feeling of confidence coming with the more systematic consideration of their prototyping process. This growing confidence was also experienced as affecting costumer relationships in a positive manner. According to the experts, customers also notice a more thought-through analysis of the "ideal" prototype depending on the phase of product development, thus fostering a relationship of trust within various projects.

***SD:** Great to hear that your growing expertise in prototyping has so many positive effects on different levels. How are you planning to further enhance and sustain such an awareness regarding goal-oriented prototyping within your organization?*

NV: Well, I guess communication is key. We are really making an effort to create an ongoing discussion about prototyping approaches and methods. Throughout the project, we might have had challenges due to changing team members. Yet, this led to many colleagues being involved in this process of reflection regarding our prototyping process and thus influenced a very large group within our organization in a positive manner. We can adopt many insights we gained from this for various other ongoing projects.

TM: On the one hand there is an improvement in the mind-set regarding the importance and goal-orientation of prototyping, but on the other hand a certain maturity and structural preconditions on the side of the organization are necessary, too. There is still potential for improvement in order to truly facilitate fundamental and sustainable change. We should not forget that.

In sum, the experts described a sharpening of their awareness regarding the importance of the fit between prototype and underlying research question and various resulting, positive consequences on their work. Nevertheless, a still existing need for improvement regarding time- and structure-based organizational factors, in order to nurture these developments, was highlighted. Along with that, specific challenges for prototyping in practice were named and elucidated through examples of projects that did not work out as planned.

1.2 The Role of Stakeholders in Prototyping

SB: During one of our recent projects we applied classical *Storytelling*, since we were still in a phase of ideation. Yet, the use of this specific prototype at that particular stage of interaction with the client turned out to be the wrong choice. The client was expecting to see an almost finalized product and could not grasp the concept presented in such an abstract way. Another client insisted on high-fidelity prototypes, although what he took interest in at the time, were general aspects of the User Experience (UX), which could have been easily illustrated and evaluated in a way more abstract and faster manner. In such situations we are confronted

with the importance of considering the involved stakeholders in each individual project phase. It is not only about us and which method or tool we have chosen to apply after detailed consideration but, for example, also about the client, who might have a different understanding. Such experiences still surprise us and deliver valuable insights.

ST: *This is an interesting aspect; the individual choice of prototype also depends on the stakeholders involved. Did all of you make such experiences? Could you illustrate this with examples from your daily prototyping practice?*

TP: We recently had a project, where we designed a prototype for UX evaluation. In this prototype visual components and functionalities could be altered and tested, in order to choose one option. Yet, for the costumer this level of UX design was too complicated, as he had not been used to the cycles of prototyping within product development. Therefore, we designed a prototype more similar to the final product. Surprisingly, this prototype is now used for apprentice trainings. A great example for the importance of stakeholders but also the various purposes of prototyping.

SB: Another interesting experience was an interaction with a client. We suggested a very innovative and creative prototyping process for the development of a certain product concept. Unfortunately, the cooperation did not continue, and we realized, that prototyping approaches and methods can be very mature and goal-oriented, yet many organizations in the industry need scalability. They prefer solutions that not only offer a prototype of the concept but also link to further resources for the material, necessary to implement the concept idea. Thus, we realized that it is an advantage to be able to not only simulate the final product concept in a cost- and time-efficient way, but also plan ahead on connecting providers, that can ensure an efficient practical implementation of such.

1.3 Prototyping as a Trigger to Reflect on Organizational Processes

Apart from evaluating established prototyping methods and reflecting on the prototyping process as a whole, within the research project ProFI, all of the industry partners focused on developing their own prototyping tool based on insights about generally existing challenges of prototyping in practice as well as within their own organizations in particular. The tools be shortly described as follows:

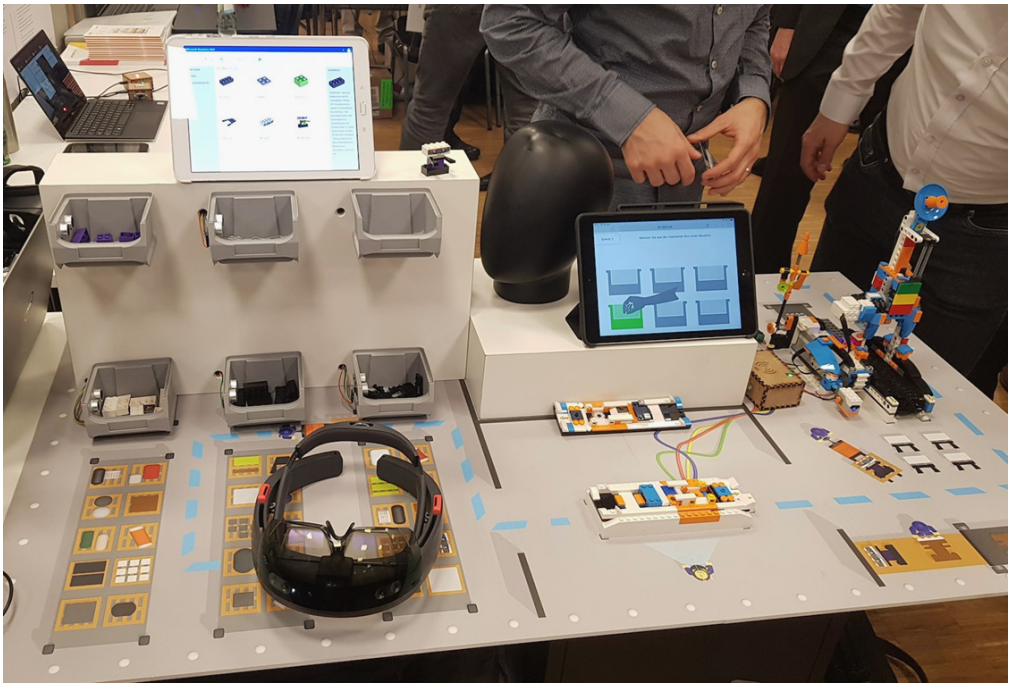

Figure 3: A demonstrator presented at the BMBF Mittelstandskonferenz 2019, which included prototypes assisting in (a) picking up lego parts (assistance by HoloLens AR application, assistance by web interface on tablet), (b) positioning lego parts (assistance by HoloLens AR application), and (c) operating the machine (assistance by HoloLens AR application). In addition, prototypes consisting of C-Blocks were integrated to recognize when lego parts were taken out of the boxes and which component carrier was placed (with the help of RFID tags).

- A tool (ExProtoVAR; Pfeiffer & Pfeiffer-Leßmann [8]), that supports quick and lightweight prototyping of Augmented Reality applications and Mixed Reality interfaces for IoT using Virtual Reality technology
- A development environment for easy creation of high and low fidelity webapp prototypes based on HTML, CSS and JavaScript
- A tool, which enables the creation of HTML prototypes without programming knowledge as well as a direct evaluation of such
- An ideation tool, where different stakeholders can cooperate in the generation of a prototype with its many different components, e. g. user stories as well as technical and operational specifications

LC: *How would you say did the development of your individual prototyping tool affect your perspective regarding prototyping as well as the way you work?*

NV: Initially, we started developing the tool for a certain purpose, or more precisely a specific design phase. We planned the tool for the purpose of ideation, enabling the creation of different user stories but also as a platform for the purpose of communication within the organization. Reflecting about it, we realized that the tool could also be used for the purpose of interactive product development. In general, I think, there are many different projects, where we could achieve many different outcomes using this tool. Somehow, we stopped only focusing on continuously improving the prototype quality but gained a broader perspective focusing on different ways to work, which are enabled and enhanced through the tool. This does not only apply for designers but also for our clients. Depending on the project, we always have varying requirements, this is an approach we want to highlight through this tool and that will also lead to the tool being continuously adjusted.

MF: Our tool might enable colleagues, for example, UX Designers, to try out new tasks, that didn't use to be a regular part of their job, such as the iterative interaction and confrontation with a prototype. Through focusing on this tool and the integration of it in our company, we kind of moved away from classic roles within the organization towards skill sets. Nowadays, employees with diverse backgrounds take part in the different tasks and phases of the design process. This is a significant change compared to earlier days, where people would not have been involved in tasks and decisions that did not exactly match their defined role within the organization. It will be interesting to further observe such changes and new possibilities that have resulted from the participation in such a research project.

SD: *The developments are really impressive. In fact, the prototyping tools you mentioned are not highly complex, yet they obviously trigger essential changes in the way you work or communicate within the organization.*

TP: Indeed, I mean ultimately – on a meta level – developing new prototyping tools implies the analysis and close examination of processes within the organization as well as the way we work. You are forced to ask yourself: "How can I improve and optimize organizational processes (e. g. the process of prototyping)?". In our case the technology applied in the prototyping tool is the same we use within production. Thus, people develop competences they can make use of in the further design process. The engagement in the development of such a tool should be a central focus within an organization – how should it be presented on the market? What is our unique selling proposition? – as we want to show that we do not only deliver a product but the competence to make a change. Reflecting about such questions, we continuously work on and adapt our own corporate philosophy.

2 Conclusion

In sum, the present discussion among representatives from different branches of digital innovation pointed out that a systematic reflection on the goal-orientation of prototyping within their organizations raised general awareness for the quality of prototyping and yielded benefits on many levels. Still, according to the experts, there is room for improvement. Organizational routines and structures must allow for and even foster reflecting about such issues instead of simply maintaining routines, which are sometimes merely based on easy accessibility of prototyping methods and time-pressure. Furthermore, the general importance of stakeholders within the prototyping and design process was highlighted, as many project-examples were given, where problems rooted in insufficient consideration of stakeholders' needs and expectations regarding prototyping approaches and methods. As this had been a repeated issue during our research project, we decided to conduct a workshop with the industry partners, focusing on stakeholders involved in the product design process within their respective organizations. As a result, we came up within an initial set of stakeholder categories (see Figure 4) in the form of personas (e. g. Chang, Lim, &

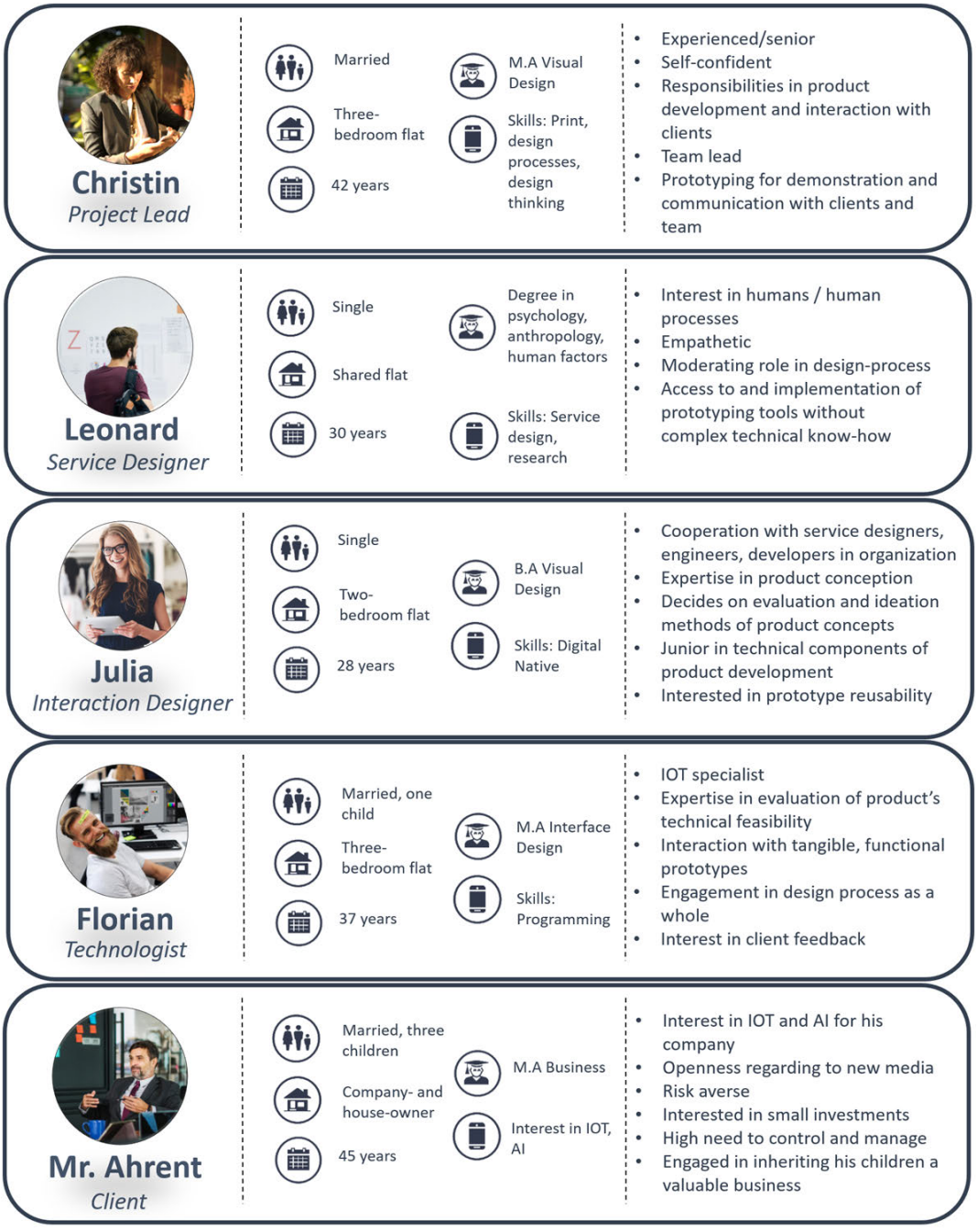

Figure 4: Initial set of stakeholder-personas within the design and prototyping process of the industry partners.

Stolterman [2]; Pruitt & Grudin [6]). They are illustrated as fictional characters with typical demographic attributes, goals, motivations and behaviour patterns and provide guidance for choosing methods based on such stakeholders' needs and project context. According to the industry partners, such a systematic structure, considering interrelations between stakeholders involved in the design and prototyping process on the one hand and different purposes of prototypes on the other, can serve as a practically applicable approach and helpful guide for goal-oriented prototyping. Yet, to confirm the applicability of such a stakeholder-based approach within various organizations and branches, further experiential evidence from practitioners, e. g. from companies with different organizational structures and clients, are needed.

The general insights of the present expert discussion are not limited to the industry partners' specific domains but can be applied to various branches and organizational

structures. Prototyping itself basically encompasses the process of filtering certain aspects of a concept idea and manifesting those in a tangible manner [5]. Thus, these insights can be relevant for typical prototyping domains, like the development of Internet of Things concepts, as well as for the Human Resources context, e. g. within change management processes, where new organizational structures need to be prototyped to evaluate possible needs of various stakeholders involved. Along with the increase of technological development and therefore many unpredictable, ever-changing circumstances within the industry, it is ever more important for various branches and organizations to reflect on established prototyping processes and approaches as well as the specific fit between a prototyping method and its purpose of application.

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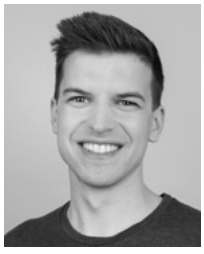

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