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Design and design management in the incubation phase of high-tech start-ups

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Abstract: Because engineers founding start-ups often lack access to financial resources, engineers and designers rarely cooperate during incubation phase. Engineers also know little about the potential benefits of cooperating with designers, although design is increasingly seen as a method of incubating business ideas and creating new, unique and novel approaches. – To investigate the contributions and effects of design and design management a research team worked in an action research project with six high-tech start-ups from various fields. All start-ups were from the Innovation and Entrepreneurship Laboratory of the Swiss Federal Institute of Technology in Zurich. This paper introduces a framework that was used during data collection and data analysis to tie the results of collaboration to generalizable insights. There is evidence that design and design management are able to professionalise and foster and accelerate the start-up's access to network resources such as finances, reputation, and market.

Keywords: design**,** design management research, high-tech start-ups, early stage, incubation or seed phase, designers and engineers

1. Introduction

Natural scientists and engineers[1] who are capitalizing on innovative technologies they developed during their research and who are founding start-ups often go through a so-called "Valley of Death"[2]. At the early stage or incubation phase, high-tech start-ups lack the financial means to fully fund product/service development, and to bridge the gap between basic or applied research and product/service introduction on the market. The financial straits during the incubation phase are further acerbated by the fact that engineers lack the entrepreneurial skills how to shape viable business propositions and to transform a technological innovation into a product or service with an added value for the future user. At this stage, designers and engineers would greatly benefit from collaborating, since design is "increasingly seen as a

[1]For the sake of simplicity, we will use the term „engineer" in this text, since during this project we mainly interacted with researchers applying technologies rather than undertaking fundamental research.
[2] Investors and innovators claim that a 'Valley of Death' exists between basic research and commercialization of a new product.

method of incubating business ideas and creating new, unique and novel approaches to issues of marketing, strategy, and consumption (Kolko, 2002 cf. Nussbaum 2001, 2005, 2007)".

However, budding entrepreneurs from the engineering disciplines often associate the term 'design' with art and as not relevant for their future business. Wanting to demonstrate the operability of their technology as soon as possible, they follow approaches from their scientific training. Products are often created without awareness for the user's need to intuitively understand and connect with technical devices. In Switzerland, engineers and designers have few opportunities to get to know each other or to cooperate during their studies. – High-tech start-ups, thus, rarely present professionally designed product concepts and scenarios to investors or other stakeholders that would be able to support them in bridging the "Valley of Death".

With a view on these preconditions, an action-research-based project (Andelman, 1993; O'Brien, 1998) named "DesignSeed" was conducted, aimed at answering the following questions: What can design and design management add to the incubation phase of high-tech start-ups? What are the effects of a collaboration of designers and engineers during this phase? How can design accelerate the commercialization of engineering products and services?

A research team composed of designers and design managers worked with six high-tech start-up teams from various fields such as robotics, medical and laboratory technology, technical work aids. All teams were from the Innovation and Entrepreneurship Laboratory (ieLab) of the Swiss Federal Institute of Technology in Zurich (ETHZ). The design research team provided design and design management support depending on the individual requirements of the start-up. This support included the analysis of how design can generate added value in the given project, participatory workshops including various design and design management methods, and actual design work. While the design team developed corporate design and branding proposals, product- and packaging design concepts as well as design for graphical user interfaces, it also documented the process of collaboration including design results as well as the communication and alignment of different approaches or expectations. During collaboration, the design research team developed a number of models[3] to map and understand processes and to improve the interactions between designers and engineers during incubation phase.

This paper gives a short introduction to the main literature underpinning this project and introduces a framework that was developed during the early stages of data collection and was used as a critical framework during data analysis. We will compare the design output that was achieved by the start-ups through the collaboration with the design research team, tie these outputs to evidence, describe generalizable insights and draw conclusions on the added value of the collaboration of designers and engineers in the incubation phase.

[3] In this paper, we introduce one of three models, which were developed during the project. See Acklin & Wanner, 2016.

2. Literature and critical framework

Due to limited space[4], we very succinctly elaborate on definitions and concepts that make up the theoretical foundation of this project, which are: science, engineering, design, and design management. We will not go into innovation or entrepreneurship, which also would have to be considered. Instead, we will shortly investigate the differences as well as the overlaps between engineering and design and define this relationship as a systemic interplay between technology, environments, and markets. Finally, we will introduce a critical framework that was developed during the first and used during the second part of data collection during the research project.

2.1 Literature

The engineer and researcher David Blockley (2012) describes the differences between some of the above mentioned notions as follows: „(...) science is what we know, art is making extraordinary things, engineering is making useful things, technology is applied science, mathematics is a tool or a language, and craft is a special skill". So the goal of engineering is the development of technologies or tools that are useful, practical, safe, inexpensive, and sustainable. Sometimes these tools will be as complex as a computer or an airport, sometimes as simple as a paper clip. In today's complex world, engineers also have to deal with the risks of implementing 'hard systems' such as innovative technologies into 'soft systems', which will be run by fallible human beings (Blockley, 2012). This is where design has an important role. Design scholar Richard Buchanan (2002) states that design is instrumental in "humanizing technologies" and turning them to human purpose and enjoyment.

Using Aristotle's notions of 'logos' and 'mythos', Blockley (2012) states that new knowledge is not only created through 'logos' or reason but by 'mythos', intuition, dreaming, emotions, etc. – a statements that resonates well with Buchanan's stance on "humanizing technology". Accordingly, engineering and design have the similar goal of creating useful things. Engineers and designers alike place a premium on performance, "but the designer's stance is more intimately involved with human experience" (Buchanan, 2000, p. 2). By focusing on "human factors" and giving attention the human-machine-interfaces, designers bridge the gap between 'hard' and 'soft systems'.

Guy Bonsiepe (1995) compared the difference between science, technology, and design in the innovation chain as follows: While the objective of technological innovation consists in producing know-how of how a product is made, with what materials and tolerances, design's objective is the "articulation of the interfaces between artefact and user" (p. 36). Design's standard practice is the creation of variety, but also "its reduction in order to create coherence in the fields of use, appearance, environment, and lifestyle" (p. 36). Other than science, which takes place in an academic environment, design occurs in the context of companies, the market, or the competition (Bonsiepe, 1995).

However, while the criterion for success of a design activity is a positive reaction of the client to the product/service (Bonsiepe 1995), design management measures its success by determining how effectively a company is able to positions itself on the market and its environment. Design management is not creating new designs but a management function (Acklin & Steffen, 2012) that embeds design or design processes in companies in order to create added value in products, services, experiences, processes, and structures. The same can be said about human computer interaction (HCI): While it focuses on the relation between technology and its users (Shneiderman et al., 2016),

[4] We are aware that there exist multiple definitions of design and engineering, but for the sake of clarity in argumentation and due to limited space we will focus on only a few in this paper.

in the context of high-tech start-ups, a wider range of stakeholders (such as industry opinion leaders, or investors) has to be considered.

Based on the concepts presented above it can be said: Design and engineering in a start-up context have complementary roles. Design develops the interfaces necessary between the 'hard systems' (or technological innovations) of the engineering disciplines and 'soft systems' (or users, competitors, investors, business models, etc.). Design management will integrate and orchestrate different design activities of a start-up to most effectively address the 'soft systems' (or the markets).

2.1 Critical framework

"The Valley of Death" innovation and start-up model[5] depicts the early stage product development process as a linear process from basic research to product introduction and revenue growth. This model delineates the relationship between the product development process and investment, but it doesn't represent the often erratic and dynamic process of venture creation. According to Petterson et al. (2016), during incubation phase, entrepreneurs need more than investment; they also necessitate "network resources to generate or test ideas, develop new technology, identify market opportunities, obtain access to financial funding, and gain legitimacy (pp. 1-2)". Besides product development's focus on how to create value for future customers, the incubation phase is about access to such resources such as "financial contributions", "organizational reputation", and the "market" (Petterson et al., 2016).

In our project, a "start-up stakeholder journey" (see Table 1) was developed. Based on the concept of a customer journey, which is used in service design or design management to understand the basic needs of customers at each touch point of a firm, our model describes the process of starting up a business as a *communication effort,* addressing stakeholders. With reference to the concept of "network resources" the most important stakeholders are:

- Business angels, juries of start-up competitions, investors, etc. (financial contributions)
- Opinion leaders, members of the press, etc. (organizational reputation)
- Industry members, business partners from incumbent firms, first customers etc. (market access)

The critical framework "Start-up stakeholder journey"(see Table 1) consists of four phases: 1. Raise awareness amongst stakeholders to build organisational reputation; 2. Awaken interest to establish contacts with potential partners; 3. Build commitment and gain access to financial contributions; 4. Create buy-in of central stakeholders of the market.

Table 1. Critical framework: Start-up stakeholder journey

Phase	Raise awareness	Awaken interest	Build commitment	Create buy-in
Network resource	Organisational reputation	Organisational reputation Financial contributions	Financial contributions Market access	Market access
Success indicators	Positive response of opinion leaders, incumbent firms,	Contacts to potential partners, angels, or investors	Seed money, awards, investment	Product launch, first clients, business

[5] As an example see UC Davies, Center of Entrepreneurship, n.a.

	press articles	partnerships

For each of these phases designers are able to provide the different means of communication. Many design contribution such as mock-ups, sketches, or prototypes can be used to address the stakeholders mentioned above

3. Methods and data collection

The design team engaged in an action research project (Andelman, 1993; O'Brien, 1998) with the aim to identify the contribution of design and design management to the incubation phase. The primary source of data collection was the collaboration between the design research team and six high-tech start-ups, which were nominated for the collaboration by the ieLab. Another source, mainly for data analysis, was a detailed documentation and reflection on phenomena that occurred during shared work. The design team documented these processes chronologically: The encounters – workshops and individual contacts – were protocolled using standardized observation categories, documenting the iterative design process over approximately one year per project.

The research project was structured in two phases: starting with a first batch of high-tech teams; in parallel understanding the needs of high-tech start-ups and developing a model to structure future cooperation. Models such as the critical framework mentioned above were developed inductively, based on first experiences with the collaboration with the engineering teams, and were tested during later stages of the project. This way, a more descriptive mode of research (insights emerging from reflections) was alternated with a more prescriptive one (using the insights to better structure collaboration). At the end of each project, projects were evaluated by interviewing the engineers on the perceived added value of the collaboration with the design team.

We here shortly introduce the six high-tech start-ups, listing them in a chronological order:

ANYbotics was developing a four-legged robot adapting to different walking grounds. The robot operates in different modes – autonomously, semi-autonomously, or totally remote-controlled. As a possible business case, the team identified the sale of robotic hardware including the motion intelligence and sensors. The design team developed a brand and corporate design including a logo, key visuals for a brochure as well as use scenarios such as the robot as fire fighter, mine sweeper, inspector of storage facilities or as part of the rescue team in the wake of an earthquake.

rqmicro developed a device to detect legionella in water samples. Nano-particles are used to separate these microorganisms magnetically allowing for counting them more rapidly and accurately than in existing lab procedures. This method facilitates monitoring the water quality in hotels, swimming pools, or sprinkler systems. In the collaboration with rqmicro, the design team developed product design prototypes, interfaces, information graphics and a corporate design, integrated in an overarching design concept.

The "Chairless Chair" by noonee is a posture support that can be attached to the backside of a factory worker's legs. It allows for a comfortable seating position reducing the strain on legs and knees, but unlike a chair, it walks with the person wearing it. The design team supported the start-up with their communication and corporate design, helped establishing a brand architecture and a customer experience strategy. An illustrated user manual was developed, and the product was made more self-explanatory with printed instructions on its surface.

Pregnolia was working on a medical device allowing gynaecologists to measure the stiffness of the cervix; this procedure predicts and prevents the risk of a premature delivery. The challenge consisted in designing for the doctor-patient relationship during the measurement. Imagery and a product visualization for presentations and pitches were designed, together with core messages, stories, key visuals, a logo with a slogan, and a web design.

CellSpring discovered a new technology to build spatial structures of biological cell cultures. The „3D Bloom“ technology allows cells to grow rapidly within in a three-dimensional scaffold resembling human tissue, and thus allows for good predictions in pharmaceutical studies. The design team clarified the brand architecture, developed a giveaway, a lab-kit consisting of packaging and functional elements, represented the product's value proposition with scientific illustrations and assisted the team in designing exhibition posters.

The technology of TapTools measures the elasticity of any material, allowing for the identification of different types of materials but also potential defects. While this technology can be used with a wide range of materials and industries, the team concentrated on the analysis of concrete. The design team iterated a series of low-fidelity prototypes and early product visualizations, resulting in a sophisticated vision of a user-friendly product. The information flow from the handheld to other devices was drafted. In parallel, a brand persona and a corporate design was developed as well as a slide presentation and other communication products.

4. Data Analysis

For the purpose of data analysis, the "start-up stakeholder journey" (see Table 1.) is extended by the category of "exemplary evidence". This allows for the mapping of individual design outputs of the six high-tech start-ups onto the phases of awareness, interest, commitment, and buy-in. "Exemplary evidence" qualifies for a specific event, through which a start-up succeeds in connecting to its stakeholders and in accessing network resources in a significant way. To map evidence in such a way also allows for a more comprehensive understanding of how start-ups are able or unable to attract network resources.

This method, however, does not measure quantifiable impacts of the collaborations but rather describes qualitative effects such as the change in perception of stakeholders with respect to a specific start-up. That is why in most cases we will use the testimony of the start-ups itself on how design affected stakeholder's reactions to support our claims. Design contributions cannot claim to be the sole reason for making a step forward on the journey. It is the business idea that is the most important asset in attracting network resources.

Table 2. Critical framework to assess the success of the start-up stakeholder journey

Phase	Raise awareness	Awaken interest	Build commitment	Create buy-in
Network resource	Organisational reputation	Organisational reputation Financial contributions	Financial contributions Market access	Market access
Success indicators	Positive response of opinion leaders, incumbent firms. Press articles	Contacts to potential partners, angels or investors	Seed Money, Awards Investment	Product launch, first clients, business partnerships

Exemplary Evidence	CellSpring: attracts responses with trade booth	TapTools: design enables industry contacts	Pregnolia: “Falling Walls Young Innovator Prize” rqmicro: “Heuberger Winterthur Jungunternehmer Preis” noonee: design enables partnership with car manufacturer	rqmicro: functional prototype leads to product launch

4.1 Awareness Phase

The awareness phase intends to foster conversation with opinion leaders and strengthen organizational reputation. In the case of CellSpring, general awareness about the product, company, and key technology was increased. The design team supported the start-up with exhibition design at the Annual Meeting 2015 of the national competence centre for 3D cell cultures TEDD (Tissue Engineering for drug Development) through posters, a giveaway, and scientific illustrations highlighting the benefits of their biochemical technology. The team stated that their booth was the “best attended at the conference” and that even competitors reacted to their presentation. Visitors were convinced that “3D Bloom could be a solution for problems they are facing in the lab”. In the opinion of CellSpring the exhibition design was instrumental in improving on the organizational reputation of the start-up and making it known to a wider audience.

4.2 Interest phase

TapTool exemplifies how design can play a crucial role in the interest phase: A corporate design and a slide presentation as well as early product visualizations were developed at a stage, in which the start-up was not yet able to decide, which target market it was going to address. Nevertheless, the mentioned design assets proved instrumental in approaching partners in different industries resulting in TapTool’s decision, which market to target. The team specified that a professional company appearance had proven to be more effective in raising the interest of industry leaders than to address them as a research group.

4.3 Commitment phase

We found evidence that design contributions supported several start-up teams during the commitment phase. Pregnolia was awarded the Falling Walls Young Innovator Prize in 2015. A predominant criterion of the prize is, how feasible product implementation will be. The start-up confirmed that the product visualization had been instrumental in convincing the jury in awarding them the prize. Also rqmicro benefited from design contributions in winning the “Heuberger Winterthur Jungunternehmer-Preis“. A design prototype demonstrated the “look and feel” of the product as well as a user-friendly interface, thus presenting the technology as an actual product. Workers of the automotive industry tested noonee’s posture support. As future users, they played a important part in the purchase decision of their company. As noonee reported, during the first pilot study the manual instructions contributed to building users’ confidence in the device, which resulted in a subsequent industry test with the same manufacturer. Earning the worker’s trust was ultimately instrumental in moving towards commitment and buy-in of company decision-makers.

4.4 Buy-in phase

During our collaboration, rqmicro achieved a breakthrough with investors, some months after the design prototype was built. A second prototype was developed based on the first one that included more functional aspects of the technology. The engineers used these two prototypes as a basis for a manufacture-ready first series of devices, while continuously verifying with the design-team that the production remained faithful to the initial design. Investors were found and a small series of commercially available devices was produced and made available on the market.

5. Insights

The exemplary evidence demonstrates how design can make a contribution to all four phases of the stakeholder journey. In each phase, indicators point to achievements, which in some cases allowed start-ups to enter the subsequent phases. One start-up (ANYbotics), however, did not embark on the stakeholder journey at all. This team was focusing on fundamental research topics and did not have the same need to access network resources to further venture creation compared to the other start-ups.

Seen from a more generalizable perspective, most projects unfolded in a similar dynamic, entrepreneurial, and developmental process. During this process design and design management made a number of discernable contributions:

1. Zooming in on the market: Designer's ability to early on "humanize technology" (Buchanan, 2000) is essential to create human-centred product/service concepts or user scenarios based on innovative technology. The more ground-breaking the technology, the more translation and embodiment is needed to communicate the added value of an innovation through the product/service itself. At this stage, design zooms in on the market, the future user, and context of use. *By zooming in on the market, design complements engineering in a way to accelerate early stage product/service development and venture creation.*
2. Creating a new venture identity: During incubation phase, members of universities make a transition from researchers to entrepreneurs intent on capitalizing on their inventions. The process of building a corporate identity for the start-up can be professionalised by design approaches such as visualisation or corporate design. *Designers will use "mythos" to intuit the brand in the making and add emotional (and not purely cognitive) value to it, which in return will have the effect of drawing the market closer.*
3. Using design management to orchestrate start-up touch points: This step consists in orchestrating core messages at each touch point and in strategically creating means of communication for the stakeholders along the phases of awareness, interest, commitment and buy-in. An integrated approach to the market builds up the *power of persuasion and creates a self-fulfilling prophecy of things to come.* Business angels and the investors rely on good business planning but will also use 'affect heuristics" (Aspara, 2012) to decide whether they want to commit to a start-up or not.

6. Conclusions

The above-mentioned generalizable insights summarise the added value and effects of design and design management to the incubation phase of high-tech start-ups. The four phases do not have to

be gone through chronologically; at times, a team may have operated in different phases at the same time. However, the model can support engineers and designers to be aware of where a team stands and concentrate its efforts on the phases, in which a design contribution is able to make the biggest impact. Another conclusion from working with the framework is that design contributions may be helpful, even if not directly aimed at the final product or brand. Design contributions during incubation phase may have a temporary purpose, e.g. in finding the necessary network resources or helping with other communication efforts. At an early stage, designers and design managers will have to design and to strategize for unknown and often hypothetical markets. Under these circumstances, designers have to refrain from having a perfectly stable product or service in mind, but need to be open to contribute to the "unperfected".

In this project, the collaboration between designers/design managers and engineers was possible because of research funding. So the setting was somewhat artificial because in the "Valley of Death" usually no seed money exists to fund collaboration. In addition, this project is a snap shot view of six high-tech start-ups; the design research team had no opportunity to systematically enquire on how the start-ups developed, and whether design is still being used or not. In one case a start-up (TapTools) gave up after our time of collaboration, despite the fact that they were able to access network resources during awareness and interest phase of the stakeholder journey.

This project was a first step in exploring the contributions of design and design management during incubation phase. In future research, other forms of measurement could be developed to quantify the effects of design and design management contributions.

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