EARLY PROTOTYPING FOR ORGANIZATIONAL LEARNING IN UNCERTAIN ENVIRONMENTS

Master thesis to reach the degree of

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Abstract

In order to cope with a rising complexity of products, an on-going digitization and an accelerated change of market demands firms have to take a proactive step towards uncertainties. One way to do so is the adoption of iterative, learning-oriented methods in order to incrementally adapt to changing environments.

The concepts "early prototyping in design" and "business experiments", which are predicated on an iterative mind-set, have been so far remained relatively unconnected. By investigating their commonalities, differences and benefits in detail, it is shown that the concepts could supplement each other on various levels and could be combined into one comprehensive framework.

The framework integrates both concepts with each other and links them by utilizing literature from organizational learning as well as aspects of modern project management to present crucial aspects for the development, presentation and discussion of early prototypes and business experiments. To ensure a practical feasibility, practitioners have been interviewed to include their opinions and challenges in the framework design. Furthermore, the framework has been validated by interviews with business consultants.

By applying the framework, managers can unhinge early prototypes and business experiments from their particular discipline boundaries. Furthermore, the framework shows how managers can combine both concepts in a structured manner in order to unfold their benefits on a organizational-wide level.

Keywords:

Early Prototyping, Business Experiments, Organizational Learning, Agile Development, Digital Economy

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1. Introduction

The omnipresent innovation imperative of the last decades has changed many business environments fundamentally: Steadily shortening product life cycles, the ever increasing speed of new technologies, an endless float of new product categories as well as rapidly changing market demands and customer needs bid defiance to companies of all shapes and sizes. This development is not only but essentially influenced by an all-embracing digitization that forces even well-established corporations to expand and remodel their ancestral business operations. That is why companies have to accept that traditional planning paradigms do not work in a usual manner anymore in this dynamic and highly competitive environment. For this reason, representatives of both the business and academic realm have to rise to the occasion and conceive new methods and managerial perspectives that successfully address those pressing problems.

1.1. Conceptual Background

Some disciplines and professions cope with uncertainties by adopting iterative product & service development processes: They try to adapt to their particular challenges and requirements by on-going prototyping and experimenting.

In Design-related professions, iterative working is an essential practice and widely discussed under the term "early prototyping"[1] (e.g. T. Brown, 2009; Coughlan, Suri, & Canales, 2007; Cross, 2006; Houde & Hill, 1997; Junginger, 2007; Schrage, 2000). Methods that are grouped under this term focus mostly on building tangible representations of early ideas in order to discuss them internally and externally and refine them in iterative steps.

Mainly in the start-up and entrepreneurship space, iterative, learning-oriented approaches gained recent attention under the term "business experiments" (Anderson & Simester, 2011; Ariely, 2010; Chesbrough, 2010; Davenport, 2009; Govindarajan & Trimble, 2004; Schrage, 2007, 2010). Approaches to "business experiments" highlight the importance of trial-and-error-learning and offer a comprehensive process-view for the testing of ideas and prototypes with real customers in order to optimize product and service development.

[1] Some publications use the term "rapid prototyping" with a definition that is similar to "early prototyping". However, "rapid prototyping" is used in manufacturing as well for a specific set of manufacturing methods (e.g. 3D printing). To circumvent misunderstandings the term "early prototyping" is used exclusively in this thesis.

On a more theoretical level, "organizational learning" scholars focus on uncertain and complex environments and suggest iterative, learning-by-doing approaches to deal with those challenges. Famous scholars like Karl Weick ("sense making" - e.g. Weick, 2009), Henry Mintzberg ("learning school" - Mintzberg, Ahlstrand, & Lampel, 2009), Peter Senge ("The Fifth Discipline" - Senge, 1990) and Peter Drucker ("knowledge worker" - Drucker, 1999) emphasize the necessity to accept uncertainties and ubiquitous unknowing and to react to them by continuous organizational learning.

It can be stated that different disciplines and professions rely on learning-oriented practices and consider prototyping and experimenting as an adequate response to uncertain, unpredictable environments. Furthermore, these methods gain a rising importance, through the ongoing digitization, which offers opportunities to track and measure customer behaviours. Hence, it is possible to prototype new digital ideas and concepts at extremely low costs and verify assumptions at a fraction of time (Schrage, 2010, pp. 58–60; Thomke, 1998a, p. 747).

1.2. Problem Statement

However, it should be pointed out that theories and methods regarding prototyping- and experimentation-oriented practices rarely extend beyond the boundaries of their respective disciplines and approach the topic with a highly specialized focus on their field (for example early prototyping for interaction designers, or business experiments for start-ups). Hence, the central terms and concepts are discussed in a fragmented manner: The present literature is not connected and does not build on findings from each other. Furthermore, a more general perspective on managing early prototyping and business experiments is not existent. Consequently, scholars (P. M. Hughes & Cosier, 2001, p. 2; Liedtka, 2004; Rhinow, Köppen, & Meinel, 2012, p. 6) as well as practitioners call for new perspectives that understand prototyping and business experiments as a management tool.

The master thesis at hand assumes that the mentioned iterative approaches, namely "early prototyping" and "business experiments", could add value to each other by exploiting commonalities and supplements. Furthermore, it is assumed that a managerial focus on prototyping and experimentation will foster organizational learning and could help companies to successfully sustain in uncertain environments.

2. Research Issues & Methodology

Based on the presented problem statement a detailed research goal and a corresponding research question have been derived. Based on those starting points a three step research design has been developed.

2.1. Research Goal

The main goal of this research is to close the depicted gap between business experiments and the methods of the design domain in order to develop a strengthened, extended view on early prototyping that builds on the most relevant aspects of each discipline and identifies overlooked managerial aspects of early prototyping. To do so, the master thesis at hand aims at integrating knowledge from the different research fields into a comprehensive, practical framework for the management of early prototyping. To ground this outcome in already established management literature, the framework will also draw on ideas from the organizational learning literature. Expert interviews with practitioners ensure that the designed framework has sufficient practical relevance and is capable to answer current, practical challenges innovating firms have while using early prototyping.

As the final outcome, this thesis presents a framework that guides practitioners through early prototyping and business experiments by exploiting knowledge from three different fields of research. It gives them guidance on how to setup and steer early prototyping and highlights relevant stumbling blocks and optimization opportunities. Furthermore, the introduction of such a framework should shed light on the power and advantages of early prototyping and should inspire managers to attach greater importance to it in order to improve organizational learning capabilities in the early phases of new product development projects. In the best case, managers are able to achieve improved product market fit (e.g. Ries, 2011), save costs due to early problem identification (Thomke, 1998b, 2003) and enjoy a wide range of communicative advantages (e.g. Erickson, 1995; Hartmann, 2009; Lim, Stolterman, & Tenenberg, 2008; Mascitelli, 2000; Rhinow et al., 2012) by using the presented framework.

From an academic point of view, it is the goal to answer the mentioned call to understand prototyping as a management tool and to conflate the different involved research fields in order to extent the evolving base of early prototyping literature and understands the method as a general and fundamental practice to innovation.

2.2. Research Questions

Derived from the aforementioned research goal, the primary research question is formulated. It includes the mentioned fields of literature and asks for a meaningful connection of these fields in order to develop a framework that combines the most relevant insights of the disciplines. Furthermore, the research question incorporates a focus on complex and fast changing business environments (e.g. businesses, which have to deal with the ongoing digitization) in order to lay a specific research focus on the application of early prototyping in environments with high uncertainties.

> *"How can insights from organizational learning, business experiments and design research on early prototypes be combined to a framework for the management of early prototyping in complex and fast changing business environments?"*

This central question can be separated into three distinctive sub-questions, which structure and guide the research.

> **Sub-question 1:**
> *Which differences and commonalities between early prototyping and business experiments can be identified and what benefits do they pursue?*

First of all, the current status of literature has to be evaluated in order to examine the concepts of early prototyping and business experiments. Due to the broad set of research fields that mention early prototyping in different ways it is necessary to highlight connections, complements and contradictions between the different fields.

> **Sub-question 2:**
> *What kind of challenges do innovation managers have by using early prototyping?*

It is the goal to develop a framework that helps managers to exploit the identified benefits and advantages of early prototyping. By including practitioners' experiences into the research it should be assured that practical perspectives and problem perceptions on early prototyping are considered. Therefore, it was imperative to conduct expert interviews with practitioners who already established early prototyping to a certain extant in their companies.

Sub-question 3:

What could a comprehensive framework for the management of prototypes look like?

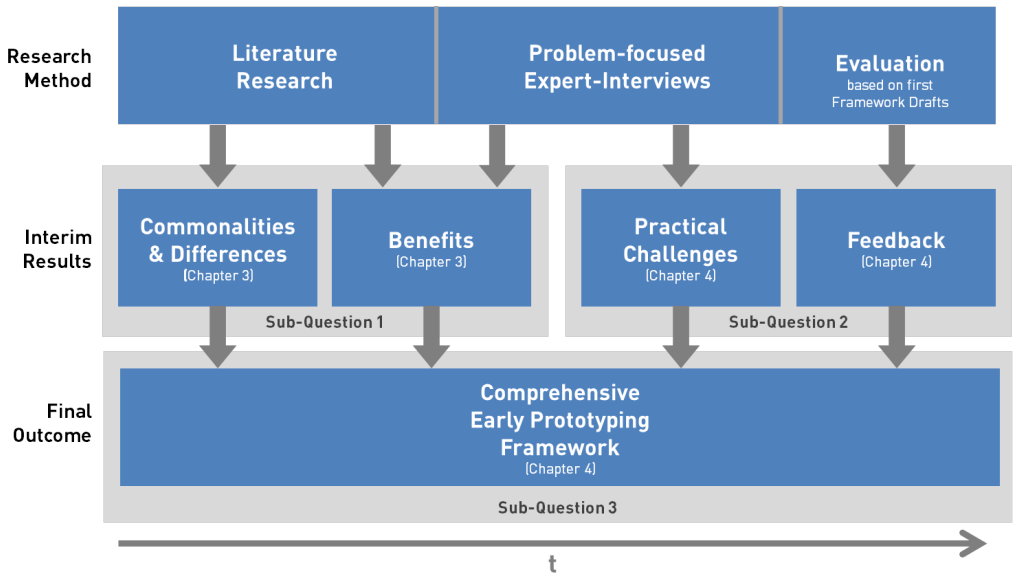
Finally, the results of sub-question one and two will be consolidated to develop a comprehensive framework that takes the identified criteria for prototyping (sub-question 1) and practitioners' needs and problems regarding early prototyping (sub-question 2) into account. The ultimate goal of this thesis is to suggest a framework that gives managers the opportunity to manage early prototyping and business experiments in a structured way.

2.3. Research Design

Based on the presented research questions, the research design is separated into three interrelated steps that lead to the intended "early prototyping framework" (see Figure 1-Research Design). The process starts with a comprehensive literature review in all mentioned fields of interest in order to collect all aspects of early prototyping and insights from business experiments as well as organizational learning. By doing so, a detailed understanding of the subject of study was established (see chapter 3, answering research question 1). Simultaneously, the design and sketching of first possible early prototyping frameworks began.

Afterwards, a qualitative expert interview series was initiated. From this point on, the literature review was guided by first results of the interviews and deepened when interviewees highlighted new aspects. For this reason, the research design at hand is rather iterative than linear. Finally, after the results from the interview series had reached the necessary degree of saturation and the literature research process had been completed, the developed framework was evaluated with practitioners to assure that it has practical relevance and value. This feedback was incorporated into the final framework as well. The results of the problem-focused expert-interviews as well as the evaluation were directly integrated into the description of the "early prototyping framework" in order to present a conjoint explanation of the developed steps (see chapter 4).

Figure 1 - Research Design



2.3.1. Qualitative Expert Interviews

In order to enrich theoretical findings about early prototyping with practical perspectives a series of qualitative expert interviews was conducted.

2.3.1.1. Goal

The interviews were geared towards obtaining a deeper understanding of the usage of early prototyping and business experiments in new product development processes. Therefore, it was intended to acquire knowledge about how companies manage their early prototypes and how they perceive the relevance of them. In doing so, a main focus was on problem descriptions of the interviewee: By giving these problem narratives a high relevance the interviews helped to identify weak spots in the use of early prototypes that could be potentially filled by literature. The combination of the results of the qualitative interviews with recent research findings should culminate – as already described in the beginning - in a framework for the management of early prototypes that has a practical relevance and is capable to support managers with their problems.

Therefore, the leading research question for the qualitative expert interview series – as stated in sub question two - was:

> *What kind of aims, needs and problems do innovation managers have by using early prototyping?*

This research question is best addressed in an explorative, qualitative research approach with semi-structured interviews that are open enough to capture unexpected, new insights that are not covered in the literature. It has to be expected that the respondents will have relatively different approaches to early prototyping. The resulting differences and commonalities would not be covered with a quantitative research that relies on a fixed, "closed" set of previously defined items. Nevertheless, it is necessary to develop an interview guide to be able to focus and steer the interviews if necessary and to assure comparability between the interviews.

2.3.1.2. Sampling & Acquisition

Littig (2008, p. 3) - with reference to Dexter (1970) - argues that an expert status is always an ascription in relation to the field of research. Meuser and Nagel (Meuser & Nagel, 2009, p. 17) support this notion and state that an expert has knowledge about the company or a certain context of interest that is not accessible to the researcher. This does not mean that an expert has to be a top manager: The mentioned knowledge is often obtainable in the middle management in the second and third level of a company due to the fact that those managers have detailed knowledge about internal structures and events (Meuser & Nagel, 2009, p. 18). It follows that not only knowledge regarding the particular field of research – in this case early prototyping and business experiments - is necessary but also practical knowledge about the processual organizational context in the particular organization (Bogner & Menz, 2009, p. 46; Sprondel, 1979). Therefore, this research is looking for internal experts with practical know-how about the object of investigation rather than external experts with academic knowledge. The interview sample was not predetermined but continuously extended based on replies and gaps in the data as it is suggested by Strauss and Corbin's theoretical sampling (Corbin & Strauss, 1998, p. 201).

All interviews were conducted with experts that are working in innovative environments and have a position in innovation management departments of larger European corporations. The focus on members of innovation management departments was chosen to make sure that the interviewees can report from and share insights of different new product development projects. Furthermore, it is assumed, with reference to Hauschildt's promotor model (Hauschildt & Kirchmann, 2001), that innovation managers are relatively well connected inside their particular innovation projects and in general inside the company. So they are expected to have a broad knowledge about early prototyping activities in the company and can describe experiences, problems and challenges of different departments with early prototyping. The inputs of experts with specialized professional backgrounds like engineering or design were disregarded even if they would have interesting and helpful insights from their profession regarding early prototyping. This decision was taken in order to sustain comparability between the interviewees ((Meuser & Nagel, 2009, p. 30) and circumvent a Babylon confusion of tongues due to varying understandings and methods of early prototyping between different disciplines.

A careful and conscious acquisition of the experts was required: It was necessary to assure that the potential interviewee has already experiences with early prototyping and has the assumed network position inside the company to be able to provide an interesting set of insights. This selection problem was solved by two different approaches: The larger part of the addressed interviewees was recommended by friends and partners that knew that these people work with early prototyping. Cold calls were only made to practitioners that published articles or blogposts about early prototyping.

Due to the vague and often conflicting usage of the term "early prototyping" it was crucial to inform the potential interviewees upfront about the used understanding of the term to circumvent confusions and false expectations. To accomplish this, the requested interviewees received a short, two slide-long PowerPoint pitch deck that introduced the research project, presented the used understanding of early prototyping and gave the interviewee an overview over exemplary questions. This preview offered the interviewee the chance to assess the style of the interview and should increase the likelihood of the willingness to participate (Christmann, 2009, p. 158). Queries of the interviewees were seldom and answered mostly via e-mail.

Table 1- Overview of Interview Partners

Company	Position	Industry
Deutsche Telekom Value Added Services	Vice President Strategy Head of internal incubator program	Telecommunication Services
Siemens Corporate Technology China	Senior Innovation Manager	Industry
Siemens Industry Drive Technology	Project Manager	Industry
Deutsche Bahn Systel	Innovation Manager	IT Services / Transportations
Novo Nordisk	Innovation Manager	Health Care Equipment
Deutsche Telekom Innovation Laboratories	Technology Coordinator	IP Infrastructure
Nokia	Head of Idea & Innovation Management	Mobile Network Infrastructure
Fraunhofer - IPK	Engineer and Researcher "Virtual Product Creation Cave"	Virtual Environments
Volkswagen	Head of New Mobility	Automobile

Although mainly higher middle managers were requested it was possible to acquire nine diverse, interesting and relevant interview partners from different industries (see Table 1). Due to the theoretical sampling, the group of interviewees grew as the interview series

progressed. After the first seven interviews, the developed code and category systems seemed to be already well established (see 4.1.5. – Analysis and Coding) and only minor changes were necessary to code new material. Anyhow the already appointed eighth and ninth interview were conducted in order to back up the developed coding and make sure that theoretical saturation was reached (Corbin & Strauss, 1998, p. 212). It was made certain that additional interviews would cause only minor changes to the codes and categories, while the developed categories and codes offer a sufficient density and variation and are well related to each other (Corbin & Strauss, 1998, p. 212).

2.3.1.3. Interview Guide

In order to reach the defined goals of the expert interviews it was necessary to balance a guided structure that keeps the focus on the field of interest with an interview guide that is as open as possible. This openness was needed to give the interviewees the chance to talk about their approach to early prototyping and their opinion about it without requiring larger divergences from the original guide. At the same time, the interviewer needed a reliable way to steer and focus the interview to relevant aspects and prevent the interviewee from digressing too much. This perspective is highlighted by various qualitative social researchers, for expert interviews, especially Meuser & Nagel (2009, p. 38) and Dexter (1970).

In addition, it was anticipated that the relative newness of the topic could lead to a broader, more different set of presented approaches to management of early prototyping. Therefore, the interview questions were kept open enough to be able to capture a wider range of methodologies, processes and approaches. During the interviews the guide was used as a loose support to structure the interview. The interviewer never read off the listed questions but rather reformulated them according to the actual interview. Furthermore, the order of questions was handled flexibly and was restructured when the interview progress suggested such a change. As already mentioned, the interviews were geared towards collecting personal interpretations and understandings of the experts and did not aim to outline general opinions on early prototyping. Therefore the interviewer tried to ask for und focus on specific examples and stories in order to access the company-specific knowledge base of the interviewee.

The guide presented below constitutes the second iteration: The first version, which was shorter and more open, was largely revisited after the first interview due to the realization that a more detailed structure is necessary to give the interview partner a clearer outline and the interviewer sufficient access points to steer the interview and deepen interesting aspects.

The interview guide is structured in six subparts (see Table 2). After a first icebreaker question that asked for a short introduction of the interviewee, the interview was opened with general questions regarding the interviewee's understanding of early prototyping and related benefits and strengths. These questions were helpful to smooth access into the conversation and to assure that the interview partner does not have completely different understanding of early prototyping.

The subsequent block asks for applicability and scope in order to get an understanding of the field of application the interviewee's company uses early prototyping and business experiments for. By asking the participants for their particular fields of application it was possible to identify first goals and aims. Furthermore, in addition to the general interest of practitioners' opinions about the applicability of early prototyping these two questions were necessary to be able to contextualize the particular answers of the interview.

Afterwards the interview guide focuses on already existing processes to manage early prototyping: The questions are formulated in such a way that it is easily possible to admit that no defined process is in place. This is needed because it cannot be presumed that every company uses or sees the need for such a formalization of early prototyping. Furthermore, the topic and interview series is looking for "next practices" and does not assume that "best practice" approaches are already established and commonly implemented. Subsequently, some more detailed questions follow, which deepen process-related aspects like iterations. This block concludes with two questions on the handover of prototypes to other systematic processes in the company in order to understand how larger corporations include early prototyping activities in already existing new product development processes.

Related to the processual view on early prototyping, the next three questions elicit how far the particular company continues with the developed prototypes and to what degree it uses them for systematic experimentations. Even here the focus lay upon the management of those experiments. Nevertheless, the interviewer tried to motivate the interview partners to share vivid examples of successful and less successful experiments if the interviewee had

experiences with such experiments. This narration-oriented way of questioning was particularly helpful to collect a broader set of exemplary experimentation cases that can be coded more distinctly.

Due to the multi-disciplinary nature of early prototyping, which is often mentioned in literature from all disciplines, the interview guide entails a separate block of questions regarding collaboration and stakeholder management in the context of early prototyping. It is concentrated on the collaboration of different professions, departments and hierarchy levels and elucidates the possibly arising problems that are related to this collaboration.

Finally, the interview is concluded with a section on challenges: This group of questions gives the interviewee the chance to mention challenges and problems that have not occurred yet and to highlight aspects that seem especially relevant. Lastly, the interviewer gave the interviewee the opportunity to mention and detail points that have not been covered by previous questions.

Table 2 - Interview Guide

Opener
- What is your definition of early prototyping?
- From your point of view: What are the benefits and strengths of early prototyping?

Applicability and Scope
- For which areas, questions and problems do you use early prototyping?
- From your point of view: In which areas is early prototyping not applicable?

Processes
- How do you manage the development of early prototypes?
- Does your company use a clearly defined early prototyping process?
- How does it look like? / Why is a fixed process not necessary?
- How do you handle iterations?
- Is early prototyping embedded in other product development processes?
- Which outcomes and experiences are reintegrated into other product development processes?

Experiments & Hypothesis-driven Learning
- Are you using prototypes for systematic experiments?
- How do you manage those experiments and pilot projects?
- Who is responsible for this task?

Cooperation & Stakeholders
- How do you integrate internal and external stakeholders?
- Do you use a certain approach to identify relevant stakeholders?
- How do you manage different stakeholders and the resulting – occasionally conflicting – feedback?
- At which point do you involve the top management?
- From your point of view: Does the early presentation of prototypes lead to a better acceptance of innovations inside your corporation?

Challenges
- From your point of view: Which influence has early prototyping on political barriers?
- From your point of view: What are the biggest problems and challenges of early prototyping?

2.3.1.4. Interviews

According to literature on expert interviews one of its major challenges is the information asymmetry between interviewee and interviewer (Littig, 2008, p. 90; Pfadenhauer, 2009). Already the simple request of an expert interview implies this asymmetry and suggests such an imbalance between the parties. In order to establish a relatively normal, comfortable and trustful conversation situation, which is not burdened by this information asymmetry, Honer (2000, p. 198), Pfadenhauer (2009, p. 92) and Littig (2008) highlight that the interviewer has to be highly informed regarding the investigated topic to be able to act as a quasi-expert. They emphasize that the interviewed expert has to accept the interviewee as quasi-expert to reveal his or her relevant and central internal expert knowledge. The interviewer followed this suggestion and informed himself by an extensive literature research that is presented in this thesis. In addition the interviewer followed Berg's "10 commandments" for qualitative interviews (Berg, 2004, p. 143) which comprise helpful suggestions that help achieve credible, detailed and vivid results that fulfil qualitative quality criteria.

All interviews - except two - were conducted via telephone or voice over IP calls during summer 2014. All interviews have been conducted in English. Although on-side appointments would have been better to establish a comfortable, trustful interview situation the distance to the interview partners and their high busyness did not allow such face-to-face interviews in nearly all cases. Whereas different authors problematize telephone interviews (e.g. Saunders, Lewis, & Thornhill, 2007, p. 342), the opportunity to talk to interesting, relevant experts of renowned corporations exceeded this downside. The appointed meetings were set to a length of 60 minutes maximum where the actual length varied between 45 and 80 minutes. Following a short phase of small talk, where the interviewer introduced himself and the research project the informant was asked if he agrees upon the recording of the interview and the citation in the master thesis. After the interview, all informants were offered to receive the research results when they will be finished.

2.3.1.5. Analysis and Coding

All recorded interviews were fully transcribed by the interviewer directly after they were held in order to include memories in the transcript and ease the transcription process. The transcripts use a relatively plain notation system in accordance to Meuser & Nagel (2009, p. 38). They argue that a detailed notation, like it is requested for narrative interviews or

conversation analytics, is not necessary because non-verbal expressions, larger breaks or the pitch of voice are not elemental parts of the conversation that is mainly focused on knowledge exchange. In contrast to Meuser & Nagel (2009, p. 38), following Strauss & Corbin, the interviewer transcribed the interviews completely instead of focusing on central aspects like Meuser & Nagel suggest. This decision was taken due to the fact that broader examples and narrative passages were encouraged and thereby no larger irrelevant interview sections occurred.

The coding process oriented itself to Strauss and Corbin's central data analysis process of Grounded Theory based on the types of coding called "open coding", "axial coding" and "selective coding". Although it was not the aim of the expert interview series at hand to generate the fundamentals for a new theory, it was chosen to rely on Strauss and Corbin's prominent and widely accepted coding procedure. The coding was realized with the computer-based data coding software "f4analyse" in order to handle the comprehensive transcripts effectively.

In the first step all interviews were coded openly, which means, according to Glaser (1978), to code everything that might be helpful and generate as many codes as possible (Glaser, 1978, p. 56). Thereby, the most important inclusion criteria for a new code were originality and relative frequency over all interviews. This process was continued until the data analysis did not originated new codes (Kenealy, 2012, p. 413). The next step in Strauss and Corbin's coding process, called "axial coding", focuses on relations and interconnections and aims at cleaning up and structuring the generated set of codes. This is done by forming groups and sorting codes into overarching categories, refining and consolidating codes by building subcategories. When doing so, it is central to keep in mind that the developed categories have to be tested against the data. This phase of coding leads to more connected and abstract codes with a higher explanatory power (Kenealy, 2012, pp. 413–414). Finally, the resulted, relatively straight forward codes were connected in order to visualize and highlight relations in the "selective coding" step (Kenealy, 2012, p. 416). This step resulted in the identification of important codes that have a central role in the developed coding system.

In order to sustain a high credibility (Corbin & Strauss, 2008, p. 300), the coding process – as well as the interviewing phase – was guided by Corbin & Strauss' quality recommendations (Corbin & Strauss, 2008, pp. 307–309): While developing the coding system it was taken care for the resonance – the degree to which categories and codes fully capture the data. Furthermore, the coding system was peer reviewed by two business consultants by

presenting the codes and discussing the underlying citations in order to secure an internal logic that is trustworthy, believable and useful in everyday settings.

In addition, the following description of the coding system uses in-vivo codes and present informants' notions with rich descriptions. To do justice to the stipulated reflection of the researcher bias, it has to be mentioned that the interviewer tried to find a reasonable distant position to the previously consolidated literature in order to give the interviewee's unique concepts sufficient freedom to shape the emerging codes but connecting and including established concepts from literature at the same time. This balancing act is a particular challenge of expert interviews where the interviewer needs to inform himself to appear as a quasi-expert (Littig, 2008; Pfadenhauer, 2009) and cannot neglect literature before conducting the interviews. However the extensive preceding information phase enabled the interviewer to compare concepts, opinions and meanings of practitioners with concepts from literature.

2.3.2. Validation

In order to secure the practicability of the developed framework, a set of interviews with business consultants was conducted. In these interviews the framework was applied in the context of actual consulting projects. Therefore, the framework was first presented and explained to the consultant. Afterwards the framework was simulated in a mind game by discussing and applying it to exemplary consulting projects.

This way of validation offered the chance to hypothetical check the developed framework with real project data. The consultants offered the chance to check the concept with different projects in a single interview due to their wide experience with diverse projects.

3. Comparing Early Prototyping & Business Experiments

In order to investigate differences and commonalities between early prototyping and business experiments and related benefits (research sub-question 1), the following chapter will define the central terms, followed by an analysis of benefits of the approaches as well as central differences and commonalities. The conclusions of this chapter are used for the subsequent development of the framework in chapter 4.

3.1. Defining the Key Terms

As described in the research goal, the master thesis at hand aims to investigate requirements and criteria for the management of early prototyping & business experiments. It is, hence, necessary to define the key terms on a relatively general level in order to sustain a broad applicability for different kinds of early prototypes as well as a wider spectrum of industries. By doing so, the multidisciplinary of the literature research should be sustained and it should be possible to introduce a framework that is independent from particular disciplines.

Due to the fact that experimenting is seen as an elementary part of the activities around early prototyping by a broad range of scholars (Blomkvist, 2011; Ries, 2011; Schrage, 2000; Thomke, 2003), an additional definition to so called business experiments is provided, too.

3.1.1. Early Prototyping in Design

Different authors highlight a mind-shift in prototyping: Adenauer & Petruschat (2011) as well as Schrage (1996) differentiate between organizations that have so called *specification-driven innovation cultures* that are used to manifest the outcome of a detailed analysis in prototypes to specify all needs for the upcoming production and organizations that have *prototyping-driven innovation cultures*, which tend to experiment and develop concepts and ideas on the go in an open and flexible process by using prototypes (Adenauer & Petruschat, 2011, p. 1; Schrage, 1996, p. 10:3). As Schrage points out, specification-driven prototyping entails the dangers that a uncertainty-accepting management perspective wants to circumvent: Spending a lot of efforts on the definition of detailed specifications would lead to the risk to learn too late and losing too much time and money on analyzing (Schrage, 1996, p. 10:3). For this reason, a specification-driven approach to prototyping would not fit with experimentation- and learning-focused management approaches and is therefore excluded

from the definition of early prototyping. This exclusion is already inherent in the term: While specification-driven prototyping adds the prototype at the end of a longer analysis phase, early prototyping includes prototypes in the early phases of the development process (Adenauer & Petruschat, 2011, p. 40; T. Brown, 2009, p. 80). Adenauer und Petruschat understand this action- and activity-oriented view on prototyping as a new form that is still evolving and is emancipating itself from the traditional, strict and object-oriented specification-driven prototyping.

Consequently, the term has to be understood from a processual perspective that encompasses the creation and use of prototypes. Instead of concentrating on the specific realization of a certain kind of prototype, the following definition of early prototyping is dedicated to the actions and activities around those prototypes (early prototyp*ing*). The central aspect of this thesis is the exposure to prototypes rather than different techniques of embodying an idea or concept (e.g. a paper prototype, a 3D prints or a click dummies). This perspective is in accordance to Adenauer & Petruschat (2011, p. 15) and corresponds to Schrage's understanding of prototyping as "serious play" (Schrage, 2000). Therefore, there is no need to find a detailed differentiation between a sketch, a model, a simulation or a prototype as long as the particular appearance serves the defined goals and hoped benefits. Such a broad definition (Houde & Hill, 1997) means that sketches, models as well as simulations and sophisticated technical prototypes are grouped under the term "prototype".

This reflects that the master thesis at hand is mainly interested in the management of those artefacts – independent from their appearance - and will not deepen differences, pro- and cons of different kinds to prototypes. This appearance-independent approach to prototypes is based on Blomkvist who sees prototypes as "representations, embodiments or manifestations" of "ideas, described as hypotheses or assumptions" (2011, p. 54) as well as Houde and Hill who understand prototypes as "any representation of a design idea, regardless of medium" (1997, p. 3).

Furthermore, the following understanding of early prototyping is inspired by Lim, Stoltermann & Tenenberg's approach that highlights the knowledge-generating aspects of prototypes (2008, p. 7:3). They see prototypes as a mean that enables people to "organically and evolutionarily learn, discover, generate, and refine designs" (Lim et al., 2008, p. 7:2). Analogously, Rhinow et al. highlights the ability of prototyping to evaluate "successes and problems of a design idea" (Rhinow et al., 2012, p. 3). Schrage connects this learning-oriented understanding of prototyping activities with a processual perspective and underlines

that the iterative manner of early prototyping allows "extraction and refinement of the product requirements" (Schrage, 2000, p. 15). This explorative character of early prototyping and its close relation to communication is especially emphasized by Passera et al. (2012, p. 6) as well as Lim et al. (2008, p. 7:2). Dow et al. extend this and stress that in design processes problems and possible solutions co-evolve (Dow et al., 2010, p. 18:3).

By combining those different aspects the following process-centered definition of early prototyping is inferred:

> *Early Prototyping is an iterative method for early phases of new product development. It explores and communicates representations of ideas and concepts and experiments with them to sharpen their underlying problem definition and enhance possible solutions in order to learn for the further product development.*

3.1.2. Business Experiments

Due to the fact that a broader set of literature highlights the necessity to go on with developed prototypes and that the creation and development of any kind of prototyping is only worthwhile when it is used for experimentation, a definition for experimentation with prototypes is given here.

Although many scholars – especially from the field of design – highlight the communicative and learning-oriented focus of early prototyping and emphasize that playing around and exploring prototypes in the field is central for early prototyping, the majority of publications does not provide a detailed description of how to realize those experiments in practice (e.g. design thinking methodologies). Several articles describe unstructured qualitative approaches to "experiments", where designers reach out to potential customers and discuss developed prototypes. In order to circumvent this gap in design literature, the following definition of business experiments reverts to scholars from lean management (e.g. Nonaka & Takeuchi, 1995; Thomke, 2003), including in particular relatively recent ideas from the lean start-up movement (Blank & Dorf, 2012; Blank, 2013; Ries, 2011) and further practitioner-oriented publications (Anderson & Simester, 2011; Davenport, 2009; Govindarajan & Trimble, 2004).

All subsequently cited approaches highlight that experimentation is especially necessary in uncertain, unknown and complex environments and should take place when traditional planning approaches have reached their limit in terms of assisting systematic expedient

decision-making. Furthermore, the scholars emphasize the importance of learning as the major premise of all experimentation endeavors. Learnings obtained through experiments should at the very least define the criteria for the subsequent experimental setting or generate improvements and new perspectives for new product development. This feature characterizes a notion of business experiments that is closely linked to Mintzberg's *Learning School* (2009, pp. 185–240). Hassi & Tuulenmäki (2012) differentiate between practice-driven and experimentation-driven innovation. According to them, practice-driven innovation takes place on the run while firms are engaged in serving customers and involves relatively spontaneous or accidental modifications and does not need larger preparations. The experimentation-driven approach, the authors state, requires more conscious arrangements in order to be able to learn from outcomes and failure (Hassi & Tuulenmäki, 2012, p. 6).

In accordance to Ries (2011), Davenport (2009), Govindraja & Trimble (2004) and Anderson & Simester (2011) present a hypothesis-driven approach to business experiments that are structured similarly to scientific experiments. While Ries still stresses the advantages and benefits of qualitative data (2011, p. 63), both the MIT Sloan and Harvard Business Review authors follow a strict test-learn-solution: Davenport's six steps to successful business experiments start with a "hypothesis definition", focused on the testability and measurability. The following steps "design, execute and analyze" are concerned with engaging test and control groups in the field (Davenport, 2009, p. 75). Anderson and Simester likewise argue that managers can increase profits, if they "establish control and treatment groups to test the effects of changes in price, promotion, or product variation" (Anderson & Simester, 2011, p. 101).

By consolidating the different approaches to business experiments into a coherent definition and connecting them to the previously defined understanding of early prototyping it becomes clear that business experiments and early prototyping can be seen as methods that act as complementary extensions to each other. Accordingly, the following definition of business experiments includes notions of the definition of early prototyping in the same manner that the above-noted prototyping definition already point hints at experiments:

> *Business Experiments are defined as an iterative method that utilizes early prototypes by designing, conducting and analyzing trial and error tests that check previously defined assumptions in a systematic manner in order to learn to better understand and decide in unknown, uncertain business environments.*

3.1.3. Organizational Learning as Iterative Sense Making

As mentioned in the introduction, companies and enterprises have to face substantial uncertainties in their business environments: The growing unpredictability of markets and technological changes makes forecasts and detailed strategic planning for longer time horizons nearly impossible or at least meaningless.

Those uncertainties and turbulent business environments cause so called "wicked problems" (Ackoff, 1974; Camillus, 2008; Liedtka, 2004; Rittel, 1972). A term that is widely used in business related contexts and describe problems that are

> *"[...] characterized by their level of interconnectedness, by the presence of amplifying loops that unintended consequences when interfered with, by the presence of trade-offs and conflict among stakeholders and by the nature of their constraints."*
> (Liedtka, 2004, p. 194)

Liedtka points out that business strategy as well as design has to deal with those problems (2004, p. 194). It is described that wicked problems are too complex to be solved by one right solution and potential solutions "are neither true nor false, only good or bad". Consequently, strategy and design "is a matter of choice rather than truth" (Liedtka, 2004, p. 194).

In this regard, Weick describes the position of managers in those undetermined, chaotic situations as "thrownness" – with reference to Heideggers "Geworfenheit" (Weick, 2004a, p. 76). A situation where reflecting is not possible and managers have to act and react in given environments to already existing interpretations of the reality and adapt to predetermined circumstances. Weick states that managers deal with this "thrownness" by bricolage, making-do, tolerating ambiguity and improvisation rather than rigid planning, categorization or reflection (Weick, 2004a, p. 77).

Complexities in New Product Development in the Digital Economy

One central aspect that triggers these managerial challenges are the ever increasing customer demands and the on-going technological progress that leads to more and more complex products, services, business models or – more generally – complex, dynamic systems (Budde & Golovatchev, 2011; Junginger, 2006). Simon et al. define those as "a large number of parts that interact in non-simple ways [such that] given the properties of the parts

and the laws of their interactions, it is not a trivial matter to infer the properties of the whole" (Simon in Sommer & Loch, 2004, p. 1334).

This complexity is further reinforced by a product-service hybridity, driven by digitization: This hybridity describes a recent new product development trend where more and more products are intertwined with (often digital) services and a corresponding change in organizations' business model – often called servitization (see Baines, Lightfoot, Benedettini, & Kay, 2009 for a literature overview). Therefore, the master thesis at hand applies a hybrid understanding of products, too and posits that modern products in the rising digital economy are complex combinations of tangibles as well as services that are intertwined in reciprocal interactions. Junginger (2008, p. 28) states that those complex product-service-hybrids demand increasingly extensive coordination in the whole organization.

In line with those challenges, several authors highlight that companies have to find ways to cope with the unpredictability, loss of control and overarching uncertainty (e.g. Schrage, 2000, p. 4; Wüthrich, 2012, p. 79). It is claimed that companies have to accept uncertainties rather than neglect them and try to openly discuss them in a "strategic conversation" (Van der Heijden, 2005, p. 131) rather than "plan them away" in a strategic planning process. If traditional strategic planning looses its effectiveness in uncertain environments, a more flexible, learning-oriented approach has to be found.

Organizational Learning as an Iterative Process

A central aspect of the "learning school" (Mintzberg, Ahlstrand, et al., 2009, p. 185) is the so called notion of emergent strategies (e.g. Gavetti & Levinthal, 2000; Lindblom, 1959; Madsen, 2014; Mintzberg, Waters, & Wiley, 2009; Quinn, 1980). A concept that it is in line with several iterative frameworks of organizational learning (Argyris & Schön, 1978; Kolb, 1984; Nonaka & Takeuchi, 1995; Van der Heijden, 2005). It understands "strategy" as an incremental process where managers make sense of their environments and actions. Karl Weicks notion of "sense making" describes the reflection process of organizational members on previous action and the resulting establishment of a mutual understanding of their gained experience. Weick defines sense making as an on-going, retrospective, social process that shapes the identity of an organization and is more plausibility-oriented than it is focused on accuracy (Weick, 1995, pp. 17–61). By introducing this retrospective view on organizational learning, Weick questions turns around the common sense of strategy that claims that thinking has to end before acting can start (Mintzberg, Ahlstrand, et al., 2009, p. 207).

Taking those concepts of organizational learning and the notion of strategy as an emergent, learning process as a starting point, it is evident that companies have to experiment and invest in trial-and-error learning in order to make sense of their environment. Thereby, they take a proactive approach towards uncertainty and steer organizational learning in order to mitigate the impact of environmental uncertainty (Paju, 2014).

3.2. Differences and Commonalities of the Concepts

It is possible to highlight several differences as well as commonalities between early prototyping and business experiments that are relevant for the framework development.

3.2.1. Planning Skepticism

Literature states that established, traditional, sequential approaches of problem definition, analysis and solution are ill suited to solve wicked problems (Liedtka, 2004; Rittel, 1972). According to this perspective, most experimentation-focused scholars represent a planning-skeptical opinion that is similar to positions of many organizational learning publications. These critics question the possibility to forecast innovations in detail upfront (Blank, 2013, p. 4; e.g. Hassi & Tuulenmäki, 2012, p. 2). This perspective is linkable to the mentioned paradigm shift in design-based early prototyping that changes from specification-driven prototypes to a more playful, iterative prototyping in early stages of a project (Adenauer & Petruschat, 2011, p. 1; Schrage, 1996, p. 10:3).

All three approaches (organizational learning, early prototyping and business experiments) share the belief that upfront planning that details projects in a large extent does not work in uncertain environments and coping with wicked problems.

3.2.2. Iterations

In relation to the described planning skepticism, a central commonality of all three concepts is their focus on iterative learning-by-doing:

Many scholars of "organizational learning", for example Kolb (1984), Argyris & Schön (1978) as well as Nonaka & Takeuchi (1986), structure their thoughts on organizational learning in loops and circles. Likewise, Hughes and Chafin claim that "Product development must be transformed into a continuous iterative learning process focused on customer value" (G. D. Hughes & Chafin, 1996, p. 89; Junginger, 2008, p. 21).

Hence, in contrast to the well-established stage-gate process, more recent models proclaim iterative approaches that are adopted by modern industries like software development: For example Scrum or Xtreme Programming.

With a more design related focus, it becomes clear that "designing is an iterative journey through the design space" that is "set by ideas and constraints"(Beaudouin-Lafon & Mackay, 2003, p. 8). Especially, Dow et. al. (2009, p. 1) describe prototyping as a central part of this design journey that helps designers to oscillate between creation and feedback:

> *"Creative hypotheses lead to prototypes, leading to open questions, leading to observations of failures, leading to new ideas, and so on."*
> (Dow et al., 2009, p. 1)

Therefore, prototyping is fundamentally connected to learning in the design process and is a designer's vehicle to switch between building on the prototype as well as on the ideas and assumptions and learning by building and using the prototype in an iterative manner.

The same is true for business experiments (e.g. Anderson & Simester, 2011; Blank, 2013; Ries, 2011; Thomke, 2003). Thomke et al. state that an iterative approach is fundamental to experimentation:

> *Researchers engaging in problem-solving via experimentation generally do not expect to solve a problem via a single experiment, and so often plan a series of experiments intended to bring them a solution to their problem in an efficient manner.*
> (Thomke, von Hippel, & Franke, 1998, p. 317)

Resulting from these insights, the suggested framework for early prototyping that is presented in chapter 4 adapts this explicit call for an iterative perspective on prototyping that tries to reduce planning process and should emphasize learning-by-doing as much as possible.

3.2.3. Ways of Thinking

A central difference between early prototyping with a design mind-set and business experiments can be seen in their general attitude towards the problem at hand. Liedtka describes, with reference to Cross (2006) and Simon (1996), that designers follow abductive ways of thinking and exploit conjectures to "suggest that something may be" (Liedtka, 2004, p. 195).

In contrast, Eric Ries, a proponent of the business experiment movement, states:

> *"[...] unlike a prototype or concept test, an MVP [Minimum Viable Product] is designed not just to answer product design or technical questions. Its goal is to test fundamental business hypotheses."*
> (Ries, 2011, p. 93)

According to this notion, it becomes clear that business experiments extent the range of design-driven prototypes and seek to test identified assumptions on a business level. The literature on business experiments is focused on testing hypotheses in real life setting in order to answer specific business problems.

Liedtka further elaborates on this idea: She shows that businesses needs creative approaches to be able to imagine "what might be" as well as more scientific-oriented approaches to develop "confidence that the design action taken will actually accomplish the desired purpose" (Liedtka, 2004, p. 196).

Building on that notion, it can be concluded that both aspects add to each other: While the design-perspective is focused on investigating new, creative ways, business experiments are more interested in testing clear hypotheses in the business environment.

3.2.4. Costs

The conceptualization of experiments follows cost optimization principals that apply for prototypes as well: What Lim et al. call the "economic principle of prototyping" (see p.51) is included by Eric Ries under the term "minimum viable product" (2011, p. 77) and is adapted by Passera who writes about a "optimum minimum setup" (2012, p. 12) for prototyping.

All authors state that teams should minimize their prototyping and experimentation efforts in such a way that they do not produce unnecessary features or fidelity that is not needed to collect the wanted data. This is also in line with the call for focused experiments that concentrate on single aspects of a problem (Hassi & Tuulenmäki, 2012, p. 11; Schrage, 2000, p. 131) – a claim that can be found in design literature to a similar extend. At the same time, such a focus reduces undesirable noise in data collection: Thomke highlights that complex multi-dimensional experiments tend to produce noisy data, which complicates the measurement and interpretation and makes them more time- and resource-consuming (Thomke, 2003, p. 114).

3.2.5. Blurred line between prototyping and experimenting

Although the main body of literature on experimentation is based on managerial-oriented publications, some design scholars examine the experimental usage of prototypes. Especially authors with a background in digital design and usability highlight the importance of qualitative feedback from users. Other design scholars mention feedback sessions with users which merely make superficial use of prototypes.

For this reason, it has to be expected that the lines between experimentation and prototyping can be blurry in first iterations: While a team is working out a mutual understanding of an idea and is working in different directions, it can be helpful to integrate qualitative customer feedback in quick interviews or demo sessions. Even if these sessions do not align with the requirements on business experiments they can be understood as a form of user testing and experimentation. It is assumed that this blurriness vanishes with the increasing status of the project and the need for experiments with higher validation power.

3.3. Benefits of the concepts

Before the designed framework for early prototyping is presented, it is important to reflect on the benefits of the investigated concepts. By doing so, one can understand the importance of the suggested steps in the framework, which should help to exploit the mentioned benefits. This chapter examines the benefits of early prototyping and business experiments by drawing on the literature from both research fields as well as on practitioners' feedback.

3.3.1. Reflecting own thoughts

Design literature describes the building of prototypes as an active way to think about and rethink an idea. A perspective that is represented in the notion: "We learn with our hands" (Paradiso, 2004, p. 21). Schön calls this phenomenon "conversations with materials" where designers playfully explore an idea or a concept by building it into a prototype – an activity Schön coins "reflective practice" (Schön, 1996). Furthermore, Schön introduces the notion of "backtalks", which describe moments where designer come across unexpected, unforeseen aspects and stumble upon new insights while designing a prototype. An event that gives designers more details about their problem at hand and generates new ideas and possible solutions. Some respondents highlighted that early prototyping provides a path to serendipity (see Code "Serendipity" in Table 3 - Main Category: "Prototypes are for...").

They state that they find unanticipated solutions while building prototypes:

> *"And it also shows you then to another extent some problems that just can be derived by building a prototype that you haven't thought of before."*
> Interviewee 8, line 37

This is in line with Polanyi who points out that "we know more than we can tell" (Polanyi, 1966, p. 18) and that some parts of our knowledge is only made available through action. In saying so, he refers to an implicit, tacit type of knowledge that allows designers to know how they have do something without knowing what they are doing (Polanyi, 1966, p. 7). A few interviewee expressed practices that are similar to those backtalks (see Code "Externalizing Mental Concepts" in Table 3 - Main Category: "Prototypes are for..."). This shows that even practitioners perceive this relative abstract concept in their daily work:

> *"So for me it is not so much about the particular prototype it is more about how does the prototype help you to develop your concept or your ideas further."*
> Interviewee 5, line 8

It emerges that building an early prototype and experiment with him is not just about error identification, rather it is a generator for new information, new ideas, new unexpected opportunities (Hassi & Tuulenmäki, 2012, p. 8; Schrage, 2000, p. 101). Schrage highlights that unexpected insights could bring a project more forward than a confirmation of an assumption would do (2000, p. 128). For this reason, it is essential to have a team in place that is open-minded enough to recognize those unanticipated chances (Schrage, 2000, p. 5). Lim et al. coin this by stating: "Explore not evaluate!" (Lim et al., 2008, pp. 4–5).

3.3.2. Exploring the problem space

By building and reflecting on vague ideas and specifying them while embodying an idea, designers explore the so called "design problem space" (Goel & Pirolli, 1992). Buxton, with reference to Schön (1982), explains the difference between a designer's task to set a problem in the right way as well as solve the defined problem sufficiently (Buxton, 2007). He elaborates on this difference in his book "Getting the Right Design and the Design right" and claims that prototypes help to explore the "problem setting" in an iterative manner. Cross (2001, p. 435) as well as Dow (2010, p. 18:15) show empirically that this sub-task is central to successful designs.

3.3.3. Understanding each other

The code "Demonstration" and the associated sub-codes (see Table 3 - Main Category: "Prototypes are for...") subsume expert statements regarding all interaction with colleagues that involves explaining and demonstrating ideas and concepts by using prototypes. It is stated that the presentation of prototypes induces a significantly better understanding of an idea and brings discussions and feedbacks to a new level.

> *"[...] you can touch it and can fiddle around with it and sense it. That gives a whole new level of discussion."*
>
> Interviewee 8, line 11

The experts explain that prototypes prevent misunderstandings and foster deeper interactions between team members. Teams are able to discuss concepts and suggestions in more detail and build a shared understanding. This effect is described in literature under the term "converge thinking" (Rhinow et al., 2012, p. 4) and "shared mental model" (Neyer, Doll, & Möslein, 2008). The authors explain that the externalization of thoughts and vague ideas force designers to concretize their individual mental models while the resulting representation of the ideas gives the group a basis to agree on. This process can be understood as a way of the already mentioned sense making in organizations (Weick, 1995).

Furthermore, Mascitelli (2000, p. 187) stresses the capability of prototypes to transfer tacit knowledge between team members by constantly discussing and interacting with prototypes. Accordingly, Takeuchi and Nonaka accentuate that organizational learning requires the exchange of implicit, tacit knowledge in order to generate explicit knowledge for the entire organization (1986, pp. 95–127). It is exactly such an exchange that is facilitated by prototyping: While the building phase corresponds to the "socialization" phase, the discussing and presentation is comparable to their "externalization" phase. Narrations and languages have an elementary part in such a process and can be understood as "language games" (Brandt, 2007, p. 183): Teams discuss and cultivate a distinct vocabulary to make sense of their prototypes and form a mutual understanding of the built representations (Nonaka & Takeuchi, 1995; Rhinow et al., 2012, p. 4; Schrage, 1996, p. 10:6). All in all, prototyping is a social process that can be perfectly understood as a part of organizational learning. Furthermore, it is argued that building a prototype together improves the bonding of the team (Rhinow et al., 2012, p. 12) by establishing a collective ownership of the particular prototype (Beaudouin-Lafon & Mackay, 2003, p. 9).

Table 3 - Main Category: "Prototypes are for..."

Category	Sub-Category	Summarizing Paraphrase(s)	Exemplary Quotes
Externalizing Mental Concepts		The prototyping as a thinking methodology or an external representation of mental thinking processes.	"You have an external representation of your mental concept images and that helps you to objectify what you really want."
Trying things out		New things have to be tried out to understand them better.	"Which one is the best? And I think you can't tell from the desk you are sitting at. So you just have to try it out and see how it works."
Learning to reduce uncertainty		Prototyping is about learning - especially from customers.	"I like that approach [...] because it is very fast and it is very iterative and afterwards we know much more about the risks and so on."
Front Loading: Cost Efficiency & Speed		Identify challenges and solve uncertainties early on while iterating to save money. Learn fast and fail early to prevent costly mistakes later on.	"it is so much cheaper when you change some things in the early stage of the process than down the road in the development process."
Serendipity		Stumbling upon ideas no one thought of before building a prototype.	"[...] shows you then to another extent some problems that just can be derived by building a prototype that you didn't have thought of before."
Integrability		Integrate stakeholders early on to secure acceptance and existing requirements.	"That is you can already integrate actually early opinions and early needs that they on the one hand feel but also actually are respected with their requirements."
Demonstration	Tangibility	Making ideas tangible provokes a different examination of an idea.	"[...] if you have those prototypes really on the table and have it, where you can touch it and can fiddle around with it and sense it. That gives a whole new level of discussion."
	Feedback	Thought through prototypes provoke better, more concrete feedback.	"[...] build up a demonstrator that shows the main features of your idea [...] than this is very good basis for talk with other engineers, with management and with customers."
	Shared Understanding	Prototypes evoke a shared understanding of an idea in order to improve discussions.	"It is much easier for me to pick up your idea and also to support it and imagine what you want to do really."

3.3.4. Failing faster

The central economic factor that has been raised by nearly all interviewed experts is the possibility to save costs and time through early failures (see Code "Front Loading: Cost Efficiency & Speed" in Table 3 - Main Category: "Prototypes are for..."). Expert statements show that changes in later project stages lead to significantly higher costs as they would cost in early phases. In this context, early prototyping enables managers to explore critical aspects of concepts as early as possible, which provides the potential to save budget and time by finding critical show stopper and unanticipated challenges in early project stages.

> *"Because you want to find out the strength and weaknesses of a concept as soon "as possible with as little effort and money invested as possible" [...] If it does not work you will learn it right away and that means you can stop right there and you save a lot of money, time and effort."*
>
> Interviewee 4, line 5

> *"It is so much cheaper when you change some things in the early stage of the process than down the road in the development process"*
>
> Interviewee 4, line 48

This general concept of experimentation and prototyping is investigated by different management scholars. Particularly Thomke wrote several publications about this topic (Thomke & Fujimoto, 2000; Thomke, 1998a, 1998b, 2001, 2003, 2006) and coined the term "Front Loading". He shows – mainly in relation to the Japanese automobile industry - the positive cost and time effects of front loading on an empirical basis. Interestingly, many of his works (especially older articles) concentrate on the identification of failure and errors in R&D development rather than having a whole business idea in focus. This bigger view is shared by scholars with a more entrepreneurial view: They transfer the idea of front-loading to the business model level and reason that start-ups have to search for a viable business model by trial-&-error learning (Blank, 2013; Ries, 2011; Sarasvathy, 2001).

3.3.5. Staying lean and agile

Highly connected to the "fail faster"-mind-set is the so called "Fat Baby Syndrome". An in vivo code (see Table 3 - Main Category: "Prototypes are for...") based on the perception that enterprises and corporations tend to invest too much innovation budget in the early stages. According to several interviewees, this leads to an overly complex team structure and

analysis that could be prevented by focusing on fast and agile prototypes and experiments. This is particularly relevant, if management is challenged to maintain flexibility in uncertain business environments.

> *"Try to accept that huge things start small and if we are manager you have to, you should understand that great things start small."*
>
> Interviewee 6, line 76

This perspective is in line with Neyer et al. (2008, p. 213) who state that prototypes help to focus and constrain processes and ideas in a realistic manner. Entrepreneurial-oriented authors point to budget constraints of start-ups as they contend a maximally lean structure that does not waste money in processes or features that customers do not value (Blank, 2013; Ries, 2011; Sarasvathy, 2001).

3.3.6. Validating assumptions

According to a more business-oriented view on early prototyping and business experiments, some interviewed experts underlined the value of early prototyping for the validation of underlying assumptions regarding the uncertain business environment. In line with the presented literature on organizational learning as well as the publications on business experiments, they described the benefit of early prototypes and experiments to explore and understand uncertainties by gathering learnings. On that note, the interviewees pointed out the importance of contact with real customers and the direct feedback from the market.

> *"I like that approach [...] because it is very fast and it is very iterative and afterwards we know much more about the risks and so on."*
>
> Interviewee 3, line 25

3.3.7. Gaining acceptance

Another aspect raised by the interviewees is the relevance of internal acceptance for new ideas and concepts inside the organization.

> *"[...] you can already integrate actually early opinions and early needs that they [the stakeholder] on the one hand feel but also actually are respected with their requirements."*
>
> Interviewee 4, line 25

The interviews revealed that the demonstration benefits of prototypes make it possible to use the artefacts as so called "boundary objects" that make it possible to discuss and represent

new concepts to a wider audience with diverse professional backgrounds. Star coined "boundary artefacts" as

> *"Objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites."*
>
> (Star, 1989, p. 37)

The value and importance of early inclusion of operative needs and requirements in projects with strategic relevance is discussed by several scholars from different fields. Voigt, for example, shows how a "grassroots strategy" that oscillates between operations and strategy can help to cross a potential implementation gap. Additionally, it can be assumed that those inclusive methods lead to a channeling of issue selling attempts (J.E. Dutton, Ashford, O'Neill, & Lawrence, 2001; J.E. Dutton & Ashford, 1993; Jane E. Dutton, 1986) between an operative level and top management as well as existing "bootlegging" (Augsdorfer, 2005, 2008).

As stated by Junginger (2008, p. 34), such an approach is not bottom up or top down but rather oscillates between a conceptualization stage and the operative level where affected employees can give their input as early as possible – called "grassroots strategy" (Voigt, 2003, p. 38). He proposes to include stakeholder step by step in an iterative manner depending on newly identified demands of the project. Voigt states, that such a course of action fosters the successful implementation of new products and strategies (2003, p. 60). This is because the participatory nature of the process increases the internal understanding and commitment for the prototyped ideas.

3.3.8. Changing the organization and take a look into the future

As much as the organization shapes the prototype, prototypes have the capability to change the organization. This means that the vivid presentation of prototypes initiates a reflection process within the organization. Analogous to Junginger (2008), who states that product development can lead to organizational change, and van der Heijden's notion of "strategic conversation" (2005) as well as Brown & Eisenhardt's concept of "probing the future" (1999, p. 16), it is assumed that prototyping as a general concept can stimulate a sense-making of upcoming changes on a company-wide level. This holds true in particular for more radical innovations, which tend to change the organization in a wider extent. Brown & Eisenhardt show that those probes can lead to a higher adaptability to uncertain environments, while

van der Heijden highlight that companies have to be able to talk and reflect on uncertainties in the environment. Both concepts fit perfectly into each other and can lead to organizational change through product development, as described by Junginger.

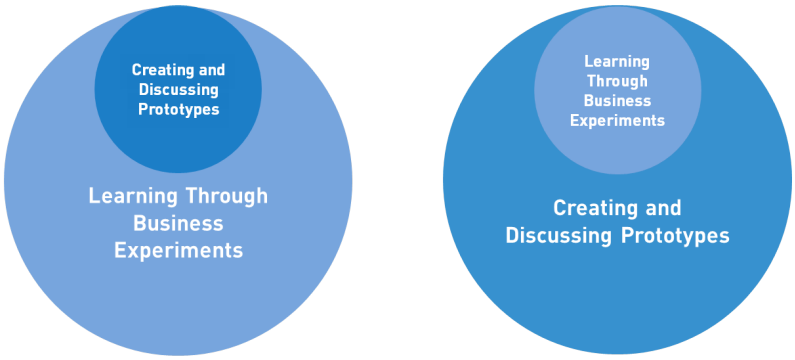
It can be expected that especially the failure-tolerating "safe space" of prototyping is beneficial for those discussions (Junginger, 2008, p. 34; Liedtka, 2004, p. 194; Rhinow et al., 2012, p. 5). Furthermore, practitioners emphasized that the tentativeness and tangibility of prototypes encourage employees to discuss and imagine in an open-minded way. With reference to Argyris and Schön, these discussions and reflections can be connected to their concept of "organizational maps" (1978, p. 17). By discussing prototypes in interdisciplinary teams and reflect on their impact on the organization the teams are able to investigate their cognitive maps and align their maps in a safe environment. Hence, employees can benefit from the proactive reflection of upcoming changes and are given the opportunity to get used to those changes as well as to participate in their evolution.

3.4. Conclusion

Finally, it can be concluded that both concepts, prototyping in design and business experiments, pursue two main objectives: On the hand, both are concerned with clarifying assumptions. At the same time, both concepts facilitate the communication of ideas, which ideally results in the evolution of a shared mind-set and fosters the generation of new ways how an idea could grow up into a feasible and promising innovation.

Moreover, it becomes apparent that the literature on business experiments mentions the creation of prototypes but does not give them as much attention as literature on design does. The other way around the literature on business experiments stresses the importance of trial-and-error-learning and thereby offers a comprehensive process-view for the further utilization of prototypes (see Figure 2).

Figure 2 - The Relevance of Prototypes in Different Research Fields



Management Scholar's Perspective on Early Prototyping and Business Experiments

Design Scholar's Perspective on Early Prototyping and Business Experiments

For this reason, the master thesis at hand understands "early prototyping" as a set of activities to build representations of early ideas, while "business experiments" utilize those early prototypes and to conduct experiments with real customers. Thereby, both activities are focused on learning as much as possible in order to build a viable solution to the given problem.

The framework, which will be presented in the following chapter, has to build on the mentioned aspects: While a normative framework itself already pays attention to a structured approach, as it is used in business experiments literature, it is important to untangle differences and commonalities of both approaches. Therefore, it is essential to pay attention to the hoped for benefits and find ways to integrate these aspects.

4. A Management Framework for Early Prototyping and Business Experiments

The following framework (see Figure 3) is based on the previously gathered insights from literature research as well as expert interviews. The presented benefits have been used as a starting point to conceptualize a practical framework that pays attention to the integrative view on early prototyping and business experiments in uncertain environments. By doing so, the framework offers a comprehensive perspective on early prototyping by utilizing strength of the design discipline as well as the literature on business experiments. It is posited that both concepts can be combined by utilizing their mutual foundations in iterative organizational learning and will complement each other as well as the learning process itself by adding aspects that are unique for the particular discipline. In this case, the previously described understanding of organizational learning acts as the connection point between both concepts. Furthermore, the expert interviewees contribute practical insights and stress especially important aspects of the framework to assure that practical relevant challenges are covered.

The framework itself was designed in an iterative process by the author and has been overworked and changed several times while reviewing the literature, conducting the interviews and gathering feedback from practitioners. Thereby, the framework is intentionally not designed in a typical process visualization language. Although this may be a bit unfamiliar, this decision has been made in order to make clear that the suggested steps should be understood in a flexible manner and do not present a strict, normative sequence.

The following chapter is structured along the framework itself: Each step is explained on a theoretical basis first (called "What to do") and afterwards supplemented by the experts' challenges. By doing so the results of the expert interview series are directly integrated into the framework and emphasize particular crucial aspects (called "Practitioners' Challenges"). Furthermore, the research results are depicted in Table 4 and Table 5. Each chapter starts with a summarizing box that highlights the central aspects of the respective section.

Figure 3 - Early Prototyping Framework

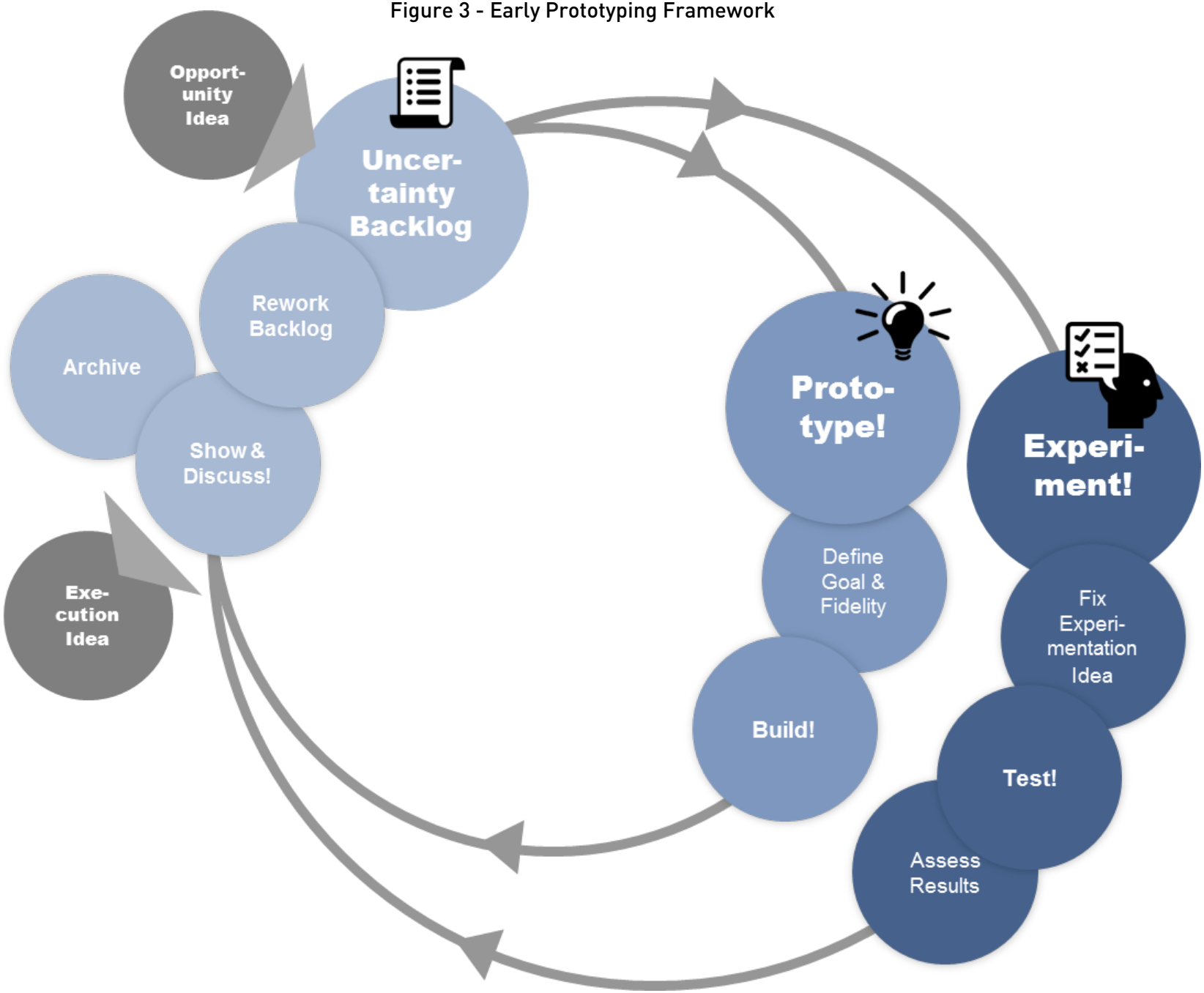


Table 4 - Main Category: "Prototypes need..."

Category	Summarizing Paraphrase(s)	Exemplary Quotes
Presentations	Presentation days for decisions and participation.	"Then engage the people in innovation days to show these prototypes, make booths, make it tangible to the employees because nothing, really nothing in the world motivates more than having a tangible prototype to show to the people"
Tentativeness	Producing rough, "crappy" products to keep speed high and learn fast.	"So you have to encourage them to be brave enough not to do something perfect rather to do lot of experiments.“
Archiving	Archiving prototype iterations make it possible to reuse results and understand its evolution.	"[...] having the evolution of a prototype also visualized. Helping people to understand how an idea emerged."
Freedom	Freedom to develop prototypes and decide in a self-determined way.	"[...] providing a freedom to act, freedom to learn also freedom to pivot and change your concept. And also relies on protecting these nascent concepts from the corporate immune system."
Space	A save and "energetic" environment to test ideas and experience existing prototypes.	"[...] like an experimental lab. Where it is okay to just bring in a brain fart [...] see that it was a good idea or a bad idea."
Supporter	Ideas need supporters - prototypes help to find them.	“[...] you need people who know people. And "Which can somehow persuade others [...]"
	Prototypes need supporters to build them.	"If you would ask for advice a lot of people are willing to help. So we encourage our teams to do a lot of networking both outside and inside the cooperation."
True innovators / intrapreneurs	Prototyping needs motivated and skilled intrapreneurs that drive the prototyping forward.	„It is really important to have such an entrepreneur selected and this is something where we taking care of the right skill sets [...] like develop a business plan, having a strong personality and the capability to present.”
Customer Focus	Customers have to be involved from the start in order to give feedback and drive the learning process.	"So the customer is key, it doesn't make sense to have a solution in search of a problem, you have to have a product market/fit."
Onboarding	People need trainings to get used to ideas of early prototyping.	"You have to educate people on that. Especially in large corporations [...] People don't think in prototypes. People only think in finished products."
Different versions of an idea	A bigger set of ideas improve the early prototyping.	"Do one beside each other [...] then your find out to find your champion. And you go with that. [...] with this procedure in the early phase you don't have those long iterations [...].
Right fidelity	Too high fidelity for small questions	"Like is it the right size, the right space, the right whatever and then went back and went to more and more high fidelity prototype every step."
	Challenge to let the fidelity increase step by step.	
	Being brave enough to build rough prototypes.	„And as I said it is very key to hold back the team not to start with technical stuff too early.”

Table 5 - Main Category: "Challenges"

Category	Summarizing Paraphrase(s)	Exemplary Quotes
Accept Failure	Projects can be more successful when failures are accepted and it is possible to stop projects.	"It is really a matter of honesty of an organization and how the company handles development processes in terms of understanding the value of failing early."
Allocation of (human) resources	Experiments are not billable therefore it is hard to allocate employee resources.	"Well, I mean I got when you buy materials for prototypes there are quite cheap and the buying department of large corporations is not made for small purchases."
	Buying materials for experiments can be complicated due purchase dept.	"At least in our company it is quite hard because we are measured by productivity and innovation is like - I don't want to say unproductive - but it doesn't count for a client's project so we don't earn within the first place."
	Outsourcing is problematic because knowledge should stay inside the company.	
Fat Baby Syndrome	Early prototyping projects should not be too big and cost heavy to stay flexible.	"Try to accept that huge things start small and if we are manager you have to, you should understand that great things start small."
Adaption	Ability to adapt concepts to new environments and new learnings.	"You have to adopt proposition to meet customers' needs quickly and properly."
	Ability to stick to a vision and circumvent adaption to already existing concepts.	"And then you get positive feedback on this because that works already and people know this and it could be that a disruptive and innovative idea could somehow get the wrong way."
Misunderstandings with customers	Difficulty for internal and external customers to differentiate between finished products and prototypes.	"[...] when you present it that we need to be clear to your audience that we talk about a prototype. Nothing final, they can't buy it by now, when they can buy it it wouldn't look like that."

4.1. Pre-Considerations

Before describing the different steps of the proposed framework, some aspects of the framework have to be discussed that can be seen as prerequisites to establish the suggested approach.

4.1.1. Applicability

Passera (2012) summarizes the issue of applicability of early prototyping in a brief statement:

> *"Prototype whenever you are in doubt and as early as possible."*
> (Passera et al., 2012, p. 13)

Other scholars agree and ascribe early prototyping a very broad applicability regarding fields, disciplines and problems (Thomke, 2001, p. 1; Wüthrich, 2012).

Especially management-oriented scholars highlight uncertainty as a key decision metric that determines whether a team should apply early prototyping to a problem or not (Möller, 2006, p. 79; Paju, 2014, p. 5; Sommer & Loch, 2004, p. 1344). In this regard, Möller (2006, p. 61) reasons that uncertainties drive the need for flexibility necessitate experimental approaches. This perspective is supported by several interviewees. It was highlighted that early prototyping is only necessary if the previously described uncertain environment is present. Otherwise, firms should rely on their existing processes.

> *"The typical product development process is acting as if the circumstances are certain not uncertain. And that is something you have to check before you start every project. So what is my product targeting at? Is it targeting at a known environment or an unknown environment and if the level of uncertainty is high you should apply these methodologies which accept that you are in search mode."*
> Interviewee 6, line 72

On the other hand, one expert interviewee expressed that some problems and projects can be too difficult or complex to separate them in workable chunks and test them with early prototypes. He exemplified this notion by a big data project that is, from his point of view, only hardly testable via early prototypes or business experiments.

4.1.2. Space

Literature and practitioners highlight the importance of a dedicated physical space for most early prototyping attempts. A safe space where teams have the impression that they can experiment and fail safely is considered beneficial for early prototyping (e.g. Jenkins, 2010; Liedtka, 2004, p. 194; Rhinow et al., 2012, p. 5). Furthermore, dedicated staff could provide know-how and expertise regarding often used methods and tools and could consult early prototyping teams (Davenport, 2009).

Additionally, it is stated that the resource requirements of many early prototyping efforts extend beyond typical organizational demands. Therefore, it can be helpful to establish a dedicated cost center that is related to the provided space and facilitates the requisition and provision of prototyping resources more easily (Neyer et al., 2008, p. 214). Nevertheless, several authors from the field of design make clear that low fidelity prototypes could be built with limited resources and are better than no prototypes at all.

A few interview partners mentioned that they think that it is fruitful to have a dedicated room where everyone in the team can access and experience all prototypes. They reported that such a show room is not only an inspiration for the prototyping teams but also a signal and reflection of the underlying mind-set and innovation culture.

> *"I cannot tell you formally why but if you go through those offices of those who develop parts for cars they are really / the physical presence [of the product] is not there. The physical presence of the object is not tangible and I think that if you would have something physically around you, you do something which is more innovative."*
>
> Interviewee 5, line 28

4.1.3. Team

An aspect that has been especially stressed by the interviewed practitioners is the importance of a well performing prototyping team. Multiple interviewees reported that an intrinsically motivated team is essential to exploit the benefits of early prototyping. If this motivation is not present, early prototyping projects will lack speed and quality.

> *"And it shouldn't be a project team which goes to the CEO and asks "What should we do next?". Because then you have a problem, because if there is someone who steers it, say "ahh, actually you have to talk to this, this and this person." Than it Is not about finding the ways through uncertainty it is more like: Did you do all the tasks from the last minutes?"*
>
> Interviewee 9, line 47

On a related note, a number of experts were convinced that teams need a charismatic leader with a broad skillset who is able to steer the team and the project as well as to communicate and present it within the company.

> *"It is really important to have such an intrapreneur selected and this is something where we are taking care of the right skill set [...]."*
>
> Interviewee 3, line 25

Furthermore, it was stated that a network of supporters is important to shape and integrate the prototype into an organizations' structure. It is the task of the team as well as the responsible manager to connect the team to helpful internal supporters. By doing so, the project will gain additional acceptance inside the company.

> *"If you would ask for advice a lot of people are willing to help. So we encourage our teams to do a lot of networking both outside and inside the cooperation."*
>
> Interviewee 6, line 72

Additionally, as mentioned by multiple experts, it is central to align internal incentives to the used innovation approaches. Contradictions in the incentive system could lead to significantly lower motivation to participate in early prototyping projects, as reported by one interviewee. He detailed that co-workers have not been willed to bring a prototype forward because they were incentivized by the billability rate for external customers (see "Allocation of "human" resources in Table 5 - Main Category: "Challenges") At this point, the acceptance of failure and stopped projects in the organizational culture could be steered by aligning offered incentives to those requirements for a successful early prototyping implementation.

4.1.4. Evaluation

The failure-positive, explorative, learning-oriented nature of early prototyping lessens the applicability of traditional project management success criteria. For this reason, alternative evaluation criteria have to be identified[2].

Sykes et al. propose learning-centered view and suggest a success evaluation based on the learning progress per dollar. A similar approach is presented by Thomke who proposes the error/cost ratio as a helpful criterion.

Nevertheless, both measures are rather rough estimations than detailed criteria. Generally, it should not be assumed that it is possible to quantify the learning progress or rate the value of an identified error in relevance to the invested costs. Without knowing the upcoming learnings and forthcoming errors it is nearly impossible to rank the importance of a new finding. This is especially relevant regarding critical learnings and errors.

However, it is important to define distinct project success criteria that are tailored to the particular project and company and more general project management success criteria (Cooke-Davies, 2002). When doing so, the management can use the mentioned learning progress as a starting point and resort to the described benefits of early prototyping as additional criteria.

[2] For example "project success" is not a promising project management success criterion due to the fact that an alleged "failure" like a project stop could lead to important learnings and important cost savings. Another example would be "timing accuracy": The iterative nature of prototyping makes it hard to forecast detailed timings.

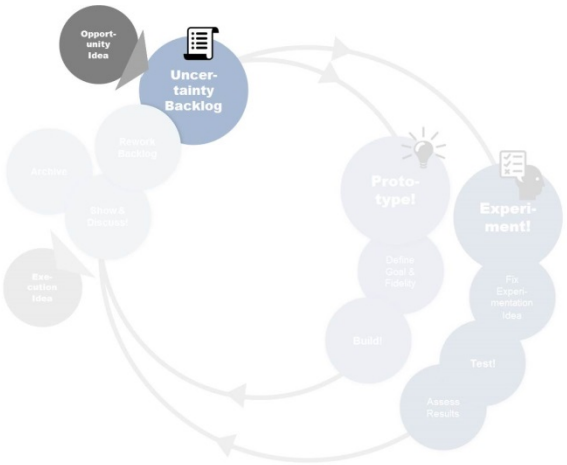
4.2. Opportunity Idea & Uncertainty Backlog

The first step of the suggested framework encompasses the necessary preparations for early prototyping: A promising but vague opportunity idea is chosen and analyzed. This analysis is mainly concerned with the identification of assumptions which are listed and sorted in the so called *uncertainty backlog*. This list is used as a support element for decision making during the entirety of subsequent prototyping and experimentation iterations.

4.2.1. Opportunity Idea

To start the early prototyping process it is necessary to identify an idea that is worth investigating. The term opportunity idea was coined by Hassi & Tuulenmäki (2012) as well as Tuulenmäki & Välikangas (2011) and refers to a first business idea that is based on a first problem identification. They point out that this opportunity idea is normally far away from a concrete, executional realization and needs further refinements. They describe opportunity ideas as "larger, complex entities" (Hassi & Tuulenmäki, 2012, p. 9), which are too big to base experiments on them.

Table 6 – Overview Step 1) Uncertainty Backlog



Goal	Development of a tentative list of uncertainties for a structured and efficient prototyping process.
Requirements	A chosen opportunity idea that will be investigated on their underlying assumptions. Project-team for the entire early prototyping process.
Method	Refinement of the opportunity idea into an easily communicable form (e.g. Business Model Canvas or User Stories). Identification and listing of underlying assumptions in the *uncertainty backlog*. Sorting of uncertainties based on their critical relevance for the success of the opportunity idea.
Results	Structured, easily accessible *uncertainty backlog* based on the chosen opportunity idea.

4.2.1.1. What to do?

Identifying possible opportunity ideas

Hassi & Tuulenmäki (2012, p. 9) do not describe where opportunity ideas can come from and assign this task to the team - this seems to be a legitimate approach in the entrepreneurial setting of their study. In contrast, corporations can access a multitude of established activities and methodologies to collect potentially promising ideas. From open innovation platforms to employed or hired technology gatekeepers (M. L. Tushman & Katz, 1980), customer research teams, especially lead user research (von Hippel, 2005), internal or external trend research, internal design thinking workshops to an continually running issue management (Liebl, 2000, 2005): Corporations nowadays have a wide range of possible ways to seek for and identify the unknown and the new. For this reason, the thesis at hand does not discuss different ways of how companies could identify customer insights and create the needed ideas. While Hassi & Tuulenmäki focus their study on autonomous business ideas, the presented early prototyping framework follows a broader scope and is usable for incremental innovations and refinements, too.

Selecting an opportunity idea

Although extensive preliminary analyses are not central because the idea of early prototyping allows the management to stop a project early and easily, if necessary, it is important to assess if the opportunity idea can be tested and split into small chunks (Hassi & Tuulenmäki, 2012, p. 10; McGrath & MacMillan, 1995, p. 49). This is a necessary prerequisite to assure that the prototyping process can unfold its strengths. Otherwise, the project team has to create a big, inflexible prototype that does not align with the basic ideas of fast, iterative learning cycles. This aspect was mentioned as a restraint, even though most interview partners attribute a broad applicability to early prototyping. One interviewee mentioned big data ideas as an example and argued that the high complexity and low modularity of big data applications make it hard to prototype separate aspects.

Metrics or indicators to support the decision process are hard to specify: Due to different strategic objectives and diverging foci of the opportunity ideas (e.g. customer frontend, technology exploitation, process optimization) it seems inappropriate to suggest a fixed set of evaluation criteria to choose an opportunity idea for the early prototyping framework.

Presenting the opportunity ideas

After one idea has been selected that is worth investigating, it is necessary to outline the chosen opportunity idea and describe it in a sufficiently vivid and understandable manner. This description is used as the basis for further investigation and will evolve over the process. To develop and present such a first draft one can use for example Osterwalder's "Business Model Canvas" (Osterwalder & Pigneur, 2010, pp. 16–19) or User Stories as they are often used in agile software development projects (see Ambler's "User Stories: An Agile Introduction" (n.d.) for a short introduction). Due to the fact that all involved team members know that the opportunity idea is based on assumptions and consists of fragmentary, incomplete parts, the idea can already evolve while developing this first idea presentation. Therefore, one can understand this first summary as "iteration 0".

4.2.1.2. Practitioners' challenge

Choosing opportunity ideas

According to a broad set of management literature (Chesbrough, 2010; Hassi & Tuulenmäki, 2012; McGrath & MacMillan, 1995; McGrath, 2010; Paju, 2014; Ries, 2011; Sarasvathy, 2001, 2008), it seems nearly impossible to identify the "right" opportunity idea that is worth to start with from the outset. As discussed, management has to accept that they cannot know if an identified problem and a corresponding idea is worth a further investigation. Nevertheless, managers have to separate the wheat from the chaff and choose an idea to go on with out of the set of available ideas.

> *[...] in order to find [something] really cool you maybe have to start 1000 products or looking at 1000 products. So you have to do more in order to be successful. If you have to do more you have to be very quick and very low budget driven...*
> Interviewee 8, Line 76

This comment on early prototyping of one of the interview partners indicates that early prototyping can help to identify promising products by iterating quickly and cheaply through possible ideas while building prototypes and experimenting with them. At this point, one can be justified in saying that early prototyping makes it easier to choose and decide: Due to the fact that the iterative approach of the framework is cheap and fast, companies are able to learn in quick cycles, if an opportunity idea offers auspicious chances.

Experts depicted a variety of different ways to decide which idea will be further investigated in early prototyping. While several interviewees mentioned a general committee that inspects and selects the ideas, others detailed a team of consultants and top managers or a dedicated team that has the freedom to decide independently. Besides, the interviewed managers also referred to a bottom up approach, where employees can ask for spare time to investigate a topic that caught their interest. This broad variety could be explained by varying levels of elaboration and style of (innovation) management in the different companies. Irrespective of the actual approach, companies who want to exploit the benefits of early prototyping have to select one promising idea out of the set of available ideas.

4.2.2. Uncertainty Backlog

In the following step, the chosen opportunity idea is investigated in detail in order to identify underlying assumptions and related uncertainties. This is necessary to structure the early prototyping in an efficient way and guarantee that the iterative learning efforts are tracked and organized.

4.2.2.1. What to do?

All eyes on the unknown and the presumed: Structuring the uncertain

As illustrated in the beginning of this thesis, the link between the investigated research fields consists in a shared focus on uncertaint environments.

Since it was not possible to find a formalized approach to rank, prioritize and track a set of identified assumptions in relation to one given idea or concept, the author suggests to exploit a tool called *product backlog* and adapt it to the requirements at hand. The *product backlog* is a project management tool in agile software development methods (especially in the relatively strict method Scrum) that helps developers to keep track of not yet coded but requested features of a software project (see Pichler, 2010, pp. 47–74 for a comprehensive introduction into Scrum's product backlog). Instead of collecting product features in the backlog, it is in the proposed framework used to structure and steer the handling of identified assumptions and the corresponding uncertainties.

It is the goal of this backlog – in the following called *uncertainty backlog* - to identify the most pressing problems of the opportunity idea that can potentially become a critical show stopper (McGrath & MacMillan, 1995, p. 49; Sykes & Dunham, 1995, p. 418). It highlights the

relevance of uncertainties and the corresponding assumptions for the project team. The adaption of the product backlog was chosen for two reasons: On the one hand, it is a viable way to structure tasks in a flexbile manner and is already suited to iterative working precedures. On the other hand, it is assumed that it is easier to setup a seamless handover to a product development team that is working with Scrum or other agile methods. Furthermore, Schrage claims that it is essential to "track, log and continually revisit the modeling assumptions" of prototypes. Several other authors agree to this perspective (Paju, 2014, p. 6; Sykes & Dunham, 1995, p. 416). Therefore, this notion is adopted here and the presented *uncertainty backlog* should help to structure and steer the uncertainties at hand.

Identifying assumptions

While, in organizational learning literature, scholars often discuss "assumptions" in broader scopes and refer to underlying assumptions of a team or a company (e.g. Junginger, 2007, p. 60; Weick, 2009, p. 11), the thesis at hand lays out the term in a more practical manner and connects it directly to the chosen "opportunity idea" and the inherent uncertainties and assumptions. Nevertheless, this does not mean that a designerly way of reflecting assumptions on a higher level cannot be helpful to identify relevant uncertainties in an opportunity idea.

For understanding the term in a practical manner, it is necessary to differentiate between "primary and derivative assumptions". According to Sykes & Dunham (1995, p. 417) primary assumptions are about

- "What the customer really wants or needs."
- "What value the customer will place on the product versus competitive alternatives."
- "Whether the product or service that the customer wants can be produced at a cost that allows sufficient gross margin."

In contrast, derivative assumptions are based on those fundamental questions and come as forecasts and calculations, like detailed business plans or sales forecasts. As a matter of course, the proposed framework will concentrate on primary assumptions, which can be experienced and therefore are directly testable. Additonal exemplary assumptions can be found in Ries (2011, pp. 61–64) and McGrath and MacMillan (1995, p. 45).

It is the task of the team to list and rank apparent assumptions that come up with the chosen opportunity idea. Thereby, the identified elements can be quite different and are dependent

on the kind of opportunity idea. For this reason, it is difficult to specify a generally reliable way to identify those assumptions.

Van der Heijden (2005, pp. 73–83) as well as Chesbrough (2010, p. 359) mention that it can be helpful to draw organizational maps and business models to identify uncertainties. In contrast, Saravasthy states that businesses have to be enacted and that uncertainties and assumptions are only identifiable while realizing them (2001, p. 244). Yet, it can be helpful to engage external experts – if this did not happen during the first opportunity identification – in order to collect a first set of assumptions. Furthermore, it is important to mention that early prototyping does not imply that decision-makers can completely refrain from desk research and analysis. The *uncertainty backlog* should rather be seen as a starting point to separate predictable less uncertain assumptions from the most relevant pressing ones. Thereby, it is central to find a good balance betweening "classic analysis" and a straight walk-through to the first early prototype.

Focusing the most critical assumption

Ries argues – in best relation to Popper's falsifactionism and Hooke's crucial experiments – that it is the core activitiy of start-ups to test the riskiest assumptions first: "If you can't find a way to mitigate these risks toward the ideal that is required for a sustainable business, there is no point in testing the others." (Ries, 2011, p. 119).

In order to identify this *most critical assumption,* management has to prioritize all listed assumptions according to their impact on the opportunity idea. In the process, the team is well advised to agree on an appropriate level of detail. While in the beginning team members are challenged to answer bigger, more extensive uncertainties, the granularity of the listed assumptions will increase with each iteration and will become more detailed. This perspective on refining tasks on the run is also borrowed form the agile software movement (see Cohn, 2010, p. 235). Thus, the validated learning-process of the framework leads to the "solving" of the listed assumptions and allows the team to incerease the level of detail.

Flexibility for unknown unknowns

Analogous to the original product backlog, the *uncertainty backlog* is a living tool that supports the early prototyping framework and acts as a starting and end point of each iteration. Due to the flexible and learning-oriented nature of the framework, the backlog should be seen as never closed as long as the project is running. The backlog has to be

rethought after each iteration and will be resorted and aligned to new learnings (see Cohn, 2010, p. 233). This notion of iterative rethinking is critical to managers' ability to incorporate so called "Unknown Unknowns" (Sommer & Loch, 2004, p. 1334) – uncertainties and assumptions that have not been identified upfront by the team. The occurrence of those should not be frightening to the team and is rather a welcome outcome of the ongoing learning process. Imagine: With a desk-focused analysis, those unknown unknowns would have come up during the product launch, would have endangered the product success and would have cost so much more to be eliminated in case of a failure.

4.2.2.2. Practitioners' challenge

Ownership

In order to involve and engage the participating team into the process, it is important that the team "owns" the *uncertainty backlog* and is always allowed to rework and restructure it according to the actual situation. This aspect is especially stressed by several expert interview partners and culminates in the code "Freedom" (see Table 4 - Main Category: "Prototypes need…").

It is pointed out that the early prototyping teams need sufficient freedom to act in order to maintain identification with the project and to keep up their responsibility for it. This perspective resonates well with the Scrum's requirement to understand backlogs as a starting point for discussions rather than a fixed list of externally assigned tasks. Therefore, the *uncertainty backlog* is a document that has to be accessible by everyone in the team just as it is an anchor for team meetings to further discuss, structure and realign the upcoming uncertainties.

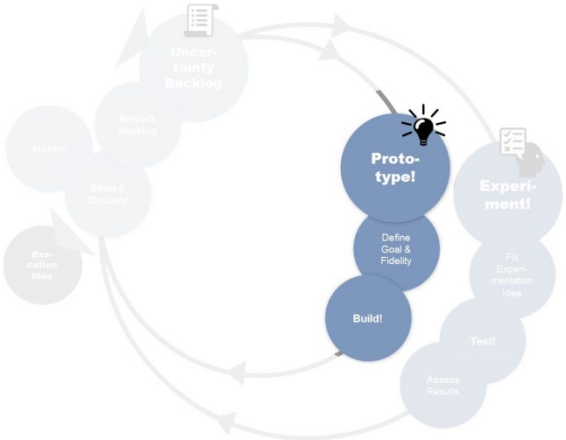
4.3. Prototype!

After preparing the *uncertainty backlog* the team can start with the *most critical assumption* and develop first ideas about the upcoming prototyping iteration. Prototyping is used as a method to build artefacts for the assumptions listed in the *uncertainty backlog*, starting with the realization of the most critical assumption.

It is stated that prototyping teams have to give particular relevance to the goal and fidelity of their prototype in order to prototype efficiently.

As a result, the prototype phase will sharpen the understanding of the investigated opportunity idea and will refine the *uncertainty backlog*. With each iteration the team learns more about the opportunity idea as it resolves and adds uncertainties to the *uncertainty backlog*.

Table 7 – Overview Step 2) Prototype!



Goal	Development of a prototype that represent the opportunity idea in such a way that the *most critical assumption* of the *uncertainty backlog* can be tested. Refinement of the team-wide understanding of the opportunity idea.
Requirements	Structured *uncertainty backlog*. Budget and resources to develop the prototype. If needed: external know-how to build the prototype (e.g. software developer).
Method	Goal and fidelity definition in alignment to the most critical assumption. Parallel development of several prototypes to explore and compare different solution opportunities.
Results	Prototype for further internal and external usage. Implicit and explicit learning in the team. Solving of assumptions. Identification of overseen assumptions and uncertainties.

4.3.1. Define Goal and Fidelity

A number of scholars (Hassi & Tuulenmäki, 2012; Houde & Hill, 1997; Lim et al., 2008, p. 7:3; Raney & Jacoby, 2010; Rhinow et al., 2012; Schrage, 2000, p. 101) state that an elementary challenge in prototyping is to choose the right fidelity. The authors describe that if this is not done properly, it can lead to unfocused and long prototyping cycles, which cost more budget and time than necessary.

4.3.1.1. What to do?

"A single question embodied"

Literature emphasizes that the fidelity of a prototype has to be based on a clearly defined goal (Houde & Hill, 1997, p. 97; Raney & Jacoby, 2010, p. 37). Hence, prototyping teams have to use their *most critical assumption* as a goal for their early prototyping attempt. Where possible, more than one assumption at a time can be tested with one prototype. Nevertheless, literature highlights that too complex, unfocused prototypes are not effective (Coughlan et al., 2007; Houde & Hill, 1997; Raney & Jacoby, 2010).

Furthermore, a clear goal is especially important for the upcoming step of knowledge transfer (called "Show & Discuss" – see chapter 6.4.1). The audience has to understand the goal in order to be able to discuss and profit from a demo of a prototype (Schneider, 1996, p. 552). Similar to the choice of the *opportunity idea* and the sorting of the *uncertainty backlog,* it is not helpful to lose too much time defining the specific goal or leading detailed analyses and discussions. Although this is an important step it should be executed quickly to save time and prevent over-analysis in an uncertain environment. It can be concluded that defining a specific goal that is aligned with the *most critical assumption* is essential for each prototype iteration.

Finding the right fidelity

Regarding the fidelity of prototypes, many scholars cite IDEO's co-founder David Kelley and his notion that prototypes have to be "rough, rapid and right" (for example T. Brown, 2009, p. 89; Thomke, 2001, p. 74) . Although this catchy phrase accentuates three very normative and general characteristics, one should keep in mind that the literature offers many more insights on finding the right fidelity for a prototype. These aspects are mostly investigated by

designers and authors who can be related to design research. As stated in the beginning, business experiment literature discusses these aspects surprisingly scarcely.

In general, the right fidelity of a prototype is important in order to balance cost and time that is necessary to build the prototype while securing that the defined goal is reached. Lim et al. summarize this perspective under the notion "economic principle of prototyping" and claim "the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable" (Lim et al., 2008, p. 7:3). Passera agrees and calls this kind of prototypes "optimum minimum setup" (2012, p. 12).

As mentioned earlier, prototyping goals should not be driven by specific methodologies but has to be chosen based on the defined goals. Regarding this, Passera et. al (2012, p. 9) emphasize that teams who are working with early prototypes should know about and be experienced with a broad set of methodologies and tools to build prototypes[3]. Therefore, the researchers stress the importance of having an understanding of the capabilities of particular techniques (Thomke, 2006, p. 2/17). Without this knowledge it will be hard to find prototyping methods that fit the goal. Regardless of the chosen methodology, the iterative nature of early prototyping enables teams to change and adapt during the building phase.

Defining fidelity by purpose

The following elaborations on the fidelity of prototypes focus on economic and communicative aspects as well as the concrete solution of uncertainties – central elements management should consider when engaging in prototyping (Thomke, 2001).

A helpful distinction of fidelities is presented by Houde and Hill: They separate the terms resolution and fidelity and understand "resolution" as the "amount of detail" while fidelity is defined as "closeness to the eventual design" (Houde & Hill, 1997, p. 3). This perspective

3 Early prototyping is used in various settings, disciplines and stages of new product and service development. The widespread adaption leads to a tremendous range of possible ways to prototype and represent an early idea: From simple sketching (Buxton, 2007) and objects, spontaneously glued together (T. Brown, 2009, p. 90), to paper prototyping , mock-ups, click dummies, Lego models (e.g. seriousplay.com) cardboard or clay models (Houde & Hill, 1997), to little plays and exemplary equipped rooms (T. Brown, 2009, pp. 92–97) or working but roughly tinkered hardware (e.g. physical computation platforms. For example arduino.cc) up to sophisticated 3D printings or complex pilot studies. For a first start one can find more or less comprehensive databases, especially by designers for designers, with different easy to realize methods and tools (designkit.org, ac4d.com, servicedesigntools.com, ideo.com/work/method-cards).

helps the prototyping team to reflect their prototype intention and evaluate if they plan to build a representation that will be helpful and goal-focused. By doing so, it is possible to avoid highly detailed prototypes that have a low fidelity and therefore a questionable cost / learning ratio.

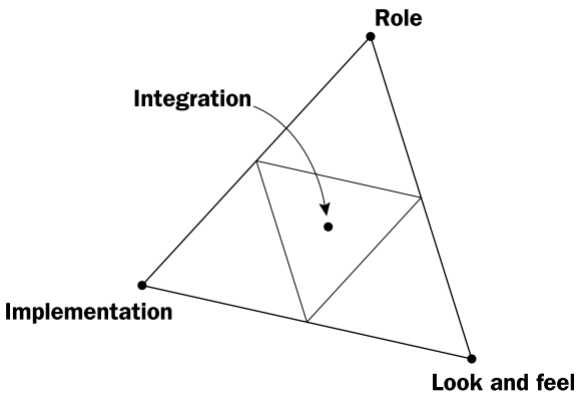
Building on that, Houde and Hill present a model that structures prototypes according to their actual purpose instead of their material (see Figure 4) and suggest four purpose categories. For example prototypes of the "implementation" category are concerned with the technical feasibility of an idea, while prototypes of the "role" category question and test the interactions and contexts of an idea. Consequently, each category demands a different, tailored prototype:

"Implementation usually requires a working system to be built; look and feel requires the concrete user experience to be simulated or actually created; role requires the context of the artifact's use to be established."
(Houde & Hill, 1997, p. 3)

Houde and Hill elaborate further:

"Integration prototypes are built to represent the complete user experience of an artifact. Such prototypes bring together the artifact's intended design in terms of role, look and feel, and implementation."
(Houde & Hill, 1997, p. 11)

Figure 4 - Four Principal Categories of Prototypes (Houde & Hill, 1997, p. 4)



Lim et al. extend this perspective and highlight the filtering capabilities of prototypes. They formulate their "fundamental prototyping principle" as "finding the manifestation that, in its simplest form, filters the qualities in which designers are interested without distorting the understanding of the whole." (Lim et al., 2008, p. 7:3). This means that teams have to specify the aspects they want to investigate (in accordance to Houde & Hill for example "role, implementation, look and feel or implementation") and build a prototype that filters exactly this part. In this case, Lim et al. suggest a balanced selection of "material, resolution and scope". If chosen wisely, the prototype will have an adequate filtering that is in keeping with Lim's "fundamental prototyping principle" and helps the prototyping team to establish a better reflection of their ideas and at an ideal cost structure.

In order to structure the decision process around a prototype's fidelity Blomkvist proposes a five-step pyramid. He suggests to start by considering the point of time in the development process, followed by thoughts about the purpose (as pointed out by Houde and Hill), going on with reflections regarding the audience and author to subsequently choose an appropriate prototyping technique and corresponding validity and finally determining the corresponding fidelity of the representation (Blomkvist, 2011, p. 120).

In conclusion, managers should support and guide teams to build prototypes with a fitting fidelity and without unnecessary high resolutions. It is suggested to guide this selection process in a structured manner (as suggested by Blomkvist) in order to reflect all relevant influences on the needed fidelity. The importance of this step is backed by several experts and is condensed in the need for a prototype's "right fidelity" (see Table 4 - Main Category: "Prototypes need..."):

> *„And as I said it is very key to hold back the team not to start with technical stuff too early."*
> Interviewee 6, Line 34

Evolution of a prototype

As shown by Thomke (1998a) prototyping teams need the capability to switch between different modes of fidelity. While several scholars state that generally prototypes evolve over time from iteration to iteration (T. Brown, 2009, p. 107; Hartmann, 2009, pp. 10–11; Thomke & Fujimoto, 2000, p. 128), Houde & Hill proclaim that prototypes can fluctuate in their fidelity related to the prototyped aspect. For this reason, Thomke's mode switching capability is central when iterating through different stages of the prototype: The team has to align the fidelity to the chosen assumption in order to adhere to the "economic principle of prototyping". Hence, according to Houde & Hill, it is suggested for the framework at hand that a constantly increasing fidelity should not be taken for granted and teams should check regularly if their balance between resolution and fidelity is adequate.

Additionally, Hartmann's notes that an increasing fidelity during the building phase leads to a switch from a focus on exploration (see "6.3.2 Build!") to more demonstration-focused prototyping (Hartmann, 2009, p. 22). This perspective is included and presented in the following experimentation phases.

4.3.1.2. Practitioners' challenge

Incompleteness

Related to this purpose-driven focus on fidelity, it is important to mention the role of incompleteness in prototyping. Lim et al. state that incompleteness has to be seen as a strength that reduces the complexity of a prototype. Furthermore, it is stated in general that a prototype per se has the status of tentativeness and dubiousness (Adenauer & Petruschat, 2011, pp. 24–28). This status is mostly discussed in a positive manner and highlighted as helpful to foster discussion and active reflection on the artefact at hand. Scholars argue that the incompleteness of a prototype leads to openness and suggests changeability. This perception makes a more detailed feedback from colleagues and external stakeholders possible. Furthermore, mixed-fidelity and incompleteness of prototypes circumvent problems of over-commitment and resistance to change: Scholars mention that sleek and expensive prototypes increase the commitment of the team for their prototype, which dilutes feedback due to the reduced willingness to change (T. Brown, 2009, p. 91; Thomke, 2001, p. 3). In addition to those communicative aspects, one can look forward to cost saving due to less complex, elaborated prototypes (Thomke & Fujimoto, 2000, p. 181).

Interestingly, many experts mentioned that they are aware of those benefits of incomplete prototypes but experienced problems with this approach from different sides. For example, some experts reported that employees are reluctant to build rough representations of their ideas because they are afraid to disappoint their bosses. Other interviewees detailed that internal stakeholders often encounter low fidelity prototypes with a great deal of skepticism and adversity. Several interviewees explained that, from their point of view, those confusions are caused by insufficient knowledge of the basic ideas of early prototyping and organizational learning. Only one participant claimed that managers with a profession in engineering do not have problems to analyze and understand rough prototypes. Some of the respondents detailed that they try to reduce the described misunderstandings by extensive trainings and explanations (see table Table 4 - Main Category: "Prototypes need..."- Code "Onboarding").

> *"You have to educate people on that. Especially in large corporations [...] People don't think in prototypes. People only think in finished products."*
>
> Interviewee 7, Line 23

A single interviewee highlighted that those issues should be avoided by a prototype-minded innovation culture that permeates the company as a whole.

Therefore, managers and prototyping teams have to choose the fidelity of a prototype not only based on the needs of the *most critical assumptions* but also on the expectations and mind-set of the audience in the upcoming *show & discuss*. Furthermore, innovation managers should educate teams as well as executives regarding early prototyping.

4.3.2. Build

One could think that after considering the previous mentioned aspects on the goal and fidelity of prototyping, the prototype building process is a trivial task that is already predetermined. This is not the case: Even in the building procedure itself, management can foster several aspects in order enhance the organizational learning effect. In general - with reference to Adenauer & Petruschat (2011, p. 36) –building a prototype could be a lot more than a simple embodiment of a predefined idea.

4.3.2.1. What to do?

Build it together

The perhaps most central aspect of this phase is the collective externalization of thoughts: By building a prototype together, the team has to communicate and embody their ideas and thoughts about the current assumption under investigation. Hence, the process forces the team to literally "think out loud" (Adenauer & Petruschat, 2011, p. 22; Bergström & Ericson, 2009).

What is more: scholars as Polanyi point out that "we know more than we can tell" (Polanyi, 1966, p. 18) and that some parts of our knowledge are only available by action. Building prototypes can be this action and supports the necessary externalization of tacit knowledge (Mascitelli, 2000, p. 179; Nonaka & Takeuchi, 1995). Ries argues accordingly that in the best case as much knowledge as possible is built in-house in order to guarantee that all learnings of the building process are kept in the team (Ries, 2011, p. 90).

The collective externalization of ideas and concepts should lead to a shared mental model (Doll, 2009, p. 261; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000, p. 280; Neyer et al., 2008, p. 215; Rhinow et al., 2012, p. 5). Jönsson (2004, p. 216) describes this as an open process where the participants "coproduce the narrative that makes sense of that artefact" –

a perspective that is analogous to Weick's notion of sense making. Therefore, acting (e.g. building a prototype) has to take place before sense making can happen.

Consequently, the early prototyping framework as a whole but especially the building phase can be understood as such a retrospective, social process of sense making. In accordance with that, Weick demands to "focus the activity of design on sense making rather than decision making" (2004b, p. 48). Prototyping teams and their managers should keep this demand in mind while iterating through the building phase: With a spotlight on sense making during the particular building phase teams will establish a shared mental model that sharpens the problem understanding and shapes subsequent iterations.

Parallel prototyping

Another often highlighted aspect regarding the fidelity of prototypes is the parallel development of different prototypes for the same goal. Lim's argumentation is based on the abductive way of thinking in design (Cross, 2006, p. 11; Liedtka, 2004, p. 195) and emphasizes that a multitude of ways exists that can solve a certain design problem. Therefore, several design scholars (T. Brown, 2009, p. 90; Dow et al., 2010, p. 18:1; Houde & Hill, 1997, p. 5; Rhinow et al., 2012) raised the point that parallel prototyping leads to better results because the team has to investigate a problem in different directions. By doing so, the team explores and widens the design space as it builds on the ideas of others (Bergström & Ericson, 2009) and compares its results and rationales in vivid discussions (Raney & Jacoby, 2010, p. 39; Schrage, 2000, p. 86). Dow et al. (2010, p. 18:16) stress that an abdication of parallel prototyping leads to a premature refinement of the prototype. This would result in missed opportunities of exploration and missed chances to stumble upon additional possible solutions.

4.3.2.2. Practitioners' challenge

Serendipity

Only a few interview partners highlighted that building prototypes supports serendipity (see Table 3 - Main Category: "Prototypes are for..."– code "serendipity"). This could be interpreted as an indicator for a lack of attention on those unexpected outcomes. If this is the case, teams and their managers should optimize their feedback procedures for serendipity. A key factor of this is the willingness to keep the process open and nebulous in order to give sufficient room for innovative, surprising solutions (Junginger, 2008, p. 29; Mascitelli, 2000, p. 186). Managers should secure that experience and open-mindedness of all team members make them to good "reflective practitioners" who are able to recognize vague, underlying opportunities in the creative process of building prototypes.

Allocation of (human) resources

Additional issues were raised by several interviewees: They reported competence shortages while building different prototypes (for example for software developer), which they solved by hiring external freelancers. Furthermore, it was stressed that the procurement of materials can constitute a difficult task in larger corporations: Some innovation managers reported that their purchase department is not able to procure unusual parts or small amounts. While one innovation manager started to circumvent those problems by organizing necessary materials by himself, another started to establish a dedicated prototyping space where materials and know-how is available. Additionally, one participant stated that he had problems to get sufficient human resources to further develop a prototype project. Another reported that executives do not mind prototyping and tinkering as long as long as it has not a bigger budget impact. All of those aspects have been summarized in table Table 5 - Main Category: "Challenges" under code "Allocation of (human) resources".

Although, those shortcomings seem trivial, they were mentioned by several experts. While resource allocation is a very individual organizational problem, it can be assumed that the implementation of formalized, official early prototyping framework, as it is suggested, could lead to bigger acceptance and therefore adapted processes for the allocation of man power and materials.

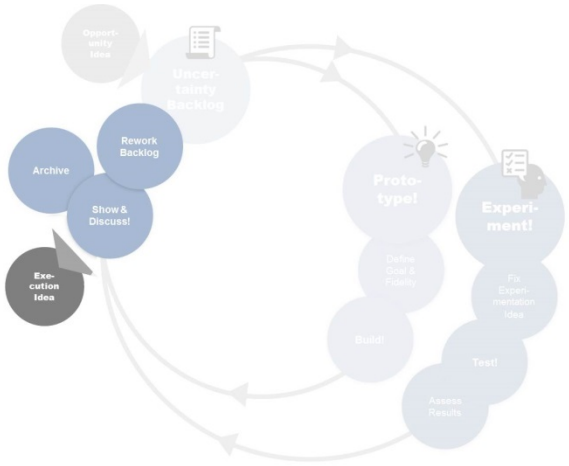
4.4. Feedback and Learn!

The early prototyping framework at hand uses the steps around the *uncertainty backlog* as recurring elements that establish the transition between prototyping and experimenting. By iterating through these steps of the process the team reflects on the accomplished learnings and sets up the next round of prototyping or experimenting. To do so, the central step is the so called *show & discuss* (see 4.4.1). Using this reflection meeting with internal stakeholders as a starting point the "Archiving" as well as the "*uncertainty backlog* Rework" can follow. Single aspects of the project, which have reached a sufficient certainty, can be passed off to classic product development structures, represented by the "execution idea".

4.4.1. Show & Discuss!

As already mentioned, the thesis' perspective on early prototyping is emphasizes interactions and communication between stakeholders around the constructed prototypes (Rhinow et al., 2012, p. 6; Schrage, 2000, p. 56). However, the authors also assume that these advantages of prototyping are not fully exploited and cannot be taken for granted. Therefore, an active management of those processes is demanded.

Table 8 – Overview Step 3) Feedback and Learn!



Goal	Identification of organizational uncertainties early as possible. Gaining internal acceptance by integrating relevant stakeholders.
Requirements	Prototype or results of experiments. Company-wide understanding of the early prototyping method. Willingness to cooperate of the relevant stakeholders.
Method	Identification of internal stakeholders that are affected by the innovation. Detailed presentation of the prototypes by the project team in front of all involved stakeholders. Incorporate feedback into the *uncertainty backlog*: Creating, deleting, reworking and resorting of uncertainties. Easily accessible archiving of the presented prototype.
Results	Extended and resorted *uncertainty backlog.* Acceptance and attention of relevant, internal stakeholders.

4.4.1.1. What to do?

Prototypes as boundary objects

It is the goal of *show & discuss* sessions to involve all relevant stakeholders into the reflection process and include their requirements and opinions as early as possible. Hence, management has to dedicate time for presentations of prototypes (Rhinow et al., 2012, p. 7; Thomke, 2001, p. 3). This is in line with organizational learning literature as well (Argyris & Schön, 1978; Kolb, 1984; Schön, 1982). Those meetings help to improve interdisciplinary discussions, evoke qualified, concrete feedback and stimulate interactions (Schrage, 2000, p. 89) by establishing a common basis for all participants – as described in chapter 4. Consequently the *show & discuss* is focused on the presentation of the built prototypes and conducted experiments and the corresponding learnings. It is highlighted that prototypes should be treated as community property (P. M. Hughes & Cosier, 2001, p. 31; Schneider, 1996, p. 522; Schrage, 1996, p. 10:7), which does not belong to a certain department, in order to enhance and support those knowledge exchange meetings.

To successfully use a prototype as a boundary object (see chapter 3.2), the prototyping team has to keep their audience in mind: The presentation has to be understandable for all present stakeholders. Hence, it is suggested by Holloway (2009, p. 54) to always present prototypes from a user-centric perspective and embed them in business scenarios everyone can relate to. Furthermore, different professions and departments have diverging expectations regarding how a prototype should look like. Therefore, several authors show that the success of such presentations is highly dependent on a vivid explanation of each prototype. They state that most prototypes are not self-explanatory and that a prototype's designer has to present goals and design decisions along with the prototype itself (Buxton, 2007, p. 25; Houde & Hill, 1997, p. 15). Schneider suggests that at least the following questions have to be clear (Schneider, 1996, p. 522):

- "What is the prototype supposed to do?
- Why should be done what the prototype does?
- How does the prototype do it?
- Why does it do it that way?
- What are concepts, and what is prototypical scaffolding?"

Following this, it is the task of managers to assure that all available prototypes are presented and discussed in an open-minded and clear manner. As it is the goal of the s*how*

& discuss sessions to identify requirements as early as possible, establishing a vivid discussion with all participants helps to spot potential problems and overseen uncertainties. Such a participatory approach is widely discussed under the term "participatory design". Scholars, who contributed to this niche of design research that is mostly linked to software design, suggest different practical methods to successfully organize those exchanges (Luck, 2003; Muller & Kuhn, 1993; Spinuzzi, 2005) and highlight social factors of the inclusion of workers into design processes (Asaro, 2000; Kensing & Blomberg, 1998). A special perspective is provided by Muller and Druin: They interpret participatory design as a "third space" at the edges of existing disciplines where "negotiation, shared construction, and collective discovery" happens (Muller & Druin, n.d., p. 17). Teams can draw on those works to design workshops and meetings that facilitate such exchanges in a beneficial way.

Who is in?

Schrage states "the key elements of a prototyping culture are who gets to be a part of it and why." (Schrage, 1996, p. 10:6). Accordingly, the team has to reflect in detail who they want to invite to their *show & discuss* sessions. Some scholars recommend to use business models and organizational maps to identify all relevant stakeholder (Chesbrough, 2010; De Geus, 2002; Osterwalder & Pigneur, 2010; Van der Heijden, 2005)

A widely established innovation culture that encourages mistakes and rough and fast built prototypes is elementary for the beneficial integration of stakeholders into early prototyping. Schrage reports that teams can hesitate to present their prototypes if they believe that other colleagues, departments and executives are not capable of seeing "beyond prototype roughness to the ultimate product" (Schrage, 1996, p. 10:7). Consequently, a company-wide understanding and acceptance of early prototyping is necessary for expedient *show & discuss* sessions (see "Incompleteness" in 6.3.1 as well). If such an understanding is given, the prototype can support the team to "zigzag through the organization" (Junginger, 2008, p. 34) and include relevant stakeholders by asking them for feedback and requirements regarding the actual prototype.

This approach gives the team the chance to introduce their opportunity idea to prospective silent designers (Gorb & Dumas, 1987, p. 152), a term that describes influencer that unconsciously shape a product by constraining the design process, and discuss and co-develop solutions by using the prototype. It is assumed that an active, integrating and open approach to innovation leads to more successful projects due to the iterative implementation

of new ideas and products. This argument is backed by several practitioners that highlighted the importance of early acceptance (see Table 3 - Main Category: "Prototypes are for...").

4.4.1.2. Practitioners' challenge

Keeping the vision alive

In contrast to this very inclusive approach that seeks for internal organizational acceptance, some interviewees highlighted a contrarian perspective and pointed out that those early concepts could collapse under the requirements of the existing experiments. Especially radical innovations could be forced to adapt to the current status due to an organizational inability to imagine and build future products. Some interviewees reported that their organization tends to adapt products to already existing, knowing products instead of endorsing an innovative, originally disruptive concept (see Code "adapt" in Table 5 - Main Category: "Challenges")

> *"And then you get positive feedback on this because that works already and people know this and it was a disruptive and innovative idea could now go the wrong way."*
>
> Interviewee 9, line 13

Furthermore, it was stated that from their point of view early prototypes and fragile, vague and potentially promising business ideas have to be protected from the existing organization. For example:

> *"Actually the [name of incubator anonymized] concept is based on providing a freedom to act, freedom to learn also freedom to pivot and change your concept. And also relies on protecting these nascent concepts from the corporate immune system. [...]"*
>
> Interviewee 6, line 38

> *"You should have to design the organization along the market needs, not along the corporate needs. Especially if you have a very early project or even early product at the market place. You have to protect it from the former organization."*
>
> Interviewee 6, line 51

The term "corporate immune system" is also used by Arie de Geus (2002, p. 163) and describes the reflex of an organization to oppose changes and innovations. Therefore, the described challenge can be understood as a classic problem of the ambidextrous organization and is related to the ability of organizations to handle existing as well as

upcoming business models, products and revenues at the same time (Gibson & Birkinshaw, 2004; O'Reilly & Tushman, 2004, 2008; Simsek, 2009; M. Tushman & O'Reilly, 1996).

Consequently, managers and teams have to balance the gathered feedback and must decide to which extent they adapt their concept to internal and external feedback and, hence, how much they align their product or service idea to market needs and organizational requirements.

Failure acceptance

Corresponding to the open and honest feedback cycles of early prototyping, many interviewees emphasized the need for a high internal failure tolerance. They claimed that an open and honest feedback culture that accepts failures and understands the value of them for a learning process is essential for an iterative, agile project management approach (see code "accept failure" Table 5 - Main Category: "Challenges").

> *"So in a six month period of a work package it can be like with classical project management you won't see the ten times where it didn't work. And you won't see the twenty time where we did progress, you just see two points in time. Where is if it comes to iterations and to these more agile methods. it is more about like showing iterations, getting feedback, everybody knows it doesn't work, nobody is mad on each other. [...] So, I think it is more like how you reflect and show the iterations rather than there are no iterations in the other case."*
>
> Interviewee 9, line 35

This not only true for single iterations or parts of the project but for the whole project, too. Interviewees reported that managers and teams have to have the courage and boldness to see when a project has to be stopped. Otherwise it is not possible to exploit the cost and time saving benefits of early prototyping.

4.4.2. Rework the uncertainty backlog

Due to the iterative nature of the framework at hand, the process starts over again after the *show & discuss* session. The team has to decide upon the gathered feedback and has to realign the *uncertainty backlog* accordingly. By analogy with the already discussed freedom to act, it is recommended to give the team the full control of the *uncertainty backlog* rework. The importance of freedom to act was highlighted by the interviewed experts, who emphasized that the team can decide which feedbacks are relevant rather than executives

who have not gained as much learnings as the team has (see Table 3 - Main Category: "Prototypes are for..." – code "Acceptance").

Consequently the team has to analyze the obtained learnings by investigating the following aspects:

a) Remove clarified uncertainties
First of all, the team can remove all validated assumptions. Thereby, it is important to keep in mind that the prototype could have tested assumptions that were not initially intended to test. The team should be aware of the possibility of those unexpected results in order to achieve the highest possible learning progress in each iteration.

b) Add overseen uncertainties and assumptions
By building and discussing the prototypes as well as the experimentation results the team may discover new, previously hidden uncertainties and assumptions. The team is then challenged to incorporate those into the *uncertainty backlog*.

c) Resort the uncertainty backlog
Due to removals and additions, the team has to revisit the whole *uncertainty backlog* in order to adapt it to the gained learnings. For example, it can happen that the team has to keep the *most critical assumption* on top for the next iteration due to a misleading or unclear prototype or a contradictory experiment result. On the same token, the team might see itself forced to shift the whole focus from one topic to another (for example from customer acceptance to technical feasibility). It is equally as possible that a team changes the general opportunity idea in a total new direction and realigns central assumptions regarding the assumed value proposition or questions the project as a whole and considers a project stop (Paju, 2014, p. 3; Sarasvathy, 2008; Sykes & Dunham, 1995, p. 423).

4.4.3. Archiving

Even if it was mentioned that prototypes need further explanations to be understandable and helpful, the relevance of proper archiving cannot be neglected. First of all, literature reveals that the recombination of built prototypes can be a fruitful way to speed up product development. To do so, it is essential to archive prototypes in an easily accessible way (Adenauer & Petruschat, 2011, p. 32). This aspect addressed by an interviewee who experienced the possibility to reuse prototype materials that have been built years ago and

fitted perfectly for a new project that was requested by top management (Table 4 - Main Category: "Prototypes need..." – code "Archiving").

> *"Where you can very fast produce the next prototype based on the insights and test again and get feedback again to have a very agile, quick repetition and have a quick development process."*
>
> Interviewee 4, line 6

The literature and interviewed experts argue that this archiving is important for new internal and external stakeholders who have been involved in the process from the very beginning. Archiving also facilitates the successful hand-over of prototyping projects to product development teams that carry over the product realization: Both parties can get an easier understanding and overview of the already gained learnings as they reconstruct the evolution of prototypes. By having all tested prototypes in one place, one can comprehend the entire prototyping process from the opportunity idea up to the final execution idea. Furthermore, pivots and changed foci become visible, which gives new team members and stakeholders a detailed impression of the project status.

Beside those on-boarding aspects, the literature shows that an easily accessible archiving can give other project teams the opportunity to learn from previous mistakes (O'Dell & Grayson, 1998). Therefore, it can be valuable to document prototyping activities in a central place where it is accessible for a broad audience. Marsh & Stock (2003, p. 145) claim that especially tangible artefacts that represent learnings in new product development are helpful to establish a knowledge transfer (so called intertemporal integration) between different projects.

Generally, the value of each artefact will be higher if the viewer gets a presentation from someone who has worked on it. Alternatively, prototype iterations have to be thoroughly documented (e.g. video recordings) or the viewer has to interpret the prototype on its own and try to guess which aspects have been under consideration. Schneider highlights that those documentations can be time-consuming, which partly contradicts early prototyping's focus on speed (Schneider, 1996, p. 523).

4.4.4. Execution Idea

The "execution idea" (Hassi & Tuulenmäki, 2012) subsumes all tested and validated learnings. If the early prototyping cycle generated learnings that are sufficiently validated to be executed, the prototyping team can translate their prototypes into executable concepts and ideas that can be handed over to a product development team.

4.4.4.1. What to do?

It is, doubtlessly, the main goal of the presented framework to identify and construct executable solutions for a given problem that can be further developed into a final product. As described on the preceding pages, untangling uncertainties and clarifying underlying assumptions as early as possible helps to circumvent larger, expensive changes in later stages.

"Execution ideas" (Hassi & Tuulenmäki, 2012) represent the outcome of the framework at hand and constitute a point of intersection with traditional product development processes. A handover can be done, if the gained learnings in one segment of the opportunity idea are mature enough to start the actual product development. If, for example, technical assumptions can be clarified by several prototyping and experimentation iterations, the development of basic product features can start. In most cases, it is not necessary to clarify and test all existing assumptions before a team can start to implement first elements in detail. This means that the early prototyping procedure continues while the realization of the actual product has already started.

From there on – as reported by the interviewees – "normal" evaluation and success criteria will be applied and the project has to comply with standards for cost control and quality. However, if the process of early prototyping was successful, all relevant assumptions and uncertainties are tested and the failure rate in the upcoming product development should be significantly lower.

4.4.4.2. Practitioners' challenge

Handover

Several interviewees highlighted that a smooth transition to the traditional new product development is crucial, if one wants to profit from the generated learnings.

> *"If I could wish something, then I would wish that the team that was working on an early prototype would also get the detailed design."*
> Interviewee 8, line 35

Nevertheless, it was reported that it is often tricky to establish such a frictionless transfer. Some experts mentioned that in the best case the team can switch completely and realize the actual product by itself. Unfortunately, the experts stated that such a straightforward handover is often not possible due to time and budget limitations. To circumvent such a loss of knowledge, few interviewees explained that they appoint a responsible and motivated owner of the project that steers the project through the later stages. This is in line with concepts of organizational learning: As stated by Nonaka and Takeuchi as well as Polanyi implicit, tacit knowledge is a key value and will be lost if not properly handed over from one team to another via externalization processes (Nonaka & Takeuchi, 1995, p. 96)

It can be summed up that management has to assure that all relevant learnings can be transmitted smoothly to the developing team and that it is possible for both sides to communicate changes and discuss further inquiries. In the best case, as mentioned in the interviews, it is possible to establish a fluent handover between the two phases.

4.4.5. Re-iterate

As mentioned earlier, the presented framework is based on iterations. Therefore, after each iteration, the team as well as the management has to decide how to proceed: Overwork the prototype? Focus on another *most critical assumption* and build a new prototype? Start a series of experiments with the current prototype? Hand over first aspects to a development team or concretize further?

It is up to the team to discuss the next steps and take an informed decision concerning the further development. To do so, the gathered feedback as well as the *uncertainty backlog* can be helpful supporters. Furthermore, the "economics of prototyping" should be always taken into consideration. Teams have to see when further iterations would lead to only minor

improvements and little decreases in uncertainty. Therefore, the margin between knowledge increase and costs have to be taken into account in order to decide if additional iterations are necessary (Möller, 2006, p. 228; Schrage, 2000, p. 99; Thomke, 2003)

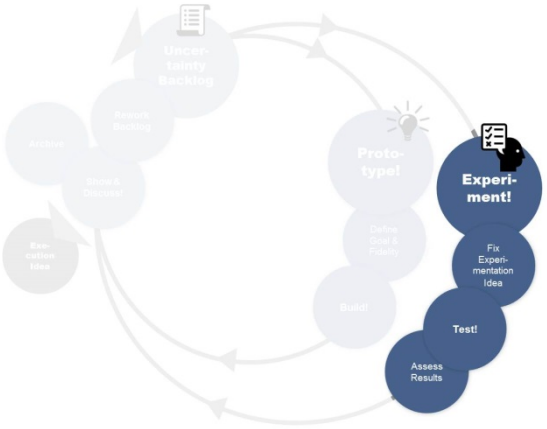
4.5. Experiment!

The outer circle of the presented framework is dedicated to the already defined business experiments. While the inner circle was mainly influenced by design literature, this phase is shaped by more managerial-oriented scholars. It will be explained how those authors suggest designing experiments and at which points in the process the literature on business experiments can profit from the subsequently presented design literature.

In general, it is the goal of this phase to bring the developed prototypes into an external environment and test the opportunity Idea and its most critical assumptions with customers. By doing so, scholars argue, organizations get the chance to understand their opportunity idea from a market perspective in contrast to the mere internal-oriented prototyping phase. Therefore, the prototyping phase is essential to further develop the chosen opportunity idea and understand it in more detail.

The described sense making while building the prototype and the first *show & discuss* session (see 6.4.1) should have established more detailed information on the feasibility of the opportunity idea to conduct more focused experiments. Therefore, every early prototyping project should start with at least one *Prototype!* cycle and a corresponding *show & discuss* session as well as a reworked *uncertainty backlog*.

Table 9 – Overview Step 4) Experiment!



Goal	Generation of validated customer feedback to assess the chosen most critical assumption.
Requirements	Structured *uncertainty backlog*. Budget and resources to build and conduct experiments. If needed, external know-how to realize the experiments (e.g. market research institutes).
Method	Planning of a business experiment that tests the most pressing uncertainty of the *uncertainty backlog*. Specification of falsifiable hypotheses. Definition of an adequate target group and sample size. Execution and assessment of the experiment. Aggregation of the results to make them presentable for a *show & discuss* session.
Results	Validated customer feedback for further decision making.

In general scholars propose relatively simple process models for business experiments. For example:

- Davenport (2009, p. 72):
  Create or Refine Hypothesis / Design Test / Execute Test / Analyze Test
- Ries (Ries, 2011, p. 75)
  Build / Measure / Learn
- Thomke (2003, p. 94)
  Design / Build / Run / Analyze

The following section outlines the most central aspects of these processes and discusses overlaps, contradictions and complements to the subsequently described prototyping literature in a practitioner-oriented manner. This section is geared towards assist practitioners in connecting their prototyping efforts seamlessly to business experiments.

4.5.1. Experimentation Idea

4.5.1.1. What to do?

General Experimentation Idea

Similar to the opportunity idea in Chapter 6.2, the concept of the experimentation idea is borrowed from Hassi and Tuulenmäki (2012). In contrast to the opportunity idea it is a focused, clear concept to test the current *most critical assumption* of the *uncertainty backlog*. The team has to conceptualize an experimentation idea that enables the testing of the present assumption by using one or more already designed prototypes. By designing the *Experimentation Idea*, the team has to consider and balance several aspects.

It has to be mentioned that one can find creative, metaphorical ways to experimentation that are equally capable of collecting meaningful results. This aspect shows that it is not necessary to build and use a complete representation of the opportunity idea to test critical assumptions that are related to it. This is especially highlighted in start-up literature where authors like Eric Ries advocate easily conducted experiments to test customers' willingness to buy. So called "smoke tests" consists of websites and marketing materials that should generate user feedback without having built the actual product (Ries, 2011, p. 95). In another example, Ries describes how an Indian laundry service tested user acceptance by simply tying a customer washing machine to a pick-up truck and placing this truck in districts where the potential target group lives even though the end product became a kiosk that is washing clothes on site (Ries, 2011, p. 77). These examples highlight the creative potential of business

experiments: Teams should use the opportunity and have the freedom to conduct unusual experiments to test their identified hypothesis (Anderson & Simester, 2011, p. 103).

Hypotheses

In order to conduct a meaningful business experiment it is necessary to have clear hypotheses that are tested/validated via the experiment. In the framework at hand, the hypotheses are highly related to the *uncertainty backlog* and will be derived from the chosen *most critical assumption.* The team has to transfer this assumption into testable hypotheses that can be falsified in the upcoming experiment (Anderson & Simester, 2011, p. 101; Davenport, 2009, p. 72; Ries, 2011, p. 57; Thomke, 2001, p. 6). At this point it becomes clear that these hypotheses are the fundamental difference between the business-driven use of prototypes and the design-driven approach to early prototyping.

Data Collection

By defining the hypotheses it is necessary to keep in mind that the *most critical assumption* has to be tested in a compelling way: The generated data has to be able to illustrate the customers' opinions and convinces internal stakeholders that a sufficient level of validated learnings has been attained (Schrage, 2000, p. 149). To assure this, it is central to choose the appropriate data collection methods (Hassi & Tuulenmäki, 2012, p. 10). One has to assure that the used methods are able to cover all critical aspects. One expert interviewee stated that he tries to collect data from as many sources as possible in order to have enough flexibility and opportunities to countercheck against inconsistent data points. This idea is reiterated in literature: It is stated that digitization offered tremendous new opportunities to track and measure customer behavior from a multitude of perspectives (Anderson & Simester, 2011, p. 103; Schrage, 2010). This holds true especially for digital services such as apps and web offerings. Therefore, companies that seek to accelerate their learning processes by experimentation should be able to exploit those new technologies, if they are to generate meaningful customer insights.

Additionally, several scholars highlight the importance of quick feedback and results. It is stressed that experiments should be designed in such a way that results can be expected immediately (Anderson & Simester, 2011, p. 102; Thomke, 2003, p. 104). A delayed reaction reduces the iteration speeds and makes it more difficult to identify causalities and conclusions from the gathered data.

Validity

At the same time, it has to be guaranteed that the participating customers are able to grasp and interact with the presented prototype(s) in the intended way. In this context, Schrage points to the importance of keeping user interactions in mind and to understand how customers use and behave when using the prototype (Schrage, 2000, p. 171). While internal presentation and feedback sessions allow early prototyping teams to comment and present thoughts behind the prototypes, business experiments require more autonomous, self-contained representations of the underlying ideas: Customers must be able to understand the prototype mostly without external support. Therefore, the prototype's fidelity has a direct influence on business experiments: If a misleading fidelity complicates user interactions due to a misleading fidelity, the experiment would lead to false results. Interestingly, this notion is not discussed in detail in none of the investigated literature. Early prototyping teams have to align a prototype's fidelity with the experimentation idea at hand and change parts of the earlier built prototype, if they do not fit to the experiment. Consequently, the team has to reflect on the internal validity (reliability of the data gathering methods) as well as the previously described external validity (does the experiment represent what was intended) (Möller, 2006, p. 88).

More generally, Chesbrough, with reference to Thomke, defines the validity of a business experiment as "the extent to which the experimental conditions are representative of the larger market" (Chesbrough, 2010, p. 360). Besides, the role of real significance is discussed contradictorily. While Ries emphasizes the role of qualitative results (2011, p. 125) as meaningful addition to quantitative data, Davenport highlights the importance of significant results in a statistic sense (2009, p. 73). This aspect was discussed in more detail during an expert interview where it was stated that the need for significance depends on the intended audience of the presentation. The expert reported that in his company it is primarily important that the early prototyping team is convinced that the gathered data proofs the defined hypothesis.

> *"So the belief that the team is on the right track does only happen if the team itself beliefs it. [...] No one is as close to the concepts and isn't as close to the learnings the team made as the team. Right, so: Convincing aspects of a pitch depend on the energy level of the team, right?"*
>
> Interviewee 6, line 21

Costs

As far as costs are concerned, business experiments can be contrasted to traditional R&D experiments: Contrary to Thomke (1998b, p. 58), it is not necessary to be overly aware of false positives as it is needed in technical engineering of security relevant systems (e.g. in car manufacturing). Due to the fact that business experiments should guide decision making in a fast manner rather than develop bullet-proofed results such a focus on detailed experimenting seem inappropriate. This perspective is underlined by Thomke in a later publication (2003, p. 102).

4.5.1.2. Practitioners' challenge

Audience

Several scholars emphasize that business experiments should include only a selected set of customers: Ries proposes to focus on early adopters (Rogers, 2003, p. 283) and states that business experiments should be conducted with people who are able to understand new, potentially disruptive ideas (Ries, 2011, p. 62). This is in line with Möller who highlights that the importance of customer feedback is depended on the disruptiveness of an idea. He outlines that ideas have to be connectable to a customer's world so that a customer can give a meaningful feedback to disruptive ideas (Möller, 2006, p. 90). Hence, the existing knowledge of the participants presents a decisive factor. This perspective is perfectly connectable with Passera's (2012) and Blomkvist's (2011) publications on prototyping: Both highlight an interrelation between validity and audience and claim that prototyping teams have to align their experiments to the demands of the audience. Consequently, it can be stated that managers and early prototyping teams have to align the selected audience with their particular experimentation idea and the prototypes' fidelity.

In relation to those requirements, several interviewees as well as scholars highlighted that the recruitment of participants can be challenging. Ariely (2010) points out that companies are reluctant to test with real customers because they are afraid to disappoint them. This point was highlighted by experts as well: Some stressed concerns regarding their company's brand and reputation: It was accentuated that it can be problematic to present incomplete prototypes to customers – especially in B2B settings – due to the risk that these customers misunderstand the incompleteness as a lag of competence and draw wrong conclusions

regarding the company (see Table 5 - Main Category: "Challenges" - Code "Misunderstanding with customers").

> *"So we got political problems because they didn't understand that this was just a prototype and an idea how we imagine [product] the future. And they were pissed and we are still not be able to go on with this project because we got real political problems.[...] That is very important to be clear. Because otherwise he would think "wow that's a very ugly solution, I don't want it." Make it clear that it is work in progress, it is a prototype, it just helps us to understand them and to really understand how the prototype works."*
>
> Interviewee 7, line 46

Furthermore, two expert interviewees that work mainly in B2B environments reported that their companies seek for tight connections with lead customers in order to get an early feedback from them during qualitative feedback sessions.

> *"So the customer focus group won't be like "we go out and test in the field". It was just like "we invited the customer to our site and let him have a look at it and tell what he thinks about it."*
>
> Interviewee 8, line 43

They pointed out that classic experiments are difficult to arrange due to their small number and high importance of customers and their highly customized products. This approach changes the experiments to a partnership between producer and client that work with prototypes to specify needs together (Schrage, 2004). Hence, it can be assumed that business experiments are more qualitative-oriented and more tightly connected to customers the less customers a company has.

4.5.2. Test & assess results

4.5.2.1. What to do?

Conducting the experiment

Finally, the early prototyping team can start with conducting the planed experiment. First and foremost, a control group is needed. The experiment could for example utilize A/B-Testing for digital products, a regional split or simply different shops of a company.

In contrast to design-driven prototyping efforts, experiments with real customers have to take real life settings into consideration. Early prototyping teams have to assure that these

real life settings do not influence the business experiment in an undesirable manner and that the used prototyping is capable of working sufficiently in those situations. Hence, it is suggested to pre-test the prototype in different real life settings before conducting bigger experiments with real customers.

Anderson & Simester (2011, p. 103) highlight the importance and value of these real life settings: While lab experiments neglect the complexity of the business environment, experiments are able to uncover new flaws and problems in realizing and implementing the opportunity at hand. Especially modern data gathering methodologies give prototyping teams a wide range of opportunities to slice the incoming data into smaller chunks and refine the experiment on the run. In addition, Anderson & Simester (2011, p. 104) point out that managers can conduct "natural experiments": They state that companies should utilize for example new shop openings to test smaller changes and compare them to existing shops. By doing so, they can exploit treatment and control groups that are defined by external factors.

Mind compliance issues

Whereas digital businesses[4] and start-ups with a modern, digital mind-set may conduct experiments in real business environments on a daily basis, the majority of brick and mortar shops (Ariely, 2010; Schrage, 2010) and larger corporations are still quite unfamiliar with this procedure. Hence, early prototyping teams should inform all participating staff members about the experiment and include the compliance department to make sure that all guidelines and policies are respected.

Assess results

Due to the multitude of inputs and data gathering points it is fundamentally important to assess the gathered data in detail and extract the relevant points. The following *show & discuss* session will not lead to new, helpful feedback, if the data is not prepared sufficiently. Early prototyping teams cannot expect that every relevant stakeholder is able to interpret tracking data, statistical tests and other outputs. Therefore, - analogous to the presentation of prototypes – the team has to prepare a meaningful presentation of the gathered learnings. Otherwise the gained knowledge cannot be transferred and the early prototyping loop will be slowed down.

[4] Many will know the often told anecdote about Marissa Mayer (former vice president product at Google, since 2012 CEO at yahoo) who tested 40 different blues in an extensive a/b-test to figure out the best converting color tone for links on the google search result webpage (Holson, 2009; Walker, 2009).

4.5.2.2. Practitioners' challenge

Keeping knowledge in house

Even though experiments are focused on specific hypotheses and are less explorative, several authors state that experiments can reveal unexpected results that have not been anticipated before (Ries, 2011, p. 58). While this aspect is rarely given explicit attention in literature on experiments, it shows a clear connection to the mentioned benefits of prototyping with a design perspective. As much as the building of prototypes can lead to implicit learnings, it can be assumed that the team learns additional aspects as well while experimenting. This aspect is in line with the high focus of internal learning that was stressed by several interviewees.

> *"And the other advice would be "Don't rely on agencies or research agencies in an early stage because they will bring in the results. […] I require that the acting guys talk to customers themselves."*
> Interviewee 6, line 86

It follows that managers should prevent the externalization of experiments, if possible, in order to assure that the early prototyping team can learn by itself through conducting the experiment. It is therefore important to include those results into the upcoming *show & discuss* as well.

4.6. Evaluation of the framework

As depicted in chapter 2.3.2, the first drafts of the framework have been discussed with business consultants in order to assess the feasibility of the framework and identify areas of improvements and potential weaknesses. Besides the generally positive feedback on the framework, some points for improvements were highlighted by the interviewees of the evaluation phase. While some of them exceed the limits of the thesis at hand, others are already considered in the presented framework.

Multiple opportunity ideas at a time

After the presentation, some consultants were not sure if the framework could investigate more than one opportunity idea at once or if it is focused on one idea. After explaining that the framework is conceptualized for one idea at a time, it was proposed to have multiple competing opportunity ideas at the same time to figure out which solution could be the better choice. It was discussed that it could be possible to run multiple instances at once and to introduce an additional reflection level between the different projects. A similar solution is proposed and described by Schwaber (2007) for Scrum in larger enterprises. Furthermore, the parallel testing is in line with Eisenhardt's suggestion to test multiple options in parallel as early as possible to increase decision speed (Eisenhardt, 1990, p. 53).

Identifying and ranking uncertainties

Multiple interview partners were interested in prescribed methods to identify assumptions and rank them in a quantitative way. While the general approach to start with crucial show stoppers was understood as positive and helpful, the identification of exemplary assumptions for the investigated project was difficult for some interviewees. After the interviewer suggested some examples, the consultants were able to come up with own ideas. The wish for a quantitative method to rank the assumptions was negated by the interviewer. In doing so, the interviewer reasoned that the high degree of specificity and distinctiveness of each opportunity idea impedes the development of a unified way to rank the corresponding assumptions. All interviewees agreed on this perspective.

Learning from traditional market research and workshops

Two consultants mentioned that they believe that it is crucial to decide to which extent market research and workshops with stakeholders can accelerate the learning process. Nevertheless, both agreed that the use of a tangible prototype in a real business environment can offer deeper and more specific insights than traditional market research. At the same time, it was discussed that both approaches can complement each other perfectly.

Integration in running projects

While discussing the proposed process within real client project, it became clear that it is hard to apply the early prototyping framework to an already running innovation project. Due to the fact that the client's team had already built different prototypes without reflecting on goal and underlying assumptions, the team members had first to take stock of the already gained learnings. This reflection was necessary to generate an *uncertainty backlog* ex-post and identify not yet validated assumptions. Hence, a kick-off workshop seems to be crucial when the early prototyping framework is used in consulting projects.

Existing processes and habits

Although several expert interviewees said that they do not use a structured, formalized process for early prototyping, aligning the proposed framework must fit with already existing innovation and prototyping processes can present a significant challenge. When implementing the framework, managers have to pay attention to existing informal as well as formal processes in their particular company, as pointed out by Schrage (1996, p. 2). Related to this alignment, it would be necessary to design a suitable handover to an existing product development process (e.g. Scrum or traditional StageGate).

IT Infrastructure

One consultant mentioned that for a larger rollout and a sustainable integration in larger corporations, it is necessary to realize and conceptualize an IT infrastructure integration. He stressed that an already huge but still increasing number of companies map all their internal processes in IT systems. If the suggested framework should be used on a regular basis, it is required to translate it to such an IT solution.

Cultural change & agility

One consultant that is experienced in the implementation of agile product development processes in companies stressed the challenge to integrate agile working teams into a traditionally organized company structure. He highlighted that realizing benefits of an iterative working style can be associated with difficulties, if neighboring departments cannot adapt to such an approach. Hence, it became clear that a well-structured handover between those departments is necessary. Furthermore, it is important to establish a company-wide acceptance and understanding of the underlying principles and mind-sets. The problem-centric expert interviewees revealed that engineering-led companies seem to be more open-minded and used to prototyping than more service-oriented enterprises.

5. Discussion

The following chapter summarizes and discusses the results of this thesis. General and methodological limitations will be addressed and a conclusion will be drawn. Finally an outlook for further research is given.

5.1. Conclusion

All-encompassing uncertainties are a fundamental part of modern business environments: A rising complexity of products, an on-going digitization and an accelerated change of market demands dramatically complicate companies' strive for long-term business success. Consequently, firms have to find ways to cope with these challenges and take a proactive step towards uncertainties.

One way to do so is the adoption of iterative, learning-oriented processes in order to incrementally adapt to changing environments. The master thesis at hand investigated the concepts "business experiments" and "early prototyping in design", which are predicated on such an iterative mind-set. Although both concepts show different commonalities and share several benefits the literature on these topics has so far remained relatively unconnected and fragmented. By investigating those commonalities, differences and benefits in detail, this thesis shows that the concepts could supplement each other on various levels and share sufficient commonalities to be combined into one comprehensive framework.

Based on this analysis, a practical early prototyping framework has been developed. The framework integrates both concepts with each other and links them by utilizing literature from organizational learning as well as aspects of modern project management. Thereby, the so called "*uncertainty backlog*" plays a central role and acts as an intersection point between the concepts as it allows for overlapping commonalities while keeping distinctive characteristics separated. Furthermore, literature from both fields as well as organizational learnings has been considered to present crucial aspects for the development, presentation and discussion of prototypes and business experiments.

While designing the framework, the opinions and insights of practitioners have been included. Expert interviews revealed that topics with minor relevance in literature often present the most pressing challenges in practice. Hence, the master thesis at hand has emphasized those challenges and proposes possible solutions to deal with these aspects.

As a result, the framework shows how managers can combine early prototyping and business experiments in a structured manner and presents a way to give the fundamental concepts a higher relevance in uncertain environments. By applying the framework, managers can unhinge early prototypes and business experiments from their particular discipline boundaries and can unfold their benefits on a broader, organizational-wide level in order to achieve advantages in cost and time. The conducted evaluation phase has revealed that the constructed framework can be applied to a diverse set of business problems and seems specific as well as adaptable enough to be helpful in diverse business settings.

Finally, it can be stated that the master thesis at hand has shown that the wide range of literature on early prototyping in design and the publications on business experiments can be linked to a meaningful, comprehensive whole. It became evident that the two concepts share various benefits and commonalities and can be connected to already established literature on organizational learning.

5.2. Limitations

Beside the already raised limitations that have been revealed during the evaluation phase, more general limitations have to be mentioned:

The most pressing limitation of the presented framework can be seen in his normative character. Beside the conducted expert interviews the result is built mainly on literature from three fields of research. Although the results of the evaluation phase suggest applicability in practice, it has to be shown that the conceptualized model can be implemented in a value-adding manner in real business settings.

Related to this theoretical applicability, one has to mind the role of organizational culture when implementing the proposed steps. While the normative character of the results presents mainly explicit guidelines and suggestions, it is difficult to cover more implicit cultural aspects. Therefore, the application of the framework is possibly hindered by complex organizational cultural problems. Thereby, especially the interdisciplinary collaborations should be of interest. This aspect has to be explored by applying the suggested framework and analyzing resulting outcomes – ideally in the form of several case studies. By doing so, one can investigate details of the organizational cultures and their influence on the implementation of the proposed framework.

This aspect leads to the question of implementation of this framework: Until now it is not worked out how managers can train their project teams about the presented early prototyping approach. A first attempt into this direction is planned by the author in form of a half day on-boarding workshop with a project team that is already used to agile working methods.

If one would apply the developed framework to this master thesis, it would have been necessary to discuss first, rough drafts of the framework with the expert interviewees and refine the draft step by step. This would have led to a higher integration of literature and practitioners' expertise.

5.3. Outlook

Due to the normative nature of the developed framework, the most important step will be an application in a real business setting. Ideally, the framework will be tested and re-evaluated during several projects in order to prove that both concepts can be meaningfully linked via the proposed *uncertainty backlog*. When doing so, it would be interesting to test different implementation methods (workshops, intensive trainings, longer consultancy projects) and observe the adoption rate to trace implementation boundaries.

Methodology-wise one has to consider that the expert-interviews cover mainly a top to middle management level with professions in innovation management or comparable positions. While these interviewees have been chosen for their relatively broad knowledge about running innovations projects, it would be interesting to survey employees with more specialized professions in design and (software) engineering. Such further inquiries are imaginable as quantitative as well as qualitative research. Especially comparative approaches could lead to interesting insights into prototyping practices in the different disciplines. Furthermore, comparisons between specialized professions and managers could reveal value-adding insights for the management of prototypes in early phases.

Such a comparison could be interesting as well, if the researcher lays a focus on company-size and investigates different prototyping behaviors in start-ups, SMEs and enterprises. If one is interested in such an analysis it could be helpful to construct a reliable questionnaire. This questionnaire could build on the presented benefits of prototyping (chapter 5) and the particular understanding of prototyping inside the company (design-driven vs. business

experiment-driven). This questionnaire could investigate diverging approaches to prototyping and relate them to a multitude of independent variables (e.g. company-size, sector, innovativeness, companies' age, prototyping department, position of respondent).

Furthermore, it would be interesting to examine managerial perspectives and implications regarding iterative, agile mind-sets and project management methods. One has to mind that the investigated methods have been conceived on a practical level and gain increasing relevance in organizations. At the same time, they demand broad changes in management style and organizational culture to be able to exploit their hoped for benefits. Although, the thesis at hand connected those methods to established management literature on organizational learning, it became clear that a body of management literature is missing that investigates and adapts management theory to those already used methods and the rising mind-sets of iterative, agile working styles.

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I, Florian Redeker, hereby certify that this thesis and the work presented in it is entirely my own, unless stated otherwise. No other person's work has been used without due acknowledgement in this thesis. All references and verbatim extracts have been quoted, and all sources of information have been properly acknowledged.

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Florian Redeker