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Unpacking entrepreneurial learning: How prior related experience and uncertainty affect learning behaviors

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Abstract

This study provides insights into why new ventures adopt different learning behaviors when managing uncertainty associated with commercializing products, services or processes. The research builds on a comparative case-study methodology using 21 in-depth semi-structured interviews and company documents. The comparative analysis builds up to an overall understanding of how new ventures develop their learning behavior over three phases: (i) research and development, (ii) opportunity framing and reconfiguration, and (iii) organization. The study demonstrates that the *relatedness* of prior experience to the ventures' new context mediates how they judge and manage uncertainties, and thus the learning behaviors they pursue as a result.

Keywords: Entrepreneurial learning, innovation, prior related experience, uncertainty, learning behaviors

1. Introduction

Research in entrepreneurship has acknowledged the importance of learning for new ventures' development (El-Awad, Gabrielsson, & Politis, 2017; König, Ungerer, & Baltes, 2018; Soetanto, 2017). Through their learning, new ventures gain knowledge of customers and suppliers, and overcome obstacles when organizing (Voudouris, Dimitratos, & Salavou, 2011; Zhang, Macpherson, & Jones, 2006). However, there is little understanding of why new ventures adopt different learning behaviors.

This is a critical gap, because the early development phase is particularly uncertain requiring new ventures to make strategic choices about where to allocate their time, attention, and resources (Chang & Hughes, 2012; Ravasi & Turati, 2005). Over time, such choices may reinforce the way new ventures continue to learn and routinize behaviors (El-Awad et al., 2017). This paper explores this gap in four technology-based ventures, seeking to understand why these learning behaviors vary across the ventures.

Dominant research in entrepreneurship investigates learning in new ventures by exploring individual-level characteristics and behaviors (Deakins & Freel, 1998; Hughes, Hughes, & Morgan, 2007). For instance, some studies associate venture level learning with entrepreneurs' decision-making (De Massis, Minola, & Viviani, 2012). On the one hand, (Dencker, Gruber, & Shah, 2009) propose that venture managers' existing knowledge and experience improve the odds of survival by moderating the survival benefits of two types of learning: early-stage planning and product-line change. Other scholars, such as (Dimov, 2007) and (Dutta & Crossan, 2005), emphasize the role that entrepreneurs play in the discovery of opportunities, suggesting that they pursue opportunities intelligently and often build on prior knowledge and experience to exploit them.

These studies, among others, place great emphasis on learning at the individual level, but provide fewer insights into how new ventures develop their learning behaviors (El-Awad et al., 2017). New ventures need to routinize specific behaviors that will allow them to go on exploring and managing ill-defined problems (Brush, Greene, & Hart, 2001).

This study unpacks the learning behaviors of four technology-based ventures, demonstrating why they vary in the learning behaviors they adopt, and revealing the underlying factors that shape such behaviors. We identify three essential phases of development during which new ventures shape the way they learn and routinize behaviors: (i) research and development, (ii) opportunity framing and reconfiguration, and (iii) organization. By investigating these phases, we offer important contributions to the entrepreneurial learning literature. First, we provide an understanding of how learning behaviors begin to occur at different phases of the new venture's development trajectory. We also illuminate the triggers that underlie and shape these behaviors during these phases. Second, we integrate concepts from the literature on uncertainty (Milliken, 1987), revealing how it shapes learning behaviors in new ventures. Third, we integrate the role of prior related experience,

demonstrating how it provides context and focus for venture members' patterns of thought and action, which in turn determine how new ventures judge uncertainty and in turn shape their learn and routinize behaviors over time.

The remainder of the paper proceeds as follows. In the next section, we present the distinctive features of learning in an entrepreneurial context. We then outline the research methodology, outlining our research setting, data collection methods, and analysis. We present the findings and discuss them in relation to a body of entrepreneurial learning literature, before modeling the aforementioned three development phases, explaining how learning behaviors evolve over these phases. We close with implications for theory and practice.

2. Entrepreneurial learning and uncertainty

Entrepreneurship is commonly regarded as a process that incorporates the transformation of resources into new innovations that are manifested in the form of products, services or processes (see McGrath, 1999). Whereas entrepreneurship is typically seen as a good thing, it often comes with various uncertainties (O'Connor & Rice, 2013; (McKelvie, Haynie, & Gustavsson, 2011). Every potentially fruitful opportunity brings some uncertainty, generally related to the commercial application of technologies (Meijer, Hekkert, & Koppenjan, 2007). For instance, ventures involved in the development of a new technology typically foresee uncertainty in how users will come to regard the benefits of that technology. Ventures might also foresee uncertainty related to public policies, market trends, or advances in technology imposed by competitors or component suppliers (Aldrich & Fiol, 1994).

Uncertainty takes the form of doubt, which typically prevents or delays a prospective actor from taking action (S. Shane & Venkataraman, 2000). Milliken (1987) defines uncertainty as "an individual's inability to predict something accurately" This idea illuminates the way individuals organize and evaluate stimuli from the environment (Meijer et al., 2007; Weick, 1995).

Entrepreneurs are typically discussed as individuals "who specialize in taking the responsibility for and making judgmental decisions that affect the location, the form, and the use of goods, resources, or institutions" (Hébert & Link, 1989, p. 155). By using their judgment, entrepreneurs evaluate and anticipate possible events, and use their reasoning to decide whether or not to engage in a specific course of action. "Action," therefore, refers to a behavior that takes place in response to judgment made under uncertainty (McMullen & Shepherd, 2006). Due to their different judgments, entrepreneurs are expected to vary in their management of uncertainty. Hence, the judgement of uncertainty is *subjective*, meaning different things to different individuals.

Research in entrepreneurship illustrates that the way individuals judge uncertainty can be largely shaped by their prior experiences (Shepherd, Douglas, & Shanley, 2000; Stinchcombe & March, 1965). For instance, scholars illuminate how previous start-up experience can make entrepreneurs better at dealing with novel or ill-defined business concepts (Westhead, Ucbasaran, & Wright, 2005). Moreover, experience is shown to influence entrepreneurs' reasoning and management of uncertainty. For instance, Sarasvathy (2001) argues that experienced entrepreneurs tend to be *effectual* thinkers. They favor experimental learning, which reinforces trial and error. They take smaller steps as they explore opportunities, thus minimizing their investment and potential losses. Similarly, Sommer, Loch, and Dong (2009), argue that trial and error learning is a common strategy for managing uncertainty. Through trial and error, ventures can actively seek for new information and flexibly adjust activities and targets to this new information, applying new and original problem solving. This type of flexible adjustment to unforeseen changes has informed various technological breakthroughs. Examples include Apple and HP's personal digital assistance, Motorola's pager, and Corning's fiber optics (see Chew et al. 1991).

Conversely, less experienced entrepreneurs tend to be more *causal* thinkers; that is, they favor planning and exploiting what is already known, and are therefore averse to risk. Hence, experience is argued to have a positive effect on how individuals judge uncertainty, and their resultant actions (Politis, 2008).

While uncertainty and experience are mainly discussed with respect to individuals' entrepreneurial actions and behaviors (McKelvie et al., 2011; McMullen & Shepherd, 2006), we have fewer insights into how the interplay between experience and uncertainty can play out at the venture level. Research in entrepreneurship has long acknowledged that in order for new ventures to sustain long-term development and survival, they need to strike a balance between learning behaviors that emphasize exploitation and exploration (Holmqvist, 2004; March, 1991).

March (1991) distinguishes between two types of learning behaviors: exploration and exploitation. By supporting exploitation, new ventures can reinforce existing experience and focus on incremental enhancements to their technology. Through exploration, they can reinforce new experiences and pursue activities that generate variety and novelty. However, because new ventures hold only limited resources at early stages of their development, they must choose between the two. The literature emphasizes conflicting task demands and company-design requirements to explain how organizations choose between exploitation and exploration (Chang & Hughes, 2012; Tushman & O'Reilly III, 1996). However, we know less about how these choices are determined by the learning behaviors that venture members routinize over time. In this paper, these choices appear to be partly shaped by the interplay between prior experience available to the venture and the judgement they enact on uncertainty.

Whereas experience is typically discussed with respect to individuals (e.g., Politis, 2005), in this paper we consider the experience available to the venture. Venture-level experience, however, is not reduced to the *sum* of individual-level experiences, but rather the *coordination* of those experiences. Similarly, we take a collective view of uncertainty, suggesting that the way new ventures manage uncertainty cannot be reduced to individual-level judgements, but must be considered through the collective view that venture members take of uncertainty.

3. Methodology

This paper adopts a comparative case study approach, focusing on the learning behaviors of four technology-based ventures: Sprintech, Swetech, Systech, and Biotech (all pseudonyms). The primary sources of data were semi-structured interviews and company documents. We conducted twenty-one face-to-face interviews with the main founders and other members of the ventures from March 2018 to December 2018. Interviews were divided into three phases. Phase one (March–April 2018) was designed to generate an overall understanding of the business, detailing the different phases of technology development, the number of patents filed, and the functional background of the venture members. Interviews at this phase were informed by the key partner(s). This was necessary to better understand the history of the ventures, and to gain insights about the invention and its development. Phase two (May–August 2018) aimed at developing an in-depth understanding of the various events, patterns, and processes related to the development and commercialization of each firm’s technology. This included understanding external collaborations, the challenges facing the ventures, and how venture members collectively perceive and manage such challenges. In phase two, therefore, it was necessary to interview people engaged in day-to-day tasks, such as engineers and business people. In phase three (September–December 2018), interview questions were designed to capture the learning behaviors adopted by each venture. Moreover, this phase aimed to capture how each of the studied ventures engaged in events and activities related to the technical and commercial development of their technology. As such, it was necessary to talk to people who are responsible for the strategic direction of the venture. These people included major partners, partner engineers or business development managers.

We used company documents in both soft and physical formats, including company websites, product sheets, and PowerPoint presentations. Company websites supported a better understanding of the ventures, their activities, their presence in the market, and their marketing messages. Product sheets, meanwhile, were used to track the ongoing development of the ventures’ technologies, and the new features integrated over time. Finally, PowerPoint presentations provided an overall view of how ventures pitched their ideas to customers or suppliers, and what

focus they brought forward to the market. Table 1 lists the four case companies, our interviewees at each firm, and their respective backgrounds and roles.

Documents as a supplementary source of data provided an official ongoing record of the ventures' activities. They also corroborated what had been discussed during interviews, and pointed to possible questions that needed further elaboration.

Table 1:
Summary of interviewees

Case	Participants	Background	Role	Phase one (March-April 2018)	Phase two (May-Aug 2018)	Phase three (Sept-Dec 2018)
Sprintech	Participant A	Electrical engineering	Partner, COO	Participant A	Participant A	Participant A
	Participant B	Business and engineering	CEO	Participant B		
	Participant C	Water engineering	Partner		Participant C	
	Participant D	Water engineering	Partner			Participant D
	Participant E	Business	Financial officer		Participant E	
Swetech	Participant A	Entrepreneurship	Partner, CEO	Participant A		Participant A
	Participant B	Water engineering	Partner			Participant B
	Participant C	Finance, sales	CFO		Participant C	
	Participant D	Engineering	Technician		Participant D	
Systech	Participant A	Plastic manufacturing	Partner, CEO	Participant A		Participant A
	Participant B	Plastic manufacturing	Partner		Participant B	
	Participant C	Engineering	Partner			Participant C
	Participant D	Engineering	Technical developer		Participant D	
Biotech	Participant A	Entrepreneurship	Partner	Participant A		
	Participant B	Industrial engineering	Partner		Participant B	
	Participant C	Business, marketing	Marketing officer		Participant C	
	Participant D	Business, economics	Business development manager			Participant D

Research context and case selection

All four ventures studied operated in the water innovation sector. Innovation in this sector is critical, given the burning challenges associated with the availability of water supplies, aging infrastructure, and water quality (Gabrielsson, Politis, Persson, & Kronholm, 2018). These challenges require ventures operating in this sector to continuously bring actionable knowledge to commercialize new

technologies into products, processes, and services (Audretsch, Segarra, & Teruel, 2014). The study drew from an initial pool of cases from the Water Innovation Network (WIN), which offers members faster access to the market and provides coaching and early feedback on business ideas. Initially, all WIN members were screened against three criteria: (i) age (3–5 years), (ii) complexity of technology (filed at least one patent since their inception), and (iii) environment (all operating within the same industry, to ensure that they were operating under similar market dynamics). Subsequent to this screening process, six ventures met the criteria, four of which agreed to participate in the research (see Table 2).

Table 2.
Case Description

Name	Founded	Patent(s)	Size	Technology and innovation process
Sprintech	2013	An LED system patent filed in 2013 in addition to a product patent filed in 2014. New patents in the pipeline.	Five members	Based in Sweden, Sprintech uses UVC LED technology to disinfect water and remove bacteria. The venture is actively selling its commercialized technology in Sweden and Africa. It is also active in exploring new applications.
Swetech	2015	Design patent filed in 2014 for filtering storm water. New patents in the pipeline.	Four members	Based in Sweden, Swetech develops filters that purify storm water, which requires knowledge of snapping (cutting and molding) filters to accommodate different absorbent material to filter a wide range of harmful substances. The venture is actively selling its filters in Sweden, Poland, and South Korea.
Systech	2014	Patent for electrified pipes, filed in 2009.	Four members	Based in Sweden, Systech develops electrified pipes that prevent the growth of bacteria and biofilm on internal surfaces. The technology requires knowledge of the optimum level of electricity needed to increase biofilm kill rate. Systech exploits alliances to gain access to complementary knowledge and assets that support existing knowledge domains.
Biotech	2015	Patent covering water disinfection using Ozone, filed in 2016.	Four members	Based in Sweden, Biotech develops water purification solutions that entail the emission of ozone into the atmosphere. Biotech is seeking to refine existing knowledge on the optimum level of ozone required to achieve the best water purification results, particularly in humid environments, and at the same time keeping ozone emissions friendly to the environment.

Data analysis

Initial data analysis took a broad scope, aiming to identify the main actors in each case, ascertain the type of activities they performed, and generate a thorough description of the observed experiences. This helped illuminate what really happened with respect to the technical and commercial development of each venture. The empirical data was transcribed and coded, leading to 341 first-order concepts. The emergent concepts were grouped into second-order categories, at which point it was possible to infer some relationships among them. Whereas the prime aim of this study is to explain why new ventures vary in their learning

behavior, it was necessary to explore the causal powers or mechanisms that could possibly generate these behaviors. This demanded further analysis of these categories and their relationships, exploring possible theories that could explain these relationships. For instance, literature on uncertainty (McMullen & Shepherd, 2006; Milliken, 1987), and prior experience (Weick, 1995; Politis, 2005) were integrated into the data analysis process.

The data analysis revealed a significant difference in learning behavior between the case firms, and they were therefore grouped on this basis. Group one (Sprintech and Swetech) adopted an explorative, “opportunity-seeking” learning behavior. This learning behavior represents actions that support: (i) exploring new market opportunities, (ii) developing new technology applications, and (iii) broadening the search for new alliances. Group two (Systech and Biotech) adopted an exploitative, “advantage-seeking” learning behavior. This learning behavior favors actions that support: (i) refining existing knowledge to verify technology, (ii) focusing on one or a few applications of the technology, and (iii) concentrating on a narrow range of alliances. The criteria underlying this grouping are theoretically grounded in the concepts of exploration and exploitation advanced by (March (1991).

Subsequently, it was necessary to aggregate the identified second-order categories into higher-order themes, which we identified as: (i) prior related experience, (ii) managing uncertainty, and (iii) learning behaviors. To facilitate cross-case comparisons, aggregate themes were tabulated along with their respective first and second-order categories and their representative quotes (see Appendix). A data structure depicting aggregate themes and their corresponding first-order concepts and second-order categories is presented in Figure 1.

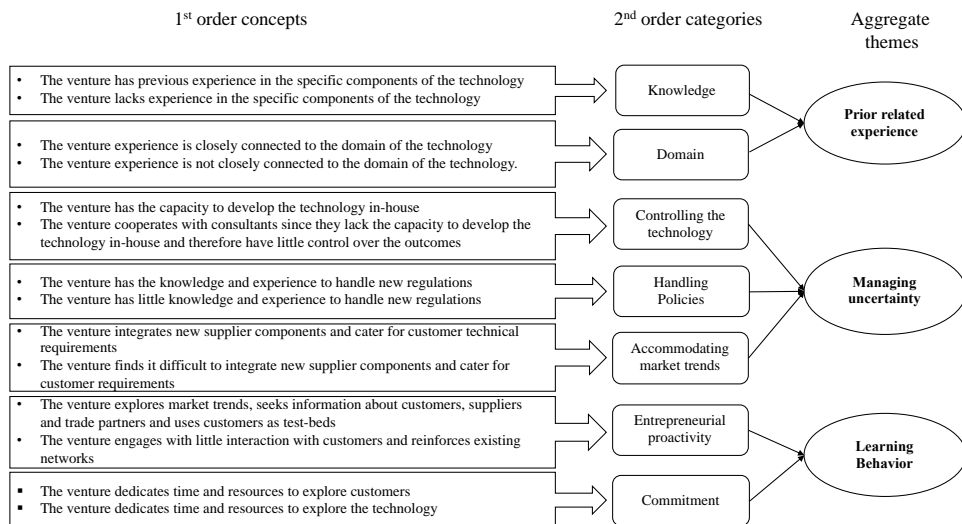


Figure 1:
Data structure

The first-order concepts demonstrated a clear dichotomy between ventures in terms of their knowledge of different aspects of the technology. Some ventures suggested that the experiences of their venture members provided them with relevant knowledge in the domain of the technology that could be transposed into a new context. In this way, they implicitly emphasized the *relatedness* of the experience as a critical driver for how valuable their knowledge would be to their new context. As such, the first aggregate theme was labeled as *prior related experience*.

These different views of prior related experience apparently resulted in a variation in how ventures approached uncertainties. Second-order categories suggested three types of uncertainties: those associated with technology, policies, and the market. At this point, research on uncertainty (e.g., Milliken, 1987; McMullen & Shepherd, 2006) provided insights on how to explain variations in approaching uncertainties. Research suggests that the decision to undertake a particular course of action depends on individuals' evaluation of the situation that surrounds that action. Therefore, those attaching high uncertainty to a situation may have a different opinion about the situation, which shapes their decision on what to do next. Therefore, *managing uncertainty* formed the second aggregate theme emerging from the first and second-order categories.

Finally, the first-order concepts illuminated differences in how ventures pursued information, how they explored market trends, and the time and resources they devoted to customers or markets. These first-order concepts were developed into two-second order categories, namely *entrepreneurial proactivity* and *commitment*. Subsequently, the relationship between these two second-order categories was aggregated to represent the *learning behavior* of the venture.

In order to aggregate the themes into a theoretically laden model, it was necessary to understand how they were related to their underlying second-order categories. For instance, how does the possession of specific domain knowledge influence a new venture's ability to control technology, manage policies, and deal with the market? By answering such questions, we can explore how these second-order categories influence the overall judgement of uncertainty, which impacts on new ventures' entrepreneurial proactivity and the time and resources they commit to pursuing innovations, which in turn explains their subsequent learning behavior.

4. Entrepreneurial learning in technology-based ventures

All four case ventures were pursuing the commercialization of a specific scientific domain. Moreover, the technically focused members of these ventures were at the forefront of research in their respective fields. This characteristic is in line with existing research on knowledge-intensive ventures, which suggests that they are typically founded by members with experience in science or technology (S. A. Shane, 2003). Whereas this study acknowledges other research suggesting that prior

experience is essential for enhancing the future performance of the venture, the results paint a different picture, suggesting that prior experience may not always be transposed into the new context. This result has critical implications for how new ventures continue to learn and routinize behaviors at different stages of their development. The comparative analysis demonstrates how each of these ventures undertook each phase of development, building up to an overall understanding of their learning behavior and the underlying factors that influence and shape these behaviors (see Table 3). Inspired by the work of (Vohora, Wright, & Lockett, 2004), the results of this paper are integrated into three distinct phases of new venture development: (i) research and development, (ii) opportunity framing and reconfiguration, and (iii) organization.

Table 3.
Characteristics of the new venture development phases

Ventures	Research and development phase	Opportunity framing and reconfiguration phase	Organization phase
Sprintech	Venture members came with prior related experience in nanotechnology, water technology, and UV-LED lamps. They used this experience to develop their technology in-house.	Having conducted their R&D in-house, venture members exercised high control over the technology, perceiving little uncertainty associated with its development. With such control, the venture members were open to a variety of potential commercial applications, and were ready to reconfigure the design of the technology to accommodate different external needs.	Sprintech dedicated time and resources to exploring the market. They engaged with customers in Sweden and Africa. They used social contacts to learn about the market and to experiment with different applications of their technology.
Swetech	The venture members had previous experience in snapping (cutting and molding) and water technology, which allowed them to develop their research and development internally.	With knowledge and experience in snapping (cutting and molding) and water technology, the venture members exhibited a positive framing of opportunities and were open to reconfiguring the technology in line with new policies or customer requirements.	Swetech dedicated time and resources to exploring new materials that they could use to enhance the absorption of their technology. They crossed borders seeking to broaden their cooperation with new suppliers who could provide them with new components that enhanced the performance of their technology.
Systech	The venture members had experience with electrified pipes, but lacked knowledge of biofilm and water properties. Therefore, they spent a long time in the lab.	With more time needed to learn about the technology, members of Systech had less control over technology development, and therefore were reluctant to consider opportunities that might introduce new complexities.	With less prior related experience in the domain of the technology, members recognized that there is high uncertainty when it comes to controlling the technology, handling external policies and accommodating market trends. To manage uncertainty, they dedicated time and resources to improve their understanding of the technology.
Biotech	The venture members were businesspeople with no knowledge of ozone. Therefore, they outsourced their research and development to external consultants.	Since they had outsourced R&D to a third party, the venture members suffered from severe uncertainty over their ability to control the technology. Therefore, they delayed connecting with customers, and saw high risk in new policies that controlled ozone output.	Biotech saw little value in involving customers at an early stage; they dedicated most of their time to lab work aiming to understand ozone.

Research and development phase

The focus of the research and development phase was to develop and perfect the technology to ensure its functionality before actualizing its commercial prospects. This phase included designing and testing the technology, registering intellectual property (IP), and fine-tuning results to meet desired outcomes. Results from this phase demonstrated that ventures differed in their ability to appropriate the technology for commercial use. Whereas each of the technically focused venture members were at the forefront of their research, in some of the cases their experience did not provide the knowledge needed for a specific component of the technology.

In literature, experience is often treated as a proxy for knowledge (Almeida, Dokko, & Rosenkopf, 2003). For instance, task-relevant knowledge typically emerges from a specific experience performing a task. However, not all experiences generate equally beneficial knowledge; some produce knowledge that may not be easily transferred to a new context. However, experiences that involve activities closely related to a new context are likely to produce knowledge that can be transposed to that context (Dokko, Wilk, & Rothbard, 2009). Therefore, *relatedness* is a key feature that determines whether an experience is transferrable or not.

Domain of Knowledge. The results demonstrate that members' judgement of their prior related experience varied across the ventures. For instance, members of Sprintech and Swetech demonstrated a strong collective belief that the knowledge they possessed from prior experience was closely related and relevant to their current technology requirements. Members stated on several occasions that they saw structural similarities between current and previous task-domain they performed—and, therefore, that the knowledge they had obtained through prior experience was relevant and could be easily transposed into their new context. Sprintech members, for instance, argued that their experience in nanotechnology, water technology, and UV-LED lamps was easily transferrable to their new context. It also allowed them to undertake complex development of the technology, and to register a number of intellectual properties early on in their development (“There was knowledge of the market and UV-LED lamps and how we can use them in the different task applications... We also knew about the drawbacks with those lamps”).

Similarly, members of Swetech displayed high confidence in the relevance and transferability of the technical know-how they possessed from previous experience. All interviewed members agreed that their prior experience was closely related to the technology, and sufficient to bring it to fruition in-house (“Apart from the tools, everything else was done internally, as we had good knowledge that fits the intended job... We possess a very diverse knowledge base in the venture”). Overall, the empirical data obtained from Sprintech and Swetech show that members' judgement of their prior related experience was critical for completing the development of the technology, and subsequently moving into the next phase of framing opportunities in order to bring that technology to market.

Systech and Biotech, on the other hand, saw less structural similarity between their previous experience and the research work required to develop the technology. Therefore, they reasoned that the knowledge they possessed in the technical domain was not close enough to the knowledge required to fully pursue the technology development on their own. For instance, members of Systech noted that despite their previous experience in developing electrified gasoline pipes, the application of these pipes in the water domain requires fundamental knowledge of biofilm, which was far from anything they had done before. Hence, Systech members spent longer trying to level up their knowledge, aiming to bring what they knew closer to the new context of application (“Within the company, we have a great depth of experience in plastic production... however, we have no idea of what kind of electric field will be optimal in terms of reducing biofilm”).

Concerning Biotech, the original inventor who created the first prototype of the technology had passed away a few years before, leaving the remaining partners with less understanding of ozone, the core component of the technology. The current owners came from a business background, and therefore their previous experience was unrelated to the technology (“Our venture is composed of business people, but we have one engineer... So, we need to cooperate with external consultants to develop the technology”). By outsourcing their development to an outside party, the venture members ceded some control over the research and development process—and, therefore, the direction or outcome the technology took.

In this way, the results show that members’ judgement of prior related experience plays a critical role in the research and development phase. Those with experience related to their new context could see how their knowledge was relevant and transferrable to the new context, and were able to transition faster to the opportunity framing and re-orientation phase, which was necessary to bring their technology to market. Together, these results lead to the following propositions:

Proposition 1a: Ventures with prior related experience are more likely to see structural similarities between previous and new tasks, thus finding their knowledge relevant and transferrable to their new context.

Proposition 1b: Ventures with no prior related experience are less likely to see structural similarities between previous and new tasks, thus finding their knowledge less relevant and transferrable to their new context.

Opportunity framing and reconfiguration phase

At the opportunity framing and reconfiguration phase, ventures evaluate whether the technology delivers value that warrants further effort towards commercialization. This phase is challenging, since it demands a good understanding of how to configure and reconfigure the technology in a way that maximizes its applicability and commercial value. Moreover, it requires deep

knowledge of the different components of the technology and how they work together to meet potential challenges imposed by competitors or the environment (Eisenhardt & Martin, 2000). The results show that, due to the deficiency of prior related experience pertaining to some aspects of the technology, some ventures lacked clarity over how the technology would perform commercially. Hence, they judged the situation to be of high uncertainty and realized that they were unable to control or predict its outcomes.

In literature, judging a situation as being uncertain or not concerns how members organize, evaluate, and impart meaning to a specific stimulus—and, as a result, judge the probability of risk and reward in an effort to optimize possible outcomes (Milliken, 1987; Ravasi & Turati, 2005). Therefore, actors' judgement of a situation depends on the richness and accuracy of the mental models that they use to interpret it (Weick, 1988). Mental models are cognitive representations that inform thought processes relating to the way things work (Lin, Murphree, & Li, 2017). As such, mental models inform individuals' understanding, interpretations, and expectations (Jonker, Van Riemsdijk, & Vermeulen, 2011), and guide how individuals behave, perform tasks and go about solving problems. Because mental models are formed and shaped by the knowledge that individuals carry, increasing that knowledge will also enhance the richness and accuracy of their mental models—which, in turn, is expected to reduce members' negative judgement of a situation and increase their motivation to engage in it (Harrison & Klein, 2007).

The empirical results highlight three factors that instigated uncertainty among the studied ventures: (i) controlling the technology, (ii) handling policies, and (iii) accommodating market trends. Each of these factors is discussed below, explaining how they influenced opportunity framing and the reconfiguration of the technology for each of the studied ventures.

Controlling the Technology. Ventures varied in the level of control they exercised over their technology. Control is “the capacity to monitor a process and to affect its direction” (Ravasi & Turati, 2005, p. 155). In the case of Sprintech, venture members revealed that prior related experience enriched the repertoire of knowledge that members could draw upon to control different tasks. For instance, members observed on several occasions that their closely related experience in the domain of their technology gave them relevant knowledge that they could transpose to their new context. Subsequently, they were able to use that knowledge to develop and control different aspects of the technology. In this way, Sprintech was able to undertake the development of their technology in-house, which was critical for conducting technical trials and closely discussing them.

We designed the technology ourselves, and we had a workshop where we were able to put different pieces together. Then we could do lots of tests and proofs of concept, and show the effects on dosage and how UV LEDs function, and therefore we know how to control the efficiency in UV disinfection.

Because they exercised close control over the technology, venture members judged uncertainty to be low on several aspects of the technology development. This allowed them to pursue different opportunities whereby they could reconfigure it to meet different applications and serve a broader customer base (“We can utilize LED technology in different forms... we presented different options to show where our products could be used”).

Similarly, Swetech revealed that their strong experience with snapping technology provided them with a rich knowledge base to control and combine the main parts of the filters in-house:

The knowledge of the technology is controlled in three parts: the assembly, the components and absorbents, and testing the absorbents to see how many pollutants we’re really filtering out. So, it’s the intersection between absorbent components, the function of the filter, and test results—and what we have learned from that.

By exercising control over technology, Swetech displayed confidence in their ability to manage uncertainties related to technology development and, in turn, revealed a positive approach to reconfiguring the technology to fit different product form factors (“We can adapt our technology to different geometries to make it larger or smaller, which can broaden the application possibilities of our technology”).

Systech and Biotech, on the other hand, argued that with little prior related experience, they lacked base knowledge of critical components of the technology, which afforded them little control over the development process. Lacking such control, both ventures saw high uncertainty in their inability to control the outcomes of the technology they were developing. For instance, Systech, which developed its technology in-house, highlighted very high uncertainty. Because they knew little about biofilm, they could not determine the correct electric current required to achieve a high bacterial kill rate:

We have no idea of what kind of electric field will be optimal in terms of reducing biofilm, so we keep varying the voltage, changing polarity and frequency... Each time we change the frequency, we have to wait and take readings for a long period until we know the biofilm has been reduced or changed. So you have parameters in a three-dimensional room and we don’t know much about that room, or how large an influence the frequency, voltage, and current have on the biofilm.

Biotech encountered a similar control challenge. The venture lacked prior related experience in the ozone domain, and therefore had to outsource the development. In this arrangement, all experiments were done by a third party, and Biotech had little influence or control over the development process. As the CEO stated, “We do not have the competence in-house, so we outsourced the developments.” With a lack of experience and control over the technology, Biotech exhibited high levels of uncertainty over whether they could consider different applications of the existing patent they had filed. In this way, the comparative results showed that the interplay

between prior related experience and the judgement of uncertainty influenced how new ventures frame opportunities. These results lead us to propose the following tendencies:

Proposition 2a: Ventures with prior related experience are likely to exercise more control over the technology and therefore can expose a positive judgment of their ability to manage uncertainties associated with the technology.

Proposition 2b: Ventures with no prior related experience are likely to exercise less control over the technology and therefore can expose a negative judgement of their ability to manage uncertainties associated with the technology.

Handling Policies. Innovation is increasingly recognized as vital by policymakers and legislators. Therefore, new policies are continually enacted aimed at creating enabling conditions that can shape innovation and the innovation process. However, while these conditions were perceived as an opportunity by some case companies, others saw them as a threat.

Sprintech and Swetech both saw value in the new water policies enacted by European Union Directive 2020. For instance, Sprintech was optimistic about the new mercury legislation, reasoning that abandoning mercury as a means of water disinfection would increase the demand for other methods, “including LED.” Moreover, such policies would open up the channels for new applications, but might require technology designs to be reconfigured to accommodate these changes. Similarly, Swetech saw value in the EU directives, as they compelled member states to maintain an acceptable quality level in “recipients,” or bodies of water into which storm water runs (primarily the sea). This implied that Swetech could increase the potential applications of their technology beyond municipality level, and expand into applications including water treatment plants and homes:

There is a decent growth where there is awareness of storm water, which is greater compared to two years ago, and under the EU directive in 2020 the member states need to have their recipients in good order, so as that draws closer, the awareness and necessity to act puts pressure on municipalities.

Both Sprintech and Swetech attested that the knowledge they had acquired from prior experience was continuously applied in reconfiguring the technology. It also reduced possible uncertainties associated with new policies, allowing these ventures to pursue different opportunities.

In the case of Systech and Biotech, policies seemed to cause both teams anxiety over the future application and potential cost of their technology. For instance, Systech recognized that new policies in the water sector could impose stricter standards for acceptable levels of biofilm in water, which their existing electrified pipes might struggle to meet (“Stricter rules on disinfection byproducts from chlorine disinfection call for new ways to reduce problems with biofilm growth that are as yet unknown”). As such, they displayed a narrow framing of the possible

opportunities they could pursue, as they were unsure about the biofilm output, they could achieve with their existing technology design.

Similarly, Biotech recognized that ozone could be harmful to the environment if produced in large amounts (see table2). Since their technology produced ozone, this implied that higher levels of that gas could run counter to its intended functionality. Thus, regulations concerning ozone, coupled with a lack of clarity over the ozone levels their current technology produced, created uncertainty among venture members and a conservative framing for what opportunities they could pursue (“We see uncertainty over our ozone emissions, and what we could do with [our technology] as a result”).

Evidently, members of all ventures recognized that complying with new policies would require some reconfiguration of their technology. However, the variation in prior related experience emerged as an important determinant for how each of these ventures judged policy uncertainty and their response to reconfiguration. Sprintech and Swetech, who possessed prior related experience, showed higher confidence in their ability to incorporate the potential changes demanded by the new policy. Conversely, Systech and Biotech possessed no prior related experience and therefore interpreted the situation as being risky, thus feeling less confident about their ability to deal with these changes. These comparative results lead to the following propositions:

Proposition 3a: Ventures with prior related experience tend to exhibit a higher capacity to reconfigure the technology, and therefore are likely to manage uncertainties associated with new policies.

Proposition 3b: Ventures with no prior related experience tend to exhibit a lower capacity to reconfigure the technology, and therefore, are less likely to manage uncertainties associated with new policies.

Accommodating Market Trends. Accommodating market trends relate to the venture’s capacity to integrate new developments imposed by suppliers who produced critical components of the technology, or catering for technical requirements demanded by customers. Sprintech, for instance, saw that new developments in LED lamps (a vital component of their technology) introduced by LED suppliers would make the technology more effective, but might also demand a technical reconfiguration to accommodate these changes. For instance, a reconfiguration of the design might allow the technology to be used for disinfecting water flowing at higher rates, which could suit other applications, such as showers.

The LED market is on the up, and it is changing and developing rapidly. In order to stay at the forefront, we need to be future-proof, so we need to have a design that can incorporate the changes that are coming, because we can see that there is a change in the base component of our technology, which is LEDs.

Similarly, Swetech realized that technical advancements introduced by suppliers of absorbent materials could boost their ability to increase the efficiency of their filters. They pointed out that despite the need to readjust the design of the filters, opting for new materials opened up immense opportunities to expand the list of metals they could filter out including Zinc and others. As a result, they could develop different applications and serve a wider customer base (“We discussed that in the team, and we could see that the development made by the French metal absorbent supplier could enhance our product, despite the changes we needed to make”). Overall, prior related experience and the control over the technology exhibited by members of both ventures were instrumental to perceiving low uncertainty and regarding technical advancements made by their component suppliers in a positive light.

Systech and Biotech, on the other hand, faced uncertainty concerning the technical requirements mandated by customers. Systech, for instance, realized that adapting the application of their electrified gasoline pipes to suit water or even beer pipes would demand a different electric voltage. Meeting that challenge would demand extensive research to prove that an electric current would be effective for such a purpose. Given their lack of prior related experience in biofilm, Systech perceived high uncertainty over exploring these options (“When you come with a pipe that has a conductive layer, you have to show lots of results to convince the customer that this works”).

Equally, Biotech saw that key customers imposed strict requirements on the amount of ozone produced throughout water purification. Moreover, and as illustrated earlier, Biotech possessed little prior related experience in ozone, and therefore exercised little control over the technology development. As such, they perceived high uncertainty over their ability to meet those requirements.

We see uncertainty in how much ozone we can produce... There is a company called Orbtech, and they have set up a demanding specification where we need to achieve a level of five grams of ozone per hour which meets new regulations of ozone emissions.

Similar to the above discussion on policies, prior related experience mediated the way venture members perceived uncertainty related to the market. In the case of Sprintech and Swetech, related experience allowed venture members to feel more confident about their collective ability to handle technical developments imposed by suppliers or customers, thus perceiving less uncertainty in adopting and framing these developments as opportunities for serving a broader range of applications. In contrast, Systech and Biotech lacked prior related experience, giving them less confidence in their collective ability to deal with technical developments imposed by their customers. As such, they perceived high uncertainty in adopting these developments. Accordingly, the comparative results lead to the following proposition:

Proposition 4a: Ventures with prior related experience tend to exhibit a higher capacity to integrate technical developments introduced by suppliers or cater for technical requirements demanded by customers, and therefore are likely to manage uncertainties associated with market trends.

Proposition 4b: Ventures with no prior related experience tend to exhibit lower capacity to integrate technical developments introduced by suppliers or cater for technical requirements demanded by customers and therefore are less likely to manage uncertainties associated with market trends.

Organization phase

The organization phase centered on how ventures allocated time and resources to pursue the opportunities they had previously discovered and framed. This included assessing what resources and knowledge they needed to acquire, and where they would access them. The decisions that new ventures take at this phase can direct their path of development, and determine how they continue to learn and routinize behaviors (Vohora et al., 2004). To understand how new ventures learn and routinize behaviors, it was necessary to investigate patterned activities—for instance, how they sought opportunities, information, or resources for learning. Based on this approach, two second-order categories were identified: (i) entrepreneurial proactivity, and (ii) commitment.

Entrepreneurial proactivity. Entrepreneurial proactivity is the extent to which a venture anticipates and acts on future needs (Wang, 2008). It is associated with behaviors of exploration and experimentation, and scanning for new information about markets, customers, and suppliers. Hence, entrepreneurial proactivity supports the production of novel ideas and creative processes that result in the introduction of products, services, and process applications (Lumpkin & Dess, 1996).

The results of this study reveal that those who judged uncertainty to be low were prone to exploring new market opportunities by supporting new ideas, novelty, and experimentation. Both Sprintech and Swetech, who judged uncertainty to be low, possessed enough prior related experience (and hence the knowledge base) to explore different paths to commercialization. As such, they adopted an “opportunity-seeking” learning behavior, seeking to define customer needs, form affiliations with suppliers and trade partners, and establish new network ties through which they could investigate new applications of their technology. For instance, Sprintech illustrated the critical role of “customers as test beds” in developing different applications of their technology:

We approached customers very early to get early feedback... We always try to identify potential customer segments... We tried to identify the niche and identify the market for that niche. Technology does not sell itself; you need to sell it.

Moreover, they emphasized behaviors that reinforced the cross-fertilization of scientific knowledge:

We started to explore different markets where we had a better understanding of whether there was a market segment. We also developed knowledge about suppliers [of UV LED lamps], as it is a big market and they are used in many different applications... We continuously reinforce cross-scientific knowledge where we go deep into our subject, and at the same time develop new relations on the market where we discuss different opportunities with external parties and see what they know in the water area.

Sprintech also emphasized how keeping track of technological developments (mainly originating with suppliers) had significant implications for how they kept their technology at the cutting edge. According to the CEO of Sprintech, “Keeping track of market trends, and improvements in LEDs, provides excellent opportunities for the development of the technology and its applications.” These behavioral patterns were also corroborated through the company’s website, which provided critical information about the venture’s earlier and planned activities and the frequency of these events. For instance, the Sprintech website offered essential information about existing and potential agreements and partnerships with customers, as well as past and future networking events (e.g., exhibitions) attended by the firm.

Similarly, Swetech demonstrated high entrepreneurial proactivity in the way they engaged with customers and suppliers, and how they went about exploring the different channels that enhanced and promoted their technology (“Our sales strategy is to sell through channels; the guys who clean the drains, and environmental companies, are people we approach”). The idea behind the technology development was often introduced together with customers and network partners, thus reinforcing a focus on aligning the final product with market needs (“We need more competence in marketing, more knowledge about channels, cost-effective marketing coverage, and converting interested parties into customers, and now we have a sales guy joining us too”). Entrepreneurial proactivity was also corroborated through the company’s website, where it was possible to track the firm’s activities and interactions with the business environment. For instance, news content in the form of press releases highlighted the Swetech team’s various interactions with universities for research purposes. Moreover, the website offered news concerning exhibitions and water-related summits, which were emphasized as essential arenas for meeting with investors, policymakers, and entrepreneurs.

Systech and Biotech, on the other hand, judged uncertainty to be high. They claimed that a great deal was yet to be discovered about the functionality of their technology, so as not to take a big risk by misreading market signals. In doing so, they adopted an “advantage-seeking” learning behavior in which they sought to develop their scientific knowledge to back up the claims they were making about their technology. Systech, for instance, were not convinced that their technology

had yet matured enough to make an early connection with customers. They stressed the need to learn more about what was happening when a low electrical current ran through their pipes, and how this affected biofilm growth on the pipes' internal surface. These results were endorsed on the website and written research documents, which presented comparisons of how their electrified pipes affected biofilm growth in different liquids, such as water and beer.

We are not putting in any effort with customers at the moment. We want to be able to ensure that the electrical control unit can change voltage, and we have not tested it yet.

Similarly, Biotech were seeking product verification, and thus searched out information that supported product development and performance. For instance, they attempted to achieve verification of the ozone levels produced by their technology via an external agency. As such, they focused less on customer feedback than on acquiring information that could only "hypothetically" contribute to improving the efficiency of their technology. Moreover, they were less risk-tolerant, locking themselves into their preset standards instead of opening up to other possibilities that could get them to market more quickly.

I would say there is a lot still to do to make our product perfect. Someone told us, "You have to be embarrassed when releasing your products," but we don't want to be that embarrassed... We want to have somebody outside where we have a specific kind of verification... We are very much focused on the technical aspect, wanting to make it perfect concerning the level of ozone emissions, so that all customers can be confident that they can use it in their applications.

Taken together, these results lead to the following propositions:

Proposition 5a: Ventures that judge uncertainty to be low are likely to routinize behaviors that support high levels of entrepreneurial proactivity, thus supporting activities that foster experimentation, discovery, and the creation of new knowledge.

Proposition 5b: Ventures that judge uncertainty to be high are more likely to routinize behaviors that support low levels of entrepreneurial proactivity, thus supporting activities that foster efficiency, refining existing procedures, and reinforcing existing knowledge.

Commitment. Commitment relates to the time, attention, and resources dedicated by the ventures to exploring or exploiting specific networks, sales channels, and sources of knowledge. As ventures exhibited different judgement of uncertainties, their levels of commitment in terms of the time and resources dedicated to the innovation process varied. Ventures perceiving low uncertainty spent the majority of their time and resources exploring new networks to bring their technology to market. Sprintech, for instance, spent many hours with customers, regarding them

as a source of valuable insights and feedback that allowed the firm to learn about different facets of its technology. This included a sustained effort at understanding the market in Africa, which revealed that water characteristics there differ from those in Sweden, and raised the question of how the technology might function in such circumstances.

We are always seeking to get a handle on the low-hanging fruit where we could start to build up sales volumes... Our product development is dependent on external relations, and because of our extensive network among microbiologists and different researchers and their connections, we know what we are talking about regarding knowledge-based products. And I think that has been a good backbone for our members.

Similarly, Swetech dedicated time and resources to customizing the functionality of their technology to meet customer needs. For instance, they triangulated efforts with a French supplier and a well-known car manufacturer in Sweden to develop novel variations of their technology.

We got in touch with a big car manufacturer here in Sweden, and we invented Swetech QM ["Quick Metal"] to fit their requirements... The plan is to dedicate more time and money to focusing on customers and enhancing marketing and sales.

Systech and Biotech, on the other hand, judged uncertainty to be high. Therefore, they dedicated time and resources to reinforcing existing networks that could help them perfect their technologies. Instead of focusing on proactivity, exploration, and collaboration that might yield early insights into what customers wanted from a final product, they preferred to steer their entrepreneurial learning efforts towards the technology itself. As such, they spent more time in the lab, seeking to secure the performance of the technology before introducing it to the market. Systech, for example, alleged that understanding biofilm growth in electromagnetic fields is a complicated matter, and that it was essential to build a track record before entering the market:

We are dedicating all resources to show that we can go a long way with our technology, and we have some really interesting results... We have to focus, and be cautious about where we should take our first real step into the market.

Similarly, Biotech committed a lot of their time and resources to improving the efficiency of their technology. The venture members did not see value in involving customers at an early stage, arguing instead that developing an ozone technology that operates in a humid environment is a novel idea that requires extensive proof of concept before it is presented to customers:

While we were trying to make a market entrance or find a way to get this invention to market, but we thought it was not good enough... We have to get up to such a level that customers say, "This is good enough for us."

Overall, these results lead to the following propositions:

Proposition 6a: Ventures that judge uncertainty to be low are likely to routinize behaviors that support exploration, whereby they commit more time and resources to explore new options and possibilities.

Proposition 6b: Ventures that judge uncertainty to be high are likely to routinize behaviors that support exploitation, whereby they commit more time and resources to refining procedures or products and reaping value from existing knowledge.

5. Discussion

This study examines why new ventures undertake different learning behaviors as they engage in commercializing their technology. Our empirical results demonstrate that new ventures’ prior related experience plays a critical role in how they judge uncertainties, and thus the learning behavior they undertake as a result.

The findings illuminate the development of learning behaviors over three vital phases: (i) research and development, (ii) opportunity framing and reconfiguration, and (iii) organization. The findings demonstrate how prior related experience, and the relevant knowledge it generates, mediates how new ventures judge uncertainty and how that builds up to an overall learning behavior at each of the depicted phases. These relationships are depicted in Figure 4.

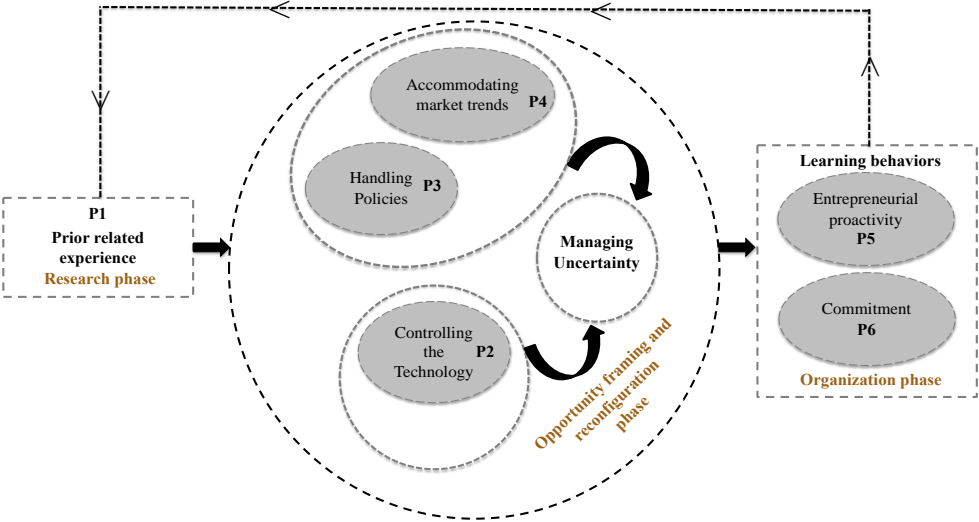


Figure 4: Factors influencing learning behaviors

Past research highlights that when firms judge a situation as being uncertain, they are impelled to explore new resources or information in an attempt to manage that uncertainty (Hoskisson & Busenitz, 2002). For instance, (Podolny, 2001) suggests that firms facing high uncertainty typically try to manage it by developing external relationships. This viewpoint is supported by economic and sociological approaches (Powell, Koput, & Smith-Doerr, 1996), which highlight that allocating more time and attention to a variety of external information and sources improves a firm's risk management and growth strategy. (Beckman, Haunschild, & Phillips, 2004), who argue along these lines, suggest that the action taken as a result of uncertainty depends on the nature of the uncertainty itself. If it is firm-specific (i.e., unique to the firm), the venture will probably cope by taking on a broadening strategy, such as expanding network alliances to build a wider net of information and resources. If the uncertainty is market-specific (i.e., outside the firm's control), a venture may assume a reinforcing strategy, such as capitalizing on existing networks, maintaining its own integrity and control over the situation. This argument explains broadening and reinforcing as forms of explorative and exploitative behaviors respectively (March, 1991). Through broadening, a venture expands its existing knowledge base by experimenting with and trialing new alternatives and forming new relationships (for a review, see March, 1991; Holmqvist, 2004). Through reinforcing, ventures follow path dependencies, seeking to improve known certainties and secure short-term results (Benner & Tushman, 2003).

We argue that ventures may not necessarily explore external relations or seek new information when faced with uncertainty. Moreover, it is not only the nature of uncertainty that determines their reaction. We find that new ventures' reactions to uncertainty—i.e., broadening or reinforcing—are moderated by the interplay between their prior related experience and their judgement of uncertainty. Our results show that in both types of uncertainty—i.e., firm-specific (such as control over technology) or market-specific (such as managing policies or market trends)—prior related experience played a fundamental role in defining the ventures' judgement of uncertainty and consequently their resulting learning behavior.

Whereas prior related experience is regarded as providing relevant knowledge that can be used in closely related contexts, another stream of research suggests that ventures lacking prior related experience can always benefit from current venture experience (e.g., Dokko et al., 2009). Although prior related experience provides essential knowledge and skills needed to perform tasks, it can still be an imperfect substitute for current learning that takes place in the actual venture context. Hence, experience in the venture context provides a closer learning fit with the demands of that context, alluding to the idea that the effects of prior related experience may diminish over time (see e.g., (Parker, 2013). While this is possibly true, our results highlight that prior related experience is particularly critical during the *research and development phase*, since this phase sets the venture's subsequent trajectory. Prior related experience moderates how new ventures judge and manage uncertainties at a critically uncertain phase. Moreover, prior related experience, along with the

knowledge base it offers, provides new ventures with the absorptive capacity that allows them to assimilate and exploit external information and knowledge more quickly, thus accelerating their learning during the early phases of development (Cohen & Levinthal, 1990).

Our study also shows that ventures with prior related experience possess a relevant knowledge base that is closely connected to their current context, and which allows them to manage and control different aspects of uncertainty that are associated with that context. Moreover, the ventures that were best placed to benefit from previous experience were those that could see structural similarities between the tasks performed during prior experience and those performed in the new context (Dokko et al., 2009). Hence, prior related experience becomes transposable to the new context when it is deemed *related* and *structurally similar* to that context. For instance, both Sprintech and Swetech saw a direct link between their prior related experience and the new tasks they were performing, and were therefore able to foresee how they could use it. However, ventures such as Systech and Biotech came with less prior related experience in their chosen technology domains, and were therefore unable to see how the knowledge they possessed could be used in their new context. As such, they exhibited a lower capacity to understand, process, and adopt new information from customers and suppliers.

Moving to the opportunity-framing phase, our results show that prior related experience impacts on the venture's ability to exercise control over technology. For instance, ventures that succeeded in transposing relevant knowledge acquired through prior related experience were able to create knowledge that helped them assimilate and interpret new information and result outputs (Cohen and Levinthal, 1990). As a result, they were able to improve their control over the technology, and manage the uncertainties typically associated with its development. As such, they were able to frame incoming opportunities that emerged from interacting with customers or suppliers in a positive light. For example, Sprintech members who possessed prior related experience in nano, water, and LED technologies were able to see how they could benefit from these experiences to interpret and make sense of the new results they obtained through interchanging the position of the LED light inside the system to improve the kill rate. By absorbing and assimilating these results, Sprintech was able to control and steer possible outcomes, consequently cutting down on possible uncertainties and opening up different opportunities evolving through key partners (customers or suppliers). Similarly, Swetech possessed prior related experience in water engineering, and snapping techniques, which was helpful for them to perform and control R&D in-house, and in turn feel more at ease considering different design and size variations of their technology.

However, ventures such as Systech and Biotech saw little connection between their previous experience and the new context. Therefore, they either had to outsource the technology development (which meant giving up some control) or spend more time aiming to build the necessary knowledge repertoire to understand the technology and interpret different outcomes. As such, transposing prior related

experience into the new context is necessary for new ventures to exercise control over technology and judge uncertainty to be low.

Our results also show that the relevant knowledge base that ventures create through prior related experience was essential for handling policies and accommodating market trends. For instance, Swetech, with its snapping knowledge, was able to control the filter design to meet municipalities' requirements while also complying with the specifications of the new metal absorbents recently introduced by suppliers. According to participants, the knowledge available in the venture allowed them to manage a wide range of requirements imposed by their environment, and therefore they framed these requirements as a source of opportunity rather than a threat. By overcoming the threats in a situation, ventures could see external challenges positively, hence judging uncertainty to be low.

Conversely, members of Systech and Biotech downplayed their ability to control the technology, maintaining that they needed more knowledge, obtained through rigorous testing, before it hit the market. As such, they judged market uncertainty to be high, and expressed concern over changes imposed by policy and technical advances. In light of these results, prior related experience provides new ventures with the knowledge base needed to overcome possible uncertainties related to handling policies and accommodating market trends. Thus, it improves the chances of reconfiguring and pursuing the technology in different ways.

Our findings also explicate that the interplay between prior related experience and uncertainty has significant implications for the behaviors that new ventures routinize when learning (McKelvie et al., 2011). The results reveal that judging uncertainty to be low uncertainty can carry on to the organization phase thus encouraging the ventures to routinize behaviors that support explorative learning, thus, supporting entrepreneurial proactivity and a commitment to learning about customers, suppliers, and the market. For instance, Sprintech and Swetech, who exposed low uncertainty towards the commercialization process of their technology, approached commercialization through trial and error (e.g., Sommer et al 2009). They launched their technology in smaller steps, seeking to mitigate uncertainties by fostering flexibility and learning from customer and supplier feedback.

Systech and Biotech, who exposed high uncertainty towards the commercialization process of their technology, exhibited low entrepreneurial proactivity and commitment to the market. Instead, they accumulated experience from current tasks, hoping to learn more about their respective technologies. Hence, they followed an exploitative approach to learning, by routinizing behaviors that support efficiency and reaping value from what is already known (March, 1991). Instead of opening up to various possibilities that could get them to market more quickly, they spent longer in the lab, trying to improve their technological output (Sarasvathy, 2001). In this way, new ventures' judgement of uncertainty can influence their choices about where to allocate time, attention, and resources to support their learning.

Finally, and as illuminated in Figure 4, the learning behaviors that a new venture enacts tend to feed back (depicted in the left pointing arrows) into the venture, influencing the type and source of experiences exposed to venture members, and in turn, affecting their knowledge base and the opportunities they consider over time.

6. Theoretical implications

This paper has several theoretical implications. First, it provides an integrative view of entrepreneurial learning that embraces the entire organization. Because prior research discussed entrepreneurial learning as an individual-level phenomenon, most studies typically sought to understand how individuals learn and develop the knowledge needed to start and run ventures (Politis, 2005; Cope, 2005). Even studies that address entrepreneurial learning at the venture level typically focus on individual-level characteristics to explain venture-level outcomes (Reuber, Dyke, & Fischer, 1990). Our results, however, show that learning is an ongoing process that operates at multiple levels, in which new ventures develop and routinize certain behaviors that over time allow them to transform ideas into new or improved products, services, or processes (El-Awad et al., 2017). As such, the results demonstrate that venture-level learning cannot be reduced to the sum of individual-level experiences, but also encompasses the manner in which these experiences are integrated and coordinated.

Second, we integrate research on uncertainty to explain entrepreneurial learning. The role of uncertainty has mainly been considered with respect to the entrepreneurial process, and particularly the pre-action phase of entrepreneurship (e.g., McMullen and Shepherd, 2006). Prior research suggests that the decision to engage or not in a course of action is conditional on whether entrepreneurs achieve higher levels of motivation that outweigh the uncertainty they perceive (e.g., McMullen and Shepherd, 2006; McKelvie et al., 2011). This argument, however, only focuses on the initial decision to undertake a particular action, and does not extend the role of uncertainty to the activities and behaviors undertaken *after* the decision to act. This paper extends the role of uncertainty from the pre-action phase into post-action, demonstrating how it interacts with the process of entrepreneurial learning in new ventures. Moreover, whereas prior research has typically attached uncertainty to the individual-level (Milliken, 1987), we operationalize a collective view of uncertainty, demonstrating how collective judgement of uncertainty is an important underlying factor that determines the routinization of behaviors in new ventures.

Third, we integrate the role of prior related experience in explaining routinization in new ventures. We show how prior related experience can influence the pattern of thoughts and actions of venture members at different phases of development, thus

demonstrating how one phase of development leads to the next, building towards the routinization of behaviors.

7. Implications for entrepreneurs

In order for entrepreneurs to develop ventures that are capable of learning in explorative and exploitative ways, they must routinize behaviors that can facilitate both learning paths. The results in this paper demonstrate how different development phases build up towards routinizing behaviors by illuminating the factors that shape and underpin these behaviors at each stage.

Our results show that entrepreneurs must acquire the appropriate resources early on, in order to facilitate a rapid and successful progression through the later phases of development. The findings suggest that involving members with prior experience related to the focal domain is necessary for providing the required knowledge base that allows ventures to assimilate and absorb information that is crucial for their development. This is particularly essential during both the research and opportunity framing and reconfiguration phases, where new ventures need to accumulate enough knowledge to create and operationalize technology.

Our findings also emphasize that possessing prior related experience is vital for accelerating learning, so new ventures can move quickly into the subsequent phases of development by committing the right amounts of time and resources to balance exploring markets with exploiting technology. The results reveal that prior related experience moderates between uncertainty judgement and how new ventures routinize behaviors and learn. We argue that ventures encompassing prior related experience exhibit higher confidence in their ability to manage uncertainties. Therefore, they are more likely to adopt behaviors that foster entrepreneurial proactivity and a commitment to transcending boundaries. Those lacking prior related experience, however, are likely to confine their time and resources to refining the technology, staying within their boundaries. Entrepreneurs, however, should not focus purely on prior related experience at the expense of on-the-job learning. Such *in situ* learning generates critical knowledge that fits closely with the demands of the venture. We suggest that prior related experience does not replace learning within the venture, but can amplify learning during the early phases of its development, suggesting that it provides venture members with sufficient absorptive capacity to assimilate, absorb, and leverage new information from different actors.

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Appendix: Supplementary empirical manifestations

First-order concepts	Second-order categories and representative quotes	Themes
<p>The venture has previous experience in the specific components of the technology</p> <p>The venture lacks experience in the specific components of the technology</p>	<p>Knowledge</p> <p>“We have the whole picture, and we set the requirements, we have the experience and knowledge and requirement of the product but then we interact with experts in different areas.” Sprintech “We are all so knowledgeable about the filter.” Swetech</p> <p>“We have to develop much more results and knowledge to prove to customers that our technology works.” Systech “We sent it to the Swedish agency to verify the capacity of the technology as we lack the know-how in-house.” Biotech</p>	<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Prior related experience</p>
<p>The experience is closely connected to the domain of the technology</p> <p>The venture experience is not closely connected to the domain of the technology</p>	<p>Domain</p> <p>“We have deep knowledge in respective areas, but we also have great relations where we discuss different opportunities and needs in the water area.” Sprintech “We could adapt our product because the foundation of the technology is there.” Swetech</p> <p>“We need to develop better knowledge of the domain in order to understand how to apply electricity to the pipes, and develop ways to connect two pipes and while maintaining the current.” Systech “Ozone is not new, but using ozone in humid environments is totally new knowledge, and not something we know well.” Biotech</p>	

First-order concepts	Second-order categories & representative quotes	Themes
<p>The venture has the capacity to develop their technology in-house</p> <p>The venture cooperates with consultants since they lack the capacity to develop the technology in-house and therefore have little control over the outcomes</p> <p>The venture has the knowledge and experience to handle new regulations</p> <p>The venture has little knowledge and experience to handle new regulations</p> <p>The venture integrates new supplier components and cater for customer technical requirements</p> <p>The venture finds it difficult to integrate new supplier components and caters for customer requirements</p>	<p>Controlling the technology</p> <p>"We control the knowledge of the nanotechnology and the water side." Sprintech</p> <p>"We control our R&D; we have sufficient R&D experience." Swetech</p> <p>"We have not come very far yet... We need a long period of time in the lab, as we have little control over results." Systech</p> <p>"We lack a lot of knowledge and control, so without both it would make it easy to fall down again; we had to work with consultants." Biotech</p> <p>Hanling policies</p> <p>"Our initial understanding was that our product could serve only drinking water, but then it was discovered that there is a big issue in Sweden and other countries that we realized that a bacterium called legionella is found in mains water pipes... This is becoming a concern to policymakers... This is an opportunity to expand our technology application." Sprintech</p> <p>"This is a recognized problem and is addressed by the EU in the water directive, which compels the member states to have an acceptable quality of water in water recipients—mainly the sea." Swetech</p> <p>"The trend I feel most wobbly about is the tax authorities in Sweden and their behavior towards entrepreneurs in general. The politicians say one great thing but do another." Systech</p> <p>"We see uncertainty in the level of ozone required by big customers and the level of our own emissions." Biotech</p> <p>Accomodating market trends</p> <p>"We keep track of suppliers and customers—where they are, how much technological development they have been doing." Sprintech</p> <p>"Big customers wanted to have a solution that fits the development of their need." Swetech</p> <p>"One major pipe manufacturer in Switzerland required us to test the pipes before they would use our technology for drinks pipes. We need to have a German approval that the pipe material itself has the capability to run drinking water, and we think this is hard to achieve now." Systech</p> <p>"There is a company called Orbtch, and they have set a specification where we need five grams of ozone per hour. This is difficult to achieve." Biotech</p>	<p style="text-align: center;">Managing uncertainty</p>

First-order concepts	Second-order categories & representative quotes	Themes
<p>The venture explores market trends; seeks information about customers, suppliers and trade partners; and uses customers as test beds</p> <p>The venture engages with little interaction with customers and reinforces existing networks</p> <p>The venture dedicates time and resources to explore customers</p> <p>The venture dedicates time and resources to explore the technology</p>	<p>Entrepreneurial proactivity</p> <p>“We keep track of suppliers and customers—where they are, how much development they have been doing. I have an Excel sheet with everything from the start on the amount of light and energy you get out of LED compared to what you pay for it.” Sprintech</p> <p>“We take a pragmatic view... We try to get the best possible products on the market; we are working together with other parties to improve our knowledge of the market, so we cross boundaries.” Swetech</p> <p>“We are not looking for other activities outside the pipes business. We might run into something—for instance, we are doing some testing with heat exchange because we were asked to do so—but we won’t take that forward.” Systech</p> <p>“Ideas mainly come from within; we still do not interact with the outside.” Biotech</p> <p>Commitment</p> <p>“We are quite active; we have a nice collaboration with microbiologists, and we’ve been working with two masters students and collaborating with the department of biology, where we learned about disinfection and how to control legionella.” Sprintech</p> <p>“Customers, suppliers, and subcontractors contribute with a lot of ideas. We are committed to meeting them face to face all the time, and they are constantly helping us and helping us by saying how good something is, or how tricky it is to assemble, so here we can improve by doing this and that, and we see if it fits the general specification of the product.” Swetech</p> <p>“We can wait; there’s no rush. We can afford another year, after which the technology will be better and better and can be sold to the market in a safe way.” Systech</p> <p>“We are committed to having an efficient working product.” Biotech</p>	<p>Learning behavior</p>