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Between a Soft Landing and a Hard Place: How Silicon Valley Software and Life Sciences Incubators Facilitate Lower and Higher Order Learning

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Abstract

Although incubators increasingly focus on facilitating the learning process of knowledge intensive start-ups, few efforts have been made to apply theories of Organizational Learning in the context of incubation. This paper qualitatively explores how incubation practices are associated with lower and higher order learning for different types of knowledge, and how the use of these practices differs across industries. Data consists primarily of 69 interviews with incubator managers and entrepreneurs in Silicon Valley?s most successful software and life sciences incubators. We show that incubators facilitate lower order learning through a variety of practices, whereas only mentoring and networks with customers and investors contribute to the start-up?s ability to engage in higher order learning. We find that incubators in both industries facilitate both forms of learning, but that the balance depends on the start-up?s level of structural inertia. Whereas the flexible software start-ups emphasize a process of improvisation and higher order learning, we find the relatively inert life sciences start-ups to primarily rely on careful preparation and optimization of existing practices through lower order learning. Our study contributes to incubator literature by exploring how incubators facilitate learning and by explaining cross industry differences among incubators. Our study also contributes to literature on Organizational Learning by outlining structural inertia as a multidimensional concept and by exploring its influence on the ability of organizations to engage in higher order learning.

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1 Introduction

Although technology-based start-ups can play an important role in modern economies, empirical studies show that most of these start-ups fail or remain small (Bartelsman 2005; Santarelli and Vivarelli 2007; Shepherd et al. 2000). To explain their failure, scholars increasingly point at the inability of start-ups to learn, as they are unable to develop the expertise necessary to transform their technological ideas into viable businesses (Blank 2013; Politis 2005; St-Jean and Audet 2012).

To achieve effective learning and long term success, theories of Organizational Learning (OL) argue that start-ups need to balance lower and higher order learning (Argyris and Schön 1978; Fiol and Lyles 1985; Senge 1990). Lower order learning is a process of incremental change. It is associated with optimizing and extending existing capabilities and leads to greater efficiency. However, relying exclusively on lower order learning limits creativity and flexibility (Spicer and Sadler-Smith, 2006). Therefore, start-ups may also engage in higher order learning, which is associated with revolutionary change. It challenges the start-up's underlying values and leads to search for radical new knowledge. Too much higher order learning constraints the start-up's ability to optimize capabilities and capture their benefits (Espedal 2008; Nicholls-Nixon et al. 2000). Accordingly, a balance between both forms of learning is required. Maintaining such a balance is not easy, as both forms of learning compete for the same scarce resources, especially in start-ups, whose resource base is still incomplete.

In light of these challenges, incubators, which have become a prominent instrument to stimulate technology-based start-ups, increasingly focus on helping start-ups to learn (Bruneel et al. 2012; Grimaldi and Grandi 2005; Miller and Bound 2011). Incubators can do so by providing access to different forms of knowledge, such as knowledge about developing technological products, knowledge about customer needs or knowledge about managing a business (Scillitoe and Chakrabarti 2010; D. M. Sullivan and Marvel 2011; Warren et al. 2009). Incubators can transfer knowledge through a variety of practices, for example by providing mentorship, by encouraging peer-to-peer learning, by organizing workshops or by providing access to a comprehensive support network (Bøllingtoft and Ulhøi 2005; Hansen et al. 2000; Rice 2002).

Despite the importance and potential of incubators to facilitate learning, the application of learning theories within the context of incubation has been remarkably sparse. Traditionally, scholars of OL have focused on established organizations, while start-ups remain an underexposed subject (Franco and Haase 2009; Wang and Chugh 2014). Meanwhile, incubator studies have favored theories such as the resource-based view and social network theory (Ahmad and Ingle 2013; Rothaermel et al. 2007). Although some recent efforts have been made to study incubators by applying learning theories (see e.g. Patton & Marlow, 2011; Lefebvre, 2013; Warren et al., 2009), the concepts of lower and higher order learning have remained unexplored. Therefore, it remains unclear how incubation practices relate to lower and higher order learning, which limits our understanding of how incubators facilitate the start-up's learning process and, ultimately, help to create more successful start-ups.

Existing studies on learning in incubators have also not yet conducted a comparison between industries. However, start-ups in different industries require different forms of knowledge. For example, providing specialized technological knowledge may be particularly relevant for incubators supporting start-ups in high-tech industries such as life sciences (Hine and Kapeleris 2006; Tidd et al. 2001). Further, start-ups in capital intensive industries may be hesitant to engage in higher order learning due to structural inertia created by sunk costs and extensive product life cycles (Hannan and Freeman 1984). These arguments suggest that incubators need to facilitate different forms of learning, depending on their industry focus. Consequently, applying concepts of lower and higher order learning in the context of incubation may help to explain cross industry differences.

Therefore, our paper answers the following research question: *"how are incubation practices associated with lower or higher order learning for different types of knowledge, and how does the use of these practices differ across industries?"* Empirically, we conducted a qualitative multi-case study in which we studied software and life sciences incubators and start-ups in Silicon Valley. We selected this region because it has the most mature and developed incubators (Aernoudt 2004; Chandra and Fealey 2009), which enabled us to identify the appropriate mix of lower and higher order learning. Comparing software to the capital intensive life sciences industry enabled us to explore how inertia influences the balance between higher and lower order learning.

The theoretical relevance of our paper is twofold. We add to incubator literature by describing the learning processes in incubators in more detail, by showing that incubators can also inhibit learning and by explaining industry differences among incubators. We also add to literature on OL by emphasizing the role of support organizations (such as incubators) as triggers for higher order learning, and by exploring the influence of structural inertia on the willingness and ability of organizations to engage in higher order learning. Practically, our study can serve as a guideline for incubators and policy makers to develop better ways to accelerate the learning processes of start-ups. In the remainder of this paper, we first outline our theoretical framework, followed by the methods section. We then present the results, after which we provide a brief discussion and conclusion.

2 Theory

In this section we start by providing an overview of OL and by discussing its most important concepts in the context of start-ups. We then explore the influence of industry characteristics on OL, and we discuss some of the characteristics of the software (SW) and life sciences (LS) industries.

2.1 Organizational Learning

Organizational Learning studies how organizations acquire, distribute and store new knowledge (Huber 1991; Levitt and March 1988; Walsh and Ungson 1991). Research on OL expanded rapidly in the 1990s and this led to a great diversity in definitions, methods and concepts (Easterby-Smith and Lyles 2003; Franco and Haase 2009). We focus on one of the most important classifications in OL literature, the distinction between lower and higher order learning (Chiva et al. 2010), in the context of incubators. These incubators can facilitate learning in different ways. For example, sessions with the incubator manager or external mentors enable start-ups to learn from experienced entrepreneurs. These sessions also help start-ups to create new knowledge through reflective activity, as mentors and entrepreneurs jointly evaluate the start-up's progress and experiences (Radu Lefebvre and Redien-Collot 2013; R. Sullivan 2000). Incubators also enable start-ups to learn from each other, as co-location

in the incubator facilitates the exchange of knowledge between start-ups (Hughes et al. 2007). 'Networked' incubators can have a catalytic function in connecting start-ups to an external network of investors, service providers and universities (Hansen et al. 2000). When learning from external sources, incubator managers enable start-ups to filter, integrate and make sense of the newly acquired knowledge, thereby further contributing to the creation of a solid knowledge base (D. Patton 2013; Dean Patton and Marlow 2011). We now explore learning processes and types of knowledge in more detail.

2.1.2 Lower order and higher order learning

Although different terminologies are used to distinguish between lower and higher order learning, such as lower level and higher level learning (Fiol and Lyles 1985), single loop and double loop learning (Argyris and Schön 1978) and adaptive and generative learning (Senge 1990), their characteristics are very similar (Chiva et al. 2010; Cope 2003; Wang and Chugh 2014). Lower order learning refers to reinforcement of existing knowledge, routines and capabilities and may be no more than optimizing practices through repetition (Espedal 2008; Fiol and Lyles 1985). It is associated with ad - hoc problem solving, as its aims to correct a particular aspect of the organization (Chiva et al. 2010; Fiol and Lyles 1985). Lower order learning leads to practical, certain and immediate outcomes and is a relatively conservative process of incremental improvement that aims for efficient operation. Examples of lower order learning are optimizing existing products or institutionalizing formal rules (Fiol and Lyles 1985). Higher order learning is associated with radical change, as organizations move away from long held practices, routines and capabilities (Spicer and Sadler-Smith 2006). Examples of higher order learning are the introduction of radically different technologies or the development of a new organizational culture (Fiol and Lyles 1985; Ven and Polley 1992). The distinguishing element of higher order learning is that it challenges and redefines the organization's 'frames of reference' (Fiol and Lyles 1985; Huber 1991). These frames of reference reflect implicit and explicit assumptions and beliefs about the organization, its goals and its environment, and they serve as the basis for making decisions (Fiol and Lyles 1985; Nicholls-Nixon et al. 2000). Higher order learning occurs when organizations realize that existing frames of reference no longer adequately meet the needs of the environment. Because these frames are deeply ingrained within organizations, some sort of 'shock', 'jolt', or 'crisis' is necessary before organizations start questioning and changing them (Cope 2003; Fiol and Lyles 1985). Higher order learning thereby not only involves the creation of new practices, but also the 'unlearning' of old ones. Compared to lower order learning, the outcomes of higher order learning are more widely applicable, as it aims to create 'a new way of looking at the world', rather than a particular behavioral outcome (Senge 1990). However, as the outcomes of higher order learning are distant from the organization's current state, they are unknown and uncertain. Therefore, higher order learning is a risky process (Spicer and Sadler-Smith 2006; Van Rijnsoever et al. 2012).

2.1.3 Technological, market and business knowledge

The goal of technology-based start-ups is to bring a new product or technology to the market through the establishment of a new organization (Bhave 1994; Vohora et al. 2004). In the process of doing so, start-ups need to develop different forms of knowledge. A common distinction is made between technological knowledge (or product knowledge) and market knowledge (Burgers et al. 2008; Scillitoe and Chakrabarti 2010; D. M. Sullivan and Marvel 2011). Technological knowledge refers to knowledge associated with technologies, products or processes. It includes knowledge about product design, manufacturing and optimization. Market knowledge refers to knowledge about what customers need

and how markets operate. It includes knowledge about potential customers' problems and preferences, as well as knowledge about market size, distribution channels, pricing and entry barriers (such as competition and regulations). In addition to technological and market knowledge, start-ups need to develop business knowledge, which is also referred to as 'organizational knowledge' or 'managerial knowledge' (Barbero et al. 2013; Becker and Gassmann 2006; Vohora et al. 2004). Business knowledge refers to knowledge about how to start, manage and grow a business and includes knowledge on hiring employees, raising capital, defining a business plan and drawing contract. Together, the start-up's technological, market and business knowledge create a particular 'technology-market-business configuration'. The immaturity of start-ups means that they are still searching for a 'technology-market-business fit'; a situation in which they formulated a proposition that is technologically feasible, commercially viable and organizationally executable (Blank, 2013; Nicholls-Nixon et al., 2000). Using this concept, lower order learning occurs when start-ups optimize an existing technology market business configuration. Higher order learning occurs when start-ups question their existing technology market business configuration and explore new ones. Because start-ups are still in search for a technology market business fit, they often find that their initial assumptions are incorrect, as their plans turn out to be technologically unfeasible or commercially unviable (Blank 2013; Nicholls-Nixon et al. 2000). Accordingly, start-ups engage relatively often in higher order learning (Wang and Chugh 2014).

2.2 The role of industry characteristics

The need and ability of start-ups to engage in lower and higher order learning differs across industries, which may affect the role of the incubator. Environments that are relatively stable favor efficiency through the optimization of existing practices and, thus, lower order learning (Garg et al. 2003; Gupta et al. 2006; Uotila and Maula 2009). In contrast, rapidly changing environments require the ability of organizations to adapt through higher order learning (Hannan and Freeman 1977; Van Rijnsoever et al. 2012). An organization's ability to engage in higher order learning may be constrained by factors that create 'structural inertia', such as sunk costs, standard procedures or commitments to external organizations (Hannan and Freeman 1984). Both the rate of change and the level of structural inertia are likely to differ across industries; to capture these influences we study incubators in two different technology-based industries.

As an example of an industry with flexible start-ups, we study the software (SW) industry. This is an example of an industry in which the competitive advantage of firms lies primarily in their ability to identify and respond to user needs (Ethiraj et al. 2005; Tidd et al. 2001). Recent developments such as cloud computing, open source software and the emergence of mobile app stores have led to a decrease in the costs required to start a SW start-up and enable start-ups to scale rapidly and deliver fast returns (Miller and Bound 2011; Siegele 2014). These developments enable SW start-ups to rapidly and cheaply experiment with different products or markets (Kerr et al. 2014), which means that the costs and risks associated with higher order learning are relatively low. We therefore expect SW start-ups to engage in this form of learning relatively often.

As an example of an industry with relatively inert start-ups, we study start-ups and incubators in the life sciences (LS) industry, which consists of biotechnology, pharmaceutical and medical devices firms (Pricewaterhousecoopers 2013). This is a high-tech industry in which the competitive advantage of firms lies in their ability to exploit and advance (basic) science and develop technically related products

(Pavitt 1984; Pla-Barber and Alegre 2007). Capital requirements are high and product life cycles are long: it has been estimated that it takes 15 years and 1 billion dollar to develop a drug and bring it to the market (Hine and Kapeleris 2006; Pisano 2006). These factors make LS start-ups more inert than SW start-ups. The technological complexity of the LS industry makes it unlikely that start-ups are able to develop all necessary technological knowledge in-house. They are therefore more likely to partner with universities, research laboratories or established pharmaceutical companies (Laursen and Salter 2004; Powell et al. 1996), which may further limit their flexibility. Finally, the strict regulations of the LS market (especially compared to the unregulated SW market) also contribute to the inertia of LS start-ups. Compared to SW start-ups, LS start-ups can therefore be expected to have a greater emphasis on lower order learning.

3 Methods

3.1 Research design and case description

To develop new theoretical insights on the learning processes of incubated start-ups, we conducted a qualitative comparative case study (Eisenhardt 1989). We collected data from the Silicon Valley area. This geographical region between San Jose and San Francisco, California, inhabits around 1 per cent of the US population, but is responsible for 12 per cent of US patents, and almost 50 per cent of US venture capital (PWC, 2014; Silicon Valley Index, 2014). Silicon Valley is arguably the most well-known and successful entrepreneurial ecosystem in the world and home to many successful start-ups and incubators in the SW and LS industries (Herrmann et al. 2012).

The SW industry is largest, and many established firms in the software industry are headquartered in the area, such as Facebook, Twitter and Google. Almost all of these firms began life as a Silicon Valley start-up. SW start-ups are still dominant in 'The Valley': in 2012, 36 percent (almost 4 billion dollar) of the region's venture capital was raised by start-ups in the SW industry (Pricewaterhousecoopers 2013). The LS industry is also well-represented in Silicon Valley. With the creation of Genentech in 1976, South San Francisco came known as 'the birthplace of biotech'. Many biotech and pharmaceutical companies have offices in this region, enabling them to be in close proximity to universities such as Stanford, UC Berkeley and UC San Francisco. The LS industry is the second largest start-up industry of Silicon Valley, raising 16% (1.8 billion dollar) of the region's venture capital in 2012 (Pricewaterhousecoopers 2013).

3.2 Sample and data collection

To identify the appropriate mix of lower and higher order learning, data collection was primarily collected from three successful incubators. Both entrepreneurs and investors regarded these incubators as the leading incubators in their industry, and the start-ups in each incubator had raised hundreds of millions of dollars in cumulative private funding. We therefore regard these three incubators as examples of successful incubators, and suitable cases to identify best practices. The differences between LS and SW industries result in different incubation models, but also within the same industry different models of incubation are used (Bruneel et al. 2012; Clarysse et al. 2005). Especially in the SW sector, the absence of regulations and large capital requirements provides more degrees of freedom in incubation models, and thus more variety. We attempted to capture this variety by primarily approaching entrepreneurs that were affiliated with two major SW incubators and the most prominent LS incubator. The first SW incubator in our sample was established in 2005, and had

supported over 500 new ventures so far. It operated with a for-profit 'accelerator' model[1], in which the incubator took a small share in the start-ups. This incubator did not offer shared office space, but had a strong focus on providing access to networks and mentorship. A small group of incubator managers provided the start-ups with advice. The second SW incubator was founded in 2010, and operated with a similar model. However, entrepreneurs were not guided by incubator management, but by a large network of external 'mentors'. This incubator did provide shared office space, although co-location in the incubator was not a requirement. The LS incubator was established in 2000 by local universities and governments. It charged tenants for renting the incubator space and using its services and facilities. In addition to the physical facilities, start-ups were provided with various support services similar to those provided by the SW incubators, such as mentorship, a support network, peer-to-peer networking, etc. The life sciences incubator housed a broad range of LS start-ups, ranging from biotech firms to start-ups developing medical devices and diagnostics platforms. The incubator was the largest LS incubator in the area, and consisted of four different facilities that were managed independently from each other. We also interviewed some LS entrepreneurs and incubators outside the LS incubator, which operated with very similar models. Therefore we consider the LS incubator in our sample to be representative for LS incubators within Silicon Valley. The LS and SW incubators supported start-ups in a similar stage of development. Most incubated start-ups were still young, typically without public funding and no or few paying customers.

The first author visited the area between February and July 2013. The second author joined for 7 days to assist in data collection, to discuss findings and to adjust the data collection where necessary. This ensured an open view and increased the reliability of the research. The interviews were the main data source, but were augmented with informal conversations and notes taken from attending meetings, events and workshops, and with written documents such as e-mail conversations, policy documents, personal weblogs, and mission statements. The interviewees were initially identified for an interview through the incubators they were affiliated with. In addition, we asked respondents after the interview to recommend other entrepreneurs or stakeholders from their incubator who they felt could provide further insights. A total of 117 interviewees were approached for an interview, out of which 71 agreed to participate. A total of 69 interviews was conducted (2 interviews were conducted with two founders at once). We interviewed 27 SW entrepreneurs and 31 LS entrepreneurs. Founders of LS start-ups were typically higher educated: 30 out of 31 LS entrepreneurs had a PhD degree, compared to only 6 out of 27 for SW entrepreneurs. LS entrepreneurs were also older on average (38.8 years compared to 28.4 for SW entrepreneurs). Most of the entrepreneurs in our sample had a technological background (80 per cent) and lacked entrepreneurial experience (66 per cent were first time entrepreneurs when they joined the incubator). We also interviewed other key stakeholders in the start-up ecosystem, such as incubator managers, investors or technology transfer officers. Finally, we conducted a number of interviews with entrepreneurs who were not incubated, to explore potential contrasts with more traditional ways learning. These interviewees were approached at the meetings and events. A detailed breakdown of the response by sector is given in table 1.

[1] Some scholars refer to the latest generation of SW incubators as 'accelerators', to distinguish them from the traditional, real estate oriented incubators (Miller and Bound 2011). However, there is no generally accepted definition of incubators and accelerators, the differences between them are unclear, and the two concepts overlap (Bosma and Stam, 2012). As we do not aim to create a typology of incubators / accelerators, we will only use the term 'incubator' throughout the rest of this paper.

Industry	Interviews
Life sciences	4 incubator representatives
	31 entrepreneurs
Software	3 Incubator representatives
	27 entrepreneurs
Other	1 investor
	1 TTO
	2 Entrepreneurship professors

Table 1. Overview interviews

3.3 Interview scheme and data analysis

During the interviews, entrepreneurs were first asked to introduce themselves and their start-up. Entrepreneurs were then asked to discuss the support they received from the incubator. We then asked entrepreneurs to discuss key skills and insights they learned over time, and to identify actors who were important in their learning process. An important part of this interview phase was for entrepreneurs to describe the changes they made to the start-up's technological, market and business knowledge base, as well as the reasons for those changes. Incubators were asked to explain the incubator's background, history, goals and support provided. Incubators were then asked reflect on common mistakes made by entrepreneurs, and skills that they felt entrepreneurs needed to develop during the incubation process. The interviews took on average 50 minutes. All interviews were digitally recorded and fully transcribed within three days.

After every interview, the interview scheme was reviewed and adjusted if the interviews revealed important information and concepts that were not yet included. Data were collected until no new concepts emerged, which suggests that theoretical saturation was reached (Glaser and Strauss 1967). Data were coded and analyzed using NVivo, a qualitative data analysis software program that allows for a systematic analysis of unstructured qualitative data. Data was analyzed as follows. First, incubation practices were identified. We initially stayed close to the interviewees' own words, after which we categorized codes to identify four mutually exclusive incubation practices. Then, using our theoretical definitions, we labelled every learning event as lower or higher order learning, and also as technological, market or business knowledge. Table 2 provides examples of codes associated with different forms of learning and knowledge. In the final phase of data analysis, we associated every incubation practices with the various forms of learning and knowledge to understand the role of the incubator in the learning process of start-ups.

4 Findings

We begin this section by discussing the various incubation practices and how these practices differ for the LS and SW industry. We then discuss how incubators balance lower and higher order learning, and how this balance differs across the SW and LS industry

Definitions	**Technological knowledge** knowledge associated with products, technologies or processes	**Market knowledge** knowledge about what customers need and how markets operate	**Business knowledge** knowledge about how to start, manage and grow a business
Higher order learning Creating new knowledge while questioning and modifying the start-up's underlying norms, policies and objectives	Questioning existing technology or product and exploring new ones Example codes: - Switch ideas - Change underlying technology	Questioning existing market and exploring new ones Example codes: - Identify target market - Change customer	Questioning existing business practices and exploring new ones Example codes: - Change company culture - Change business model
Lower order learning Creating new knowledge without questioning the start-up's underlying norms, policies and objectives	Improving existing products and technologies Example codes: - Improve efficiency - Add features	Improve understanding of markets Example codes: - Learn about market barriers or competitors	Improving and extending business practices Example codes: - Learn accounting, marketing or fundraising

Table 2. Codes associated with different forms of learning and knowledge

4.1 Incubation practices

Table 3 provides an overview of the incubation practices. Before discussing the se practices, we note that incubators enabled start-ups to outsource many of their non-core activities by providing for example a pre-setup laboratory space, legal and accounting services, or grant writing support. Such outsourcing does not lead to the creation of new knowledge, and we therefore do not consider it as an incubation practice. However, incubators hereby indirectly facilitate the learning process, as they eliminate distractions and enable start-ups to focus on their business: *"For most founders, all the stuff one has to do to set up a startup is completely unfamiliar, and thus distracting. It's better if they can spend their time working on the company".* LS incubators in particular provided a wide range of in-house services. Consequently, and in contrast with SW entrepreneurs, LS entrepreneurs regarded the ability to outsource parts of their activities as a key component of the incubation process.

	Technological knowledge		Market knowledge		Business knowledge	
Incubation practices	Lower order	Higher order	Lower order	Higher order	Lower order	Higher order
1. Organizing trainings and seminars			**LS**			**X**
2. Facilitating a community	**X**		**X**		**X**	
3. Mentoring	**X**	**X**	**X**	**X**	**X**	**X**
4. Creating external network						
- Customers	**X**	**X**	**X**	**X**		**X**
- Investors		**X**	**X**	**X**		**LS**
- Universities	**X**	**LS**				
- Service providers (e.g. lawyers, accountants)					**X**	
- Technical consultants	**LS**					

Table 3. Incubation practices. X = practice observed for both LS and SW incubators, LS = LS only

4.1.1 Organizing seminars and trainings

Incubators organized seminars and training sessions; formal settings that were focused on teaching entrepreneurs specific skills under the supervision of a renowned expert. These seminars primarily focused on business-related topics such as fundraising, accounting or marketing. In addition, the LS incubator organized seminars on market-related topics, such as industry specific regulations. These topics were all labelled as lower order. Although some entrepreneurs welcomed the ability to quickly learn skills and gain insights from experts, attendance of these seminars was rather low: entrepreneurs felt that they were too busy, that the topics did not align with the start-up's particular needs, or that the skills and knowledge they needed *'cannot be learned from taking a class'*. Consequently, none of the interviewees regarded these seminars as a key component of the incubation process, and most entrepreneurs preferred to engage in a direct conversation with their peers or mentors, as this enabled them to have a more interactive discussion that was tailored to the start-up's particular situation and problems.

4.1.2 Facilitating a community

Start-ups can learn from their peers in the incubator's internal community as they develop knowledge by imitating each other and by exchanging knowledge. Incubators facilitated the creation of an entrepreneurial community by providing shared office space, online social platforms and social events. Consequently, entrepreneurs felt comfortable asking each other for help. Almost all entrepreneurs valued this learning practice, as it is an efficient way of learning: *"Most other companies have gone through a lot of the same stuff, so why re-do it yourself? Use what's already there, and save as much effort as possible"* By quickly consulting their peers, the incubator's community enabled start-ups to efficiently overcome a particular challenge, learn a specific skill, or access missing pieces of information. Accordingly, the entrepreneurial community was an important source for lower order learning. The interviews did not show that the community played a role in higher order learning processes, which was confirmed by one of the incubator managers: *"Entrepreneurs talk with each other more about the day-to-day business and struggles. What vendors do you use? How do you solve this particular technological issue? The more strategic mentoring and advice isn't something that people can extract from the entrepreneurial community".* Entrepreneurs used the community to exchange knowledge about technology, market and business related topics. Some interviewees felt that the potential for learning on market and technological topics was relatively limited, as these topics were more start-up specific. Further, although community interactions enable start-ups to quickly access missing knowledge, they may also distract and limit the ability of start-ups to develop knowledge in-house. One SW entrepreneur said: *"If I were to do it again. I would go in and thinking that I wouldn't get any work done on the product. It's mainly for the networking"*. Entrepreneurial communities played a similar role for LS and SW start-ups, as the aforementioned patterns were observed for both groups of start-ups. However, LS entrepreneurs were more reluctant to engage in the community. Start-up communities pose a threat of involuntary knowledge spillovers (Mcadam and Marlow 2007; van Weele et al. 2014). Given the prevalence of sensitive technological knowledge in the LS industry, several LS entrepreneurs emphasized that they were careful in exchanging knowledge, especially regarding technological topics.

4.1.3 Providing mentorship

Mentoring is a process in which an experienced veteran helps to shape or guide a newcomer (Brown 1990). For the incubators in our sample, mentorship was provided by the incubator manager or

external mentors, who were often experienced entrepreneurs or investors. Similar to the community, mentors enable entrepreneurs to efficiently learn from the mentor's experience, and we found mentor sessions to address a wide variety of lower order market, technology and business topics. In addition, we found mentors to play an active role in facilitating higher order learning. During mentor sessions that entrepreneurs described as 'tough' and 'stressful', mentors brought in a different perspective and aimed to make entrepreneurs think by asking critical questions: *"It's not that they tell you you're wrong, they'll ask you to quantify your answers. Push back. Sometimes you need somebody to not assume everything you say. That was very useful".* Mentors challenged the entrepreneur's ideas and goals; forcing entrepreneurs to explicate the assumptions underlying their start-up. Because of their successful entrepreneurial track record, mentors were seen to have the credibility to make entrepreneurs re-consider these assumptions, thereby triggering a process of higher-order learning. Doing so required mentors to have a deep understanding of the start-up's business (one entrepreneur said that mentors need to 'dig in'). Consequently, higher order learning did not occur during short and superficial interactions, but required intense, long or multiple mentor sessions. One of the entrepreneurs provided an example where a critical review from a mentor led to a completely different start-up: *"[The incubator manager] wasn't excited about our idea and had some very critical questions: 'of all the things you can do right now, you think this is the best you can do?' So afterwards we spent the entire afternoon brainstorming with the three of us, to see what needed to change (…) We eventually came up with an entirely different idea".* Early on, mentor sessions are focused on higher order learning, as start-ups were still in search for a technology market business fit. In later stages of the incubation process, mentor sessions tend to focus on lower order topics, for example on presenting the start-up to investors, optimizing the start-up's technology, or growing the start-up's user base. As all incubators in our sample facilitated the creation of mentor relationships, there were no strong differences between sectors for this practice.

Although many entrepreneurs found mentors to be of great value, there were also entrepreneurs who were skeptical of mentors for several reasons. Firstly, some entrepreneurs were concerned that the experience and knowledge of mentors was outdated; one LS entrepreneur said that *"a lot of the old business axioms don't really apply anymore"*. Secondly, mentorship may lead start-ups to acquire knowledge that is not applicable to their situation. Given that mentors and incubators work with a large number of start-ups, they are able to recognize patterns on best practices and common mistakes, and transfer this knowledge to start-ups. This can be an efficient way or learning; one of the interviewees said that mentors thereby provide a 'shortcut' to learning from the incubator's entire portfolio. However, mentors may constrain learning when these common patterns are not applicable to new start-ups. One of the entrepreneurs said the following about the mentor sessions: *"We are very different from everyone else in the program ... The advice was meant well, but sometimes it was not good advice. They were (…) applying things that worked with other people"*. In the SW incubators, mentors were often former participants in the program ('graduates'), creating a rather homogenous group of mentors. Consequently, interviewees said that different mentors gave similar advice, as they had a similar background and ideas about running a start-up. This creates risks of 'groupthink'. One of the entrepreneurs said that norms and values were so deeply ingrained in the incubator's practices that he referred to them as 'clichés', and another entrepreneur said that *"it might be good to get some other experience from outside the [incubator] network"*.

4.1.4 Creating external networks

Besides connecting start-ups to each other and to mentors, incubators also acted as a mediator in connecting start-ups to stakeholders outside the incubator, such as investors, customers or service providers. All incubators played a direct role in creating such networks as mentors associated with the incubator leveraged their personal network, as the incubator organized networking events, and as the incubators maintained partnerships with for example universities or corporations. Entrepreneurs unanimously welcomed the ability to connect to the incubator's network, and it was an important source for lower order learning, for example when start-ups consulted lawyers for legal advice or universities to answer specific technological questions: *"Whatever question you may have, whether it's something technological or operational, there's always someone who has dealt with that before"*.

The incubator's external network also triggered higher order learning. Customers were an important source for higher order learning, as start-ups reconsidered their target market, technology or strategy based on their feedback. Incubators connected start-ups to customers, and mentors actively encouraged start-ups to engage with customers. One of the SW entrepreneurs said the following about the incubator manager: *"He's always been emphasizing the whole customer development thing. Get out and talk to customers, launch early. 'If you're not embarrassed, you launched too late', that sort of philosophy"*. As such, start-ups were stimulated or even forced to reach out to customers and adapt accordingly: one incubator even had a formal requirement that every start-up should talk to at least 100 customers during their stay in the incubator. Whereas SW start-ups had a clear understanding of their customer (i.e. the end user of their product), LS start-ups identified multiple customers, such as the patient who uses the product, the doctor who prescribes the product, the FDA who needs to approve the product, etc. These various customer groups were all sources for higher order learning, and part of the incubator's network. A second, but more disputed, source of higher order learning were investors. Although entrepreneurs were skeptical of investors' expertise and motives (one of the entrepreneurs said that *'investors are either useless or dangerous'*), entrepreneurs also acknowledged that in order for the start-up to appeal to investors their feedback needed to be taken into consideration, and we found several higher order learning outcomes to be triggered by feedback from investors. The importance of customers and investors was one of the reasons why the SW incubators only provided a small amount of funding, just enough to cover the founders' living expenses during the duration of the incubator program. Providing small amounts of funding forced start-ups to seek out customer and investor feedback, and adapt accordingly. One of the incubator managers said: *"If you give too much money in the beginning, good founders can work on bad ideas for too long"*. For LS start-ups, we also found universities to be a potential source for higher order learning, for example when technological breakthroughs at universities made start-ups reconsider their underlying technology.

4.2 Balancing lower and higher order learning in different industries

The aforementioned practices enable start-ups to develop their technology market business configuration through a combination of lower order learning (for example by improving the performance of a product or by introducing new features based on customer feedback) and higher order learning (as start-ups experimented with different technology market business configurations). Each start-up described one or multiple iterations that could be categorized as higher order learning. Because start-ups are still searching for a technology market business fit, their ability to adapt through higher order learning was seen as key to their success, as one incubator manager illustrated: *"You need to be able to modify your dreams on the fly (…) Don't try to construct the future like a building, because*

your current blueprint is almost certainly mistaken". In line with our theoretical framework, we found crises (such as a failed clinical trial or the inability to find customers and raise venture capital) to provide the shock necessary to trigger higher order learning, as these crises made entrepreneurs willing to question and change the start-up's underlying assumptions. Also unexpected success, such as a technological breakthrough, could trigger higher order learning. Despite the importance of higher order learning, interviewees emphasized that balancing lower and higher order learning is important for start-ups to be successful, as one entrepreneur illustrated: *"Both sides can't be taken to the extreme. I've seen entrepreneurs be super driven on one direction, unwilling to hear anything. Those people seem like ignorant. But then there's the people who change constantly. And that's not practical either, because you never know what you're doing. You're in a constant mode of brainstorming"*.

In line with our theoretical expectations, the short development time and low requirements for equipment and financial capital made SW start-ups more flexible, as the costs for experimenting with different technology market business configurations are low. Therefore, SW start-ups relied on improvisation and were open to higher order learning, as the following SW entrepreneur illustrated: *"Think of something, but don't overanalyze it (…) Just start doing something, see what the feedback is, and be open to the fact that you could be wrong".* In contrast, the long development time, strict regulations, dependence on partners to develop the technology (e.g. universities, suppliers, pharmaceuticals) and sunk costs make LS start-ups inert. Further, the technological knowledge of LS start-ups is often the result of years of development in universities or pharmaceuticals, which makes LS entrepreneurs unwilling to engage in higher order technological learning (one of the interviewees said that LS entrepreneurs are 'emotionally attached' to their technology). Therefore, LS start-ups were more hesitant to engage in higher order learning and spend much time on preparation (for example by conducting extensive market and technological analyses) prior to creating a start-up and making the decision to go in a particular direction. An LS investor illustrated: *"A lot of it has to do with hypothesis setting (…) If you are investing in a biotechnology therapeutics company, you're kind of committing to a path"*.

These differences between SW and LS start-ups were reflected in the role of the incubator. SW incubators actively promoted an iterative development process of higher order learning: *"usually we advise start-ups to launch early and iterate".* In addition, SW incubators spent much time on idea generation, and eight SW start-ups in our sample abandoned their original idea to pursue a completely new idea (and, thus, a new start-up). In contrast, we found LS incubators to emphasize lower order learning (especially with regard to technological knowledge), aiming to increase the performance of the start-up's existing technology. One of the LS incubator managers said: *"It's about improving efficiency, or 'operational excellence'. It is an important reason why life science start-ups fail: they are not able to deliver their product in a (cost)efficient manner (…) So we try to help them with this".* Given that radical technological change was difficult, higher order learning in LS incubators was focused on helping LS start-ups find an application for their existing technology, by exploring different markets and business models. One LS entrepreneur said: *"We've looked at business plans that would cover anything from pharmaceuticals to fine chemicals, to novel materials and even bio fertilizers. But at the core of all those is a common set of technology that I think could drive all these businesses forward".*

The balance between lower and higher order learning also depends on the start-up's development stage. As organizations mature, they become more inert (Hannan and Freeman 1984). Consequently,

the early stages of incubation are focused on higher order learning by defining a technology market business fit, whereas the later stages of the incubator are focused on optimizing the start-up's existing technology market business configuration.

5 Discussion and conclusion

This paper aimed to explore how incubation practices relate to lower and higher order learning, and how the use of these practices differs across industries. We found that lower and higher order learning are two distinct processes that are facilitated in a different manner. All incubation practices facilitated lower order learning, as they enabled start-ups to rapidly learn specific skills or solve particular problems. In contrast, only mentoring and the incubator's external network (through interactions with customers and investors) were associated with higher order learning. Through these practices, the incubator created a high pressure environment that challenges the start-up's existing business and stimulates it to experiment with different technologies, markets and business models. Our results suggest that higher order learning is important, as every start-up in our sample engaged in higher order learning. However, too much higher order learning will likely be inefficient, as it constraints start-ups from creating a central direction. Accordingly, we conclude that both lower and higher order learning are necessary in the context of start-up support, and that incubators need to find a balance between facilitating these two forms of learning.

This balance depends on the industry context of start-ups and incubators. SW start-ups emphasized higher order learning, by doing little preparation, experimenting with various products or markets, and adapting their start-up to feedback from mentors, customers and investors. In contrast, the inertia of LS start-ups makes higher order learning risky and costly and favors careful preparation and optimization of existing practices. LS start-ups were particularly reluctant to engage in higher order technology learning, as the factors that create structural inertia (such as sunk costs, commitments to external organizations and personal motivations of the entrepreneur) are primarily related to their technology. The balance between lower and higher order learning was also found to be dependent on the start-up's development stage, as higher order learning is more difficult for mature start-ups that are more inert.

Although negative effects of incubators tend to remain unexplored in existing studies (Mcadam and Marlow 2007), we also found ways in which incubators may constrain the learning process of start-ups. Incubators may lead start-ups to acquire knowledge that is outdated or not applicable to their situation. In addition, incubators may lead to groupthink and distract entrepreneurs from developing knowledge in-house.

5.1 Limitations

Before deriving the implications of our study, some limitations need to be taken into account. First, data was collected exclusively in Silicon Valley. Taking risks and relying on trial and error learning is typical to the Silicon Valley culture, and was also actively promoted by the Silicon Valley SW incubators in our sample. Accordingly, one could argue that the iterative development process of higher order learning that we found for SW start-ups is only applicable to Silicon Valley and its incubators. However, interviews with SW startups that were not incubated suggested that they used a similar iterative development process, which is also in line with 'lean' and 'agile' development methods that have become increasingly popular in the SW industry (Dingsøyr et al. 2012). Therefore, we are confident

that the emphasis on higher order learning found for SW start-ups is typical to the SW industry in general. Still, we encourage further research on learning processes in incubators in other geographical regions. A second limitation of our study is its qualitative nature. This research design enabled us to understand how incubation practices are related with different forms of learning and knowledge, but did not allow us to analyze the relative importance of each practice or their impact on start-up success.

5.2 Implications

Our study contributes to incubator literature by providing deeper insights into how incubators facilitate learning and by explaining variation among incubators. Incubators supporting early stage, flexible start-ups should focus on facilitating higher order learning, whereas incubators supporting mature, inert start-ups should prioritize lower order learning. Although further research is necessary to quantitatively test these propositions and explore the tipping point, we suggest incubators to focus on supporting start-ups in a particular industry and in a particular stage of development.

Our study also adds to OL literature by applying some of its concepts in a context of new ventures and start-up support programs. In particular, we contribute to our understanding of the concepts of higher order learning and structural inertia. Regarding the triggers for higher order learning, prior studies have emphasized the importance of external change or 'shocks' (Dodgson 1993) and internal crises (Cope 2003; Fiol and Lyles 1985), but little efforts have been made to explore how higher order learning can be enhanced (Chiva et al. 2010). Our study points at the role of external organizations (such as incubators) as triggers for higher order learning. We thereby suggest that higher order learning can be facilitated. Our results also emphasize the constraining influence of structural inertia on the organization's ability to engage in higher order learning. Further organizations may be inert in a particular area, but flexible in another (such as the LS start-ups in our sample that were hesitant to change their technology but open to explore different markets). Structural inertia thereby not only influences the organization's ability to engage in higher order learning is feasible, but also the direction in which such learning takes place.

Our study also has important practical implications. The successful track record of Silicon Valley software incubators, such as Y Combinator, has inspired incubator managers and policy makers around the world to learn from their practices in efforts to create successful start-up support programs. In doing so, a key discussion is the extent to which these practices can be applied outside the SW industry (Miller and Bound 2011). Our study suggests that the potential to do so is limited, as the trial and error way of creating a start-up that is typical to SW incubators is unlikely to be successful in capital intensive industries. Consequently, we advise incubator managers and policy makers to be careful not to neglect the dynamics of specific industries when designing start-up support programs. Stimulating higher order learning requires incubators to create a high pressure environment that challenges the start-up's existing ideas and stimulates or forces start-ups to explore new businesses. To do so, incubators should have experienced and credible mentors, as well as a strong network of customers and investors. These are therefore key practices that should be well-developed. Further, incubators should not be too protective and let start-ups make mistakes, as these mistakes are important to make start-ups aware of the need to change and willing to engage in higher order learning. Accordingly, incubators should not be *too* protective. We therefore conclude that they should operate between providing a 'soft landing', by enabling start-ups to quickly access missing knowledge, and being a 'hard place' that challenges the start-up.

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