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HOW SOCIAL INTERACTIONS FORM THE FUZZY FRONT END OF RADICAL INNOVATION IN LARGE FIRMS

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by
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Vienna, 30/06/2017

Affidavit

I, **DANIELA BUCHMAYR**, hereby declare

1. that I am the sole author of the present Master's Thesis, "HOW SOCIAL INTERACTIONS FORM THE FUZZY FRONT END OF RADICAL INNOVATION IN LARGE FIRMS", 73 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Preface

"Logic will get you from A to Z;
imagination will get you everywhere"

(Albert Einstein)

I really appreciated the chance to reflect in depth on an important and interesting topic like radical innovation. The fact that I accepted a new position at the beginning of the master thesis gave me the opportunity not only to reflect, but also to actively shape radical innovation in my firm. Directly by pursuing radical ideas and indirectly by helping to develop and establish a new corporate innovation management system.

I want to thank my husband Timo, who inspired me to start the MBA program, and challenges my thoughts. Thank you for being my cherished sparring partner on all business and general topics in life.

Many thanks also to my children for constantly expanding my horizon and imagination since the day they were born. Thank you, Jana for your outstanding support during the last turbulent months. Thank you, Mia, for your meticulous search for typos in this thesis. I could see the year in a UK college paid off. Thank you, Lion, for being the most patient 9 year old a mum writing her master thesis could wish for.

I finally want to thank Trevor for being a mentor on all crazy, disruptive ideas. Thank you for your support and encouragement.

Abstract

This paper aims to deepen the understanding of the mechanisms triggering radical innovation in large firms by exploring the impact of social interaction on the fuzzy front end.

The provided information shall help managers and innovators in large firms to analyse their existing innovation ecosystem and identify its shortcomings. This work will not only contribute knowledge about key influencing factors but more importantly about the holistic context in which those factors are nurtured in order to increase the firm's radical innovation performance.

The outcomes of a conducted literature review are used to develop a framework, which present the dynamics and relations between several components critical for the success of radical innovation. These components are influenced by several factors, which are identified, listed and discussed. Subsequently a graphical presentation is created to indicate the complex interrelations between those factors. The framework and its influencing factors are finally tested in a case study using qualitative research methodology. The subject of the case study is a disruptive innovation project at a large, multinational supplier to the pharmaceutical industry.

The literature review shows that the fuzzy front end has the highest impact on radical innovation success, but is characterized by high uncertainty and discontinuity of the existing status quo. In that environment, it needs imagination of the future or market visioning competence; an ability, intuitive and creative individuals possess. Hence, those individuals are able to recognize a need or an opportunity. By social interaction with internal and external peers, ideas can be generated and evaluated. Through identifying and testing possible solutions (solve problems) new knowledge is created and new learning takes place. Further social interactions within the firm transfer these learnings into new organizational procedures, strategies and culture. By that process of organizational learning, a continuous renewal and implementation of learnings occurs and influence in turn the fuzzy front end of new radical innovation projects.

The identified factors influence that genesis of radical innovation by supporting either a necessary prerequisite or by being part of the social interaction dynamics itself. Prerequisite factors are necessary on the individual level (personal traits, cognitive and creative ability, prior knowledge and experience, …) as well as on the organisational level (resources, stimulating work environment, encouragement, culture,...).

Which influencing and enabling factors are most important for a specific firm's setting, will depend on many case specific aspects, such as the nature of the industry the firm is serving, the company's risk appetite or the firm's current innovation culture and procedures. Thus, a generic conclusion on the most important single factor or factor group can and should not be made.

Nevertheless, there are a few universally valid conclusions resulting from this study:

(1) Certain personal traits and preconditions favour creativity, social interaction and problem-solving activities. While one may not know in advance which technology and prior knowledge will be of interest, there is evidence to predict which personality traits will be crucial to pursue radical innovation. Diversity and open innovation networks can help hedging the firm's technological capabilities.
(2) Social relations, (informal) exchange of knowledge, experiences or mental models need trust between peers to emerge. Creating trust to exchange, taking time for sense making and transfer of sticky knowledge, joining activities in a shared space, all this takes time, space, physical contact and above all, it takes a continuous approach and support from the firm's management.
(3) Radical innovation cannot directly be enforced to happen, but with the right managerial and leadership decisions the probability for radical ideas to emerge and radical innovation to succeed can be increased significantly.

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List of abbreviations

FFE ..... Fuzzy Front End

OSD ..... Oral Solid Dose

FDA ..... Food and Drug Association

GSK..... GlaxoSmithKline

1 Introduction

"40% of today's Fortune 500 companies are predicted to disappear in the next 10 years" (Rygaard-Hjalsted and Stengel, 2016, p.4). Their competition will no longer come from other large multinationals, but from a two-man-in-a- garage company growing a disruptive enterprise. The reason for that is the accelerated speed by which exponential technologies appear on the scene, incubated in a new economy of digital transformation. In the light of these disruptive changes, radical innovation becomes a necessity for all organizations with an appetite for future growth and competitiveness.

While most executives are aware of the importance of innovation, only 13 % reported in a recent survey done by Boston Consulting Group that their companies "have a significant ambition to deliver radical innovation" (Wagner et al., 2014, p.10). 70% of executives interviewed in the same survey, stated that "their companies' innovation capabilities are only average". (Wagner et al., 2014, p.9). Similar findings come from Arthur D. Little's Breakthrough Innovation Survey[1], where "88% of companies were unsatisfied with their current Breakthrough Innovation performance, with not a single respondent reporting being very satisfied" (Härenstam et.al, 2015, p.1). One of the reasons for that finding may be revealed in Deloitte's Global Board Survey 2016, where 25% considered "their board's understanding of Innovation/ R&D strategy as limited", and "29% attest their board have a limited understanding of talent management". (Rygaard-Hjalsted and Stengel, 2016, p. 11).

So, why do so many firms and managers struggle with developing and commercializing radical innovation? Radical Innovation means the discontinuity of existing, established, known and understood realities and mechanisms. Hence, discontinuity leads to uncertainty, in the form of technical and market uncertainty (Reid and De Brentani, 2004) as well as organizational and resource uncertainty (O'Connor and Rice, 2013). This is especially true for the front end of a radical innovation process, the so called *fuzzy front end* or *FFE.* Within the radical innovation process the fuzzy front end (FFE) is considered to have the greatest impact on the radical innovation success (Koen et al., 2001), but also shows the highest degree of

[1] 83 companies from more than 30 different industries in 14 countries, with an emphasis on European based companies were surveyed. 70% focus on B2B. Average participant turnover is €15bn.

uncertainty. Several studies have shown that taking the wrong decisions at that stage will not only lead to costly and timely deviations, but may eventually kill the idea completely. (Kim and Wilemon, 2002a; Reid and De Brentani, 2004; Verworn et al., 2008).

Dealing with high levels of uncertainty is not only difficult for managers and individuals involved in the FFE, most people simply lack the capability to deal with complexity (Tversky and Kahneman, 1974). One crucial skill needed to handle uncertainty in the context of radical innovation is the ability to link advanced technologies with market opportunities emerging in the future (O'Connor and Veryzer, 2001; Reid et al., 2014). It is the individual's intuition that leads to identification and understanding of emerging patterns in the environment (Reid and Brentani, 2004) and only the individual's creativity enables an imagination of a future before this future emerges (Scharmer, 2001). Hence, the ability to sense emerging potential or opportunities is a cognitive process at the individual level, while innovation itself requires a social context to take place (Reid and Brentani, 2004; Van de Ven, 1986). Innovation in its essence is a social process, as it needs individuals reaching out and interacting with others who may possess other pieces of the puzzle needed to solve a complex problem (Smulders, 2007).

Previous research and management practice focused more on the organizational level and managerial aspects of the FFE of radical innovation. That's probably due to the fact that those aspects are more in line with traditional managerial practice such as control and measure. This study will contribute to a better understanding of the social interactive aspects of the FFE of radical innovation by proposing a theoretical framework based on the analytical review of relevant existing literature on innovation, organisational learning and knowledge management; and the validation of this framework by means of a case study.

Companies planning to stay at the forefront of innovation will need a comprehensive understanding, more efforts and better systems to nurture and enable the social interactive processes in order to support their Intrapreneurs and spread the learnings within the organisation.

2 Literature review

2.1 Radical innovation

There are various synonyms used for radical innovation in academic literature, such as disruptive, breakthrough or game-changing innovation. Scholars define this type of innovation in several ways and the scientific community has not reached consensus yet about a universally accepted definition and terminology for non-incremental types of innovation. If one imagines a linear scale of newness or originality of innovation, the lower end (less new and original) is described as incremental innovation, while disruptive innovation would describe the other end of the scale (figure 1). In this paper the term radical, breakthrough or disruptive is used equivalently to describe the same type of innovation.

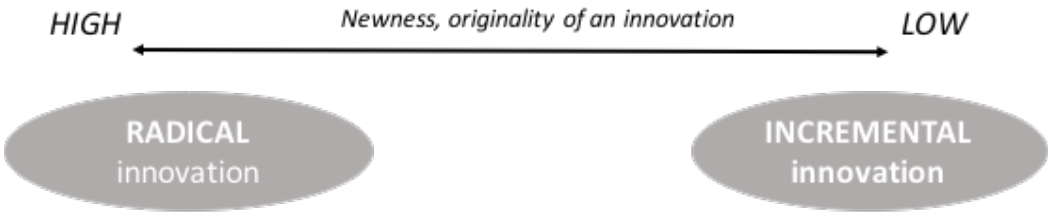

Figure 1: Originality spectrum of Innovation

Garcia and Calantone (2002) classified innovation based on a technology and market perspective on the one hand, and on a macro and micro level on the other hand. They defined radical innovation as innovation that results in marketing *and* technological discontinuity on *both* a macro and micro level (p. 120). The macro level refers to the external perspective and measures how the characteristics of the innovation are new to the world, the market, or an industry, whereas the micro level refers to the internal perspective and measures the innovativeness from the firm's or its customer's perspective. On the contrary, an incremental innovation impacts only the micro level and shows *either* a technological *or* a marketing discontinuity, but not both at the same time. Now, all other combinations of marketing/technological discontinuity on macro/micro level (all innovations between the radical and the incremental definition) are called *"really new innovations"* (Garcia and Calantone, 2002, p. 120). Table 1 gives an overview of the innovation typology based on this definition.

Table 1: Typology of Innovation (adapted from Garcia and Calantone, 2002, p. 120-121)

	DISCONTINUITY					
INNOVATION TYPE	Macro Level			Micro Level		
Radical	Marketing	AND	Technology	Marketing	AND	Technology
Really New	Marketing	AND/ OR	Technology	Marketing	AND/ OR	Technology
Incremental	-		-	Marketing	OR	Technology

Another important aspect pointed out by Garcia and Calantone (2002) is that the degree of disruption is relative to a specific firm. What may be a really new innovation to one firm may be an incremental innovation to another firm, even if both pursue the same innovation. This is important in respect to the focus of this study, namely the socio interactive aspects of radical innovations. The degree of challenge that individuals will face while pursuing a disruptive project will depend on the degree of disruption to their firm's processes. This may vary even within one large international firm, where different locations may follow different processes or show different cultural attitudes towards uncertainty. Even the discontinuous character on the macro level of one specific disruptive project may differ for an international firm in various markets and regions depending on that particular market's or region's risk attitude and openness to change.

Therefore, I suggest that this typology, as with any other definition or typology of innovation, should be considered in the specific context of interest and be accepted as a guideline rather than a hard and fast rule. For the purpose of this study, both "radical" and "really new" innovations according to Garcia and Calantone's (2002) definition were considered.

2.2 The Fuzzy Front End: definitions and managerial challenges

The fuzzy front end of an innovation or new product development process is defined as the period from generation of an idea to its formal development project installation (Smith and Reinertsen, 1991), or its termination. Typical activities of the fuzzy front end are idea generation, idea assessment and concept development. This includes assessment of ideas attractiveness and risk, alignment with existing project portfolio or strategy, market analyses,

development of product concept, early prototyping for proof of concept or other similar tasks (Herstatt and Verworn, 2004).

The fact that the early stage of radical innovation has not been so much the focus of researchers and is still hardly addressed strategically by most companies (Gassmann and Schweitzer, 2014) does not make radical innovation an easier task to perform or manage. In addition, the later stages of innovation processes are better understood and easier to control and measure due to a larger amount and greater certainty of available information. The later stages also allow traditional, well established managerial tools and practices to be used. Due to the high uncertainty at the FFE of radical innovation, future revenue expectation, project cost, goals and clear timelines are usually not available. Hence, the attempt to either ignore the FFE of radical innovation as a specific challenge or just use the established (but inappropriate) managerial tools is a widely spread practice in many firms. Easy to install, linear approaches to the management of the FFE may be simple and straightforward to understand, track and oversee, but fail to take the reality of radical innovation at the front end into consideration. Because of the high uncertainty, complexity, parallelism of several tasks performed by multi-disciplinary teams at the same time and the circular nature of human learning, the individuals in the process become more important than the strict chronology of predefined innovation process sequences. (Gassmann and Schweitzer, 2014).

Successful performance of the fuzzy front end of radical innovation requires risk taking and acceptance of failure as normal parts of the process. Evidence shows that companies being successful with radical innovation have a clear strategy for their radical innovation process and provide a supportive environment for radical innovation projects (Rygaard-Hjalsted and Stengel, 2016). A survey[2] conducted in 2015 by the Board Network (the Danish Professional Directors Association) revealed that 65% of the interviewees replied negatively to the question whether radical innovation had a formal position on their board's agenda. (Rygaard-Hjalsted and Stengel, 2016, p. 22). But this is exactly the level within the

[2] based on 582 global corporate board professionals from a representing 43 countries (Global Board Survey 2016 by Deloitte and Board Network)

organisation where radical innovation must be supported to succeed. Long term survival and successful management of a firm, in particular during turbulent economic times, requires an appropriate balance between exploitation and exploration (March 1991). Exploiting existing assets, products and 'know how' in order to increase efficiency and reduce costs as well as exploring new business opportunities to offer advanced, innovative products and services are fundamental economic success factors for the company. Unfortunately, they compete for the same scarce resources (March 1991).

Mastering this ambidexterity means continuously "exploiting proven capabilities and dynamically exploring new ones, [switching] between stability and flexibility, between certainty and uncertainty, between formal and informal interaction" (Gassmann and Schweiter,2014, p. 8). As one can imagine, this is quite challenging to unite in a single executive (Birkinshaw, Gibson, 2004; Smith and Tushman, 2005). Smith and Tushman (2005) noted in this regard the importance of paradoxical thinking skills for effectively managing exploitation and exploration.

To leverage a firm's technological competence, which is an important precept of innovation, Danneels (2007) found "that the resources, both financial and human, need to be sufficient (in amount), dedicated (in allocation), and consistent (over time)". Consistent and sufficient support is needed not only for each innovation project , but more importantly as a constant driver for a firm's radical innovation culture and processes. Individuals must be sure that failure and certain risk taking when pursuing a radical innovation idea will not put their career on risk, independent of the last quarter's figures. Securing the required level of consistency in the firm's attitude towards radical innovation, providing sufficient resources for projects not serving the current markets and customers or enabling exploitation of an idea even when it runs contrary to the prevailing strategic directive, unquestionably needs in most large companies the board's support.

2.3 Specific challenges of large firms

It became kind of common sense that start-ups are good at radical innovation and large, established firms are not. Schumpeter already argues in 1934 that small, entrepreneurial firms are most likely to be the source of most innovation (Schumpeter, 1934). After many

years of contradictory results from various studies on that topic, Rebecca Henderson could show in a field study that established firms invested more in incremental innovation and that their research efforts in seeking to exploit radical innovation were significantly less productive than the efforts of start-ups (Henderson, 1993).

In the 1980s, Asian firms competitively challenged western companies in the field of factory automation, consumer electronics, car manufacturing and other important areas. The majority of US and also European firms reacted to a great extent with an emphasis on cost competitiveness and quality improvements by creating operational efficiencies. That led, in turn, to a focus on incremental innovation of existing products and processes.

Another reason for the different approaches towards radical innovation and risk appetite lies, in my view, in organizational development. Whether one follows Greiner's evolution and revolution model (Greiner 1972, 1998) or Phelps' tipping point framework (Phelps et al. 2007), both agree that a company experiences different life cycles and thus has to change its approach on its journey of maturation and growth. Each life cycle has its own drivers and activities with varying managerial problems and practices.

A start-up will not be assessed by its last quarterly earnings report. Its success is measured on how well it identifies a market need and how well it matches its solution to that need; therein lies a promising and compelling business concept. Conversely, a large, mature firm is measured on its profit. Once the company knows how to solve a certain market problem, it is driven by optimizing processes and structures towards achieving more efficiency. As Greiner (1972) pointed out, the management focus, the firm's structure, the management style, the control system and many other aspects will change on that journey of maturation and growth. Large, mature firms are seeking operational efficiency and teach their employees to leverage existing assets and distribution channels, and listen to their best (existing) customers. Openness, curiosity and creativity have little room in an efficiency seeking corporate environment. Large firms are therefore more financially driven and less risk tolerant than start-ups.

"No company ever created a transformational growth product by asking: How can we do what we're already doing a tiny bit better and a tiny bit cheaper?" (Wessel 2012). Thus, a

large firm seeking to explore radical innovation does not have the natural setup to do so. Contrary to a start-up, it must actively create the room and the right environmental setting to pursue radical innovation.

2.4 Intuition and creativity

Now radical ideas do not usually emerge in the boardroom. So, despite the critical influence of the firm's management on strategy, processes and innovation culture, the idea for a radical innovation will typically come from the employee level. Garcia and Calantone (2002) pointed out that "radical innovations often do not address a recognized demand but instead create a demand previously unrecognized by the consumer" (p. 121). Thus, radical innovation "requires both, insight and foresight" (O' Connor and Veryzer, 2001, p. 231), an imagination of a future that does not exist yet (Scharmer 2001). But how does it happen that employees develop a foresight? How do people "discern and comprehend something new" (Crossan et al.,1999, p. 526), something for which they have no prior experience or even explanation? Crossan et al. (1999) explained this with intuition, the "preconscious recognition of the pattern and/or possibilities inherent in a personal stream of experience" (Weick, cited in Crossan et al., 1999, p.525). Crossan et al. (1999) further differentiated between two types of intuition, the expert intuition and the entrepreneurial intuition. The expert intuition builds on the expert's past experience, its recognition and awareness, reflection, feedback and the resulting learning process (Simon, 1987). After a certain period of time this initially conscious process turns into tacit knowledge. "The expert knows, almost spontaneously, what to do" (Crossan et al., 1999, p. 526). They further described the entrepreneurial intuition as future oriented, as the ability to make novel connections, to "perceive new or emergent relationships and discern possibilities that have not been identified previously "(p. 526). While expert intuition is at least in the beginning a conscious process, entrepreneurial intuition is a largely subconscious process: "in fact, trying to force it to a conscious level too soon may prevent it from happening" (Watson, cited in Crossan et al., 1999, p.527). Hodgkinson et al. 2009 describe intuition as "a judgment for a given course of action that comes to mind with an aura or conviction of rightness or plausibility, but without clearly articulated reasons or justifications - essentially *knowing* but without knowing why" (p.279).

While intuition helps to explain the foresight capability of an individual, radical innovation also requires insight (O' Connor and Veryzer, 2001). Insight is described a "sudden and unexpected solution to a problem", "the ability to see into and articulate the structure of a problem" (O' Connor and Veryzer, 2001, p.279). O'Connor and Veryzer further pointed out that it often takes an incubation period for an insight or so called "eureka" moment to occur, as the non-conscious processes need a certain freedom from rational analysis. Intuition is often a presage of an insight and the relationship between them is an object of interest for cognitive neuroscientists' research.

Neither intuition nor insight "occur in a cognitive vacuum or in an unprepared mind" (Hodgkinson et al., 2009, p.279), as learning and experience have significant influence on both. Intuition must not necessarily lead to insight. However, several studies (Ravasi and Turati, 2005; Dutta and Thornhill 2008) on intuitive decisions of managers have found a positive association between intuition and quality and speed of decision, as well as between intuition and financial and nonfinancial performance of the wider organization. To summarize, intuition and insight allows rapid problem framing and identification of appropriate actions before rational analysis can determine the course of action. "Intuition is the beginning of new learning" (Crossan et al. 1999, p. 527) and by enabling "novel and unexpected connections among concepts [intuition] is one of the hallmarks of creativity" (Hodgkinson et al., 2009).

So, while intuition influences the recognition of new patterns, it takes creativity to come up with the ideas to solve a problem.

Woodman et al. (1993) defined organizational creativity as "the creation of a valuable, useful new product, service, idea, procedure, or process by individuals working together in a complex social system" (p. 293). Creativity is not only the first step of innovation, the driver for idea generation in the fuzzy front end (Amabile, 1996; West, 2000) but also an essential part in the idea implementation process (Paulus, 2002). The nature of the highly uncertain innovation process leads to a reiterative cycle of generation and implementation of new ideas, not only in the beginning, but also later in the process to overcome newly occurring challenges.

Several frameworks describe influencing factors on individual, group or organisation creativity. Amabile (1997) focused on the environmental factors, influencing creativity on the individual and organisational level. She identified expertise, creative thinking skills and intrinsic motivation as essential factors at the individual level. Organizational motivation (providing financial and personnel resources) and managerial practice (providing challenging working environment and encouragement) are the core enabling factors on the organisational level (Amabile, 1997). Woodman, Sawyer and Griffin (1993) described the interactionist perspective and suggested that creativity is a complex interaction between the creative individual and its environment. They further pointed out the difference between individual and group creativity, which together influence the organisation's innovation capabilities ("organisational creativity"). Antecedent conditions such as prior experience and knowledge, divergent thinking and personality were identified as the main influencing factors on individual creativity. At the group level the interaction between the group members, such as group diversity, norms, values and processes are the key influencing factors on creativity.

The relation between personality and individual creativity was investigated by many researchers without creating consistent results (e.g. Woodman, Sawyer, Griffin, 1993; Amabile, 1996, …). Guo et al. (2017) analysed individual creativity based on the big five personality traits, openness to experience, agreeableness, extraversion, neuroticism and conscientiousness. He confirmed that openness to experience shows the most consistent and clearest relationship with individual creativity. Guo et al. (2017) explains that those individuals have a high willingness to explore, are curious and proactive. Hence, they absorb information easily and are more likely to generate creative ideas. He further suggests and confirms in his study that extrovert individuals are more likely to demonstrate divergent thinking (relate positively to creativity) due to their enthusiasm, proactive behaviour and willingness to take risks (Batey, Furnham & Safiullina, 2010, Guo et al. 2017).

Guo et al. (2017) could finally confirm their hypothesis that neuroticism and conscientiousness show a negative relation to individual creativity. They explained that neuroticism is negatively related to individual creativity, as it takes high emotional stability to perform under high uncertain conditions. Although conscientious individuals are generally goal oriented (George and Zhou, 2001), their tendency to follow rules and willingness to

confirm contradicts with the desire to seek change, which is a necessary precondition for creativity and innovation (Guo et al. 2017).

Sundgren et al. (2005) pointed out the important relation between organisational creativity and the individual's access to relevant scientific knowledge. Hence, free exchange of information is crucial for creativity. Woodman et al. (1993) cites research that shows that creative performance is increased if groups support open information sharing. Openness to share information with other individuals within a group or organisation requires self-initiated activities, which are primarily driven by intrinsic motivation (Sundgren et al., 2005). Sundgren et al. (2005) define intrinsic motivation "as the motivation to work on something because it is interesting, involving, exciting, satisfying, or personally challenging" (p.362). Other researchers confirmed evidence that intrinsic motivation is positively related to creativity (Woodman et al., 1993; Amabile, 1996). Due to intrinsic motivation, individuals will only make full use of their knowledge – and their creative capabilities - if they are matched with projects of their own (professional) interest (Sundgren et al., 2005).

The influence of stress and time pressure on creativity is another interesting aspect. West (2000) described that creativity occurs when individuals feel free from pressure, safe and exposed to a positive environment, whereas in a situation with a higher level of stress, individuals seem to rely rather on habitual solutions. Amabile (1996) explains this as the decrease of intrinsic motivation through external pressures or demands. This is contrary to the situation in the problem solving context of innovation, where a certain threat, pressure or urgency in solving a problem seems to have a rather stimulating effect. According to the motto "necessity is the mother of invention" high external demands help organisations to overcome resistance to change.

The idea of the lone inventor as the main source for breakthrough innovations was championed for years (Steinbeck, 1952; Schumpeter, 1934). Many researchers see creativity as an evolutionary search process build on combination of existing ideas. (Campbell 1960, Romer 1993, Weitzman 1998, Simonton 1999). The creation of an idea in the creator's mind is a process of selecting ideas and testing them against the creator's criteria towards usefulness to the problem and intrinsic novelty. After a promising idea was chosen, developed and communicated, a second selection process starts with other relevant individuals in a

social group or intellectual community (Amabile et al., 2005). Those two phases of the creativity process can happen either in a single person or within a group. This extreme version of a lone inventor without any feedback or interaction or collaboration is very rare, in particular in today's connected world. The other extreme, where both generation and evaluation of an idea are happening in a social process is increasingly common today (Wuchty et al. 2007). The last phase, the retention phase, where members of a community "evaluate the selected ideas and go on to adopt a very few of them in their own creative searches" (Singh and Fleming, 2010) is a purely social process. Singh and Fleming (2010) showed by analysis of over half a million patents that "individuals working alone, especially those without affiliation to organizations, are less likely to achieve breakthroughs and more likely to invent particularly poor outcomes" (p. 41).

Creativity, as insight and intuition, is typically not a lucky coincidence, rather it is guided by prior knowledge available for new combinations within the creator's mind. The creator's ability to identify the relevant knowledge elements, which can be used to build the new solution, influences the creative output (Amabile et al., 2005). Furthermore, several scholars (Langley and Jones, 1988; Sternberg, 1988) highlighted that the number and breadth of those cognitive elements influence the probability of novelty of the resulting ideas as well as their variation. This relation between creativity and prior knowledge shows an inverted u-shape curve. One reason why too much prior knowledge seems to block creativity lies in the functional fixedness of individuals. Individuals adhere to previous solutions or experiences when confronted with new problem solving tasks (Duncker 1935, 1945). There are several techniques described to overcome functional fixedness. Another solution to that problem is diversity. A group with larger heterogeneity has a broader range of ideas to draw on. Reflection and exchange with external sources of knowledge will bring stimulation and increase creativity.

Nonaka and Toyama (2002) suggest that firms needs to institutionalize creative routines. It is not easy to find the right balance when it comes to creativity. Too much structure kills creativity, while good organizational routines can support the FFE by promoting knowledge creation and creativity.

The issue with homogeneity and idea creation is not only relevant during the creation phase of an idea, but can also be an issue when assessing new ideas, as for example in the earlier discussed second phase of a creativity process. “Individuals, whether experts or non-experts, are notoriously bad evaluators of their own ideas” (Simonton, Runco and Smith, cited in Singh and Fleming, 2010, p.44). Hence, a diverse team has an essential advantage in the identification and assessment of the best ideas. It will consider the idea from a greater variety of viewpoints and come up with a broader range of solutions to an innovation problem.

Figure 2 shows an illustration of the so far bespoken dependencies in the radical innovation process.

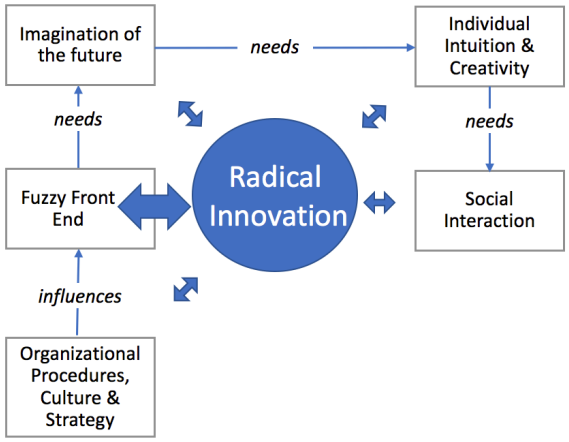

Figure 2: Dependencies of bespoken aspects in a radical innovation process

So how are the individual’s intuition and creativity linked to the organisation’s innovation success? The linking step is learning, both individual and organisational learning.

2.5 Organisational and individual learning

As today’s industries have transformed or are in the process of transforming towards a knowledge based economy, an innovative, successful company must above all be able to learn as an organization constantly. Crossan et al. (1999) described organizational learning as a “principal means of achieving the strategic renewal of an enterprise” (p.522). In other words organizational learning is also about constantly balancing continuity and change.

To do so, new ways of thinking and action must be developed and combined with existing competences and assets, on an individual, group and organizational level. Our world has become more complex, and so has the accelerated-, competition for innovative technologies and new emergent markets. These new conditions require something different to just doing more of the same. Therefore, the organization's ability to not only learn, but learn at an accelerated rate, will become a key source of competitive advantage. Or as Nonaka (2007) stated: "in an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge"

As described earlier in the text, the main issue of the front end of radical innovation is managing and dealing with high uncertainty. To reduce this uncertainty a company must either gaze into a crystal ball or "link advanced technologies to market opportunities of the future" (O'Connor and Veryzer 2001) in order to develop a so-called market visioning competence. Scharmer (2001) describes this as the "capacity for *precognition*, the ability to sense and actualize emerging potentials […] before they become manifest in the marketplace." Now, organizations don't possess the intuition needed to recognize those patterns in their environment, but humans do (Crossan et al. 1999). Reid and Brentani (2004) propose that individuals who interact with the firm's environment (so called "boundary spanners", as they act at the boundary of an organization) are primarily responsible for the information exchange, but need prior technological knowledge to interpret newly perceived information. That in turn allows them to recognize the relevant pattern. They further propose that "pattern recognition is a form of distinction making, which effectively allows individuals to separate potentially relevant from irrelevant background information" (Reid and Brentani, 2004, p.179). "The process of innovation is not simply information processing; it is a process to capture, create, leverage, and retain knowledge'' (Scharmer, 2001, p. 140).

To gain a better understanding how knowledge is transferred from the environment to the individual (boundary spanner), spread to other individuals and manifest itself within the organisation, I will discuss knowledge in more detail.

2.5.1 Different kinds of knowledge

Nonaka and Takeuchi (1995), expanding on the work of Polanyi (1966), defined knowledge as "a dynamic process of justifying personal belief towards the truth" (p. 58). They distinguished between 2 types of knowledge: explicit and tacit knowledge. Explicit knowledge is described as knowledge that exists (and can be forwarded) in the form of words, numbers, data and instructions (so called "*know what"*). Explicit knowledge is in line with the classical western management view seeing knowledge as information which can be stored and forwarded "formally and systematically" (Nonaka and Konno, 1998, p.42). The organization is consequently seen as an "information processing machine that takes and processes information from the environment in order to solve a problem" (Nonaka et al. 2001, p.491)

Contrary, tacit knowledge is knowledge linked to individuals, is impossible or difficult to articulate, communicate and therefore difficult to share as it is experience based or embedded (often referred to as "*know how"*). Or as Polanyi simply stated it: "We can know more than we can tell" (Polanyi, 1996, p.4). Tacit knowledge has two dimensions, the technical dimension is based on an individual's experience and skill (know how, craft) while the cognitive dimension refers to one's "ideas, beliefs, values, mental models and emotions" (Nonaka and Konno, 1998, p. 42). Tacit knowledge is built on past expertise and its reflections. A process, once conscious, turns into tacit knowledge, where conscious thinking is no longer necessary to take the right action. Crossan et al see this tacit character of knowledge as the main reason for the troubles experienced when transferring expertise: "It is highly subjective; deeply rooted in individual experiences; and very difficult to surface, examine, and explain" (Crossan et al., 1999, p.526)

Scharmer (2001) introduced a third aspect of knowledge, a "tacit knowledge prior to its embodiment" the *self-transcending knowledge* (p. 137). He describes self-transcending knowledge as the "ability to sense and presence the emerging opportunities, to see the coming" (p. 137). As a kind of tacit knowledge (although not embodied yet), also self-transcending knowledge is difficult to describe or transfer.

For better understanding of those 3 types of knowledge I will illustrate the differences by using the example of riding a bicycle. A person who rides a bicycle many times and learns to

keep balance has knowledge about cycling. This person will not need to think how to keep balance, as an expert she knows how to do it without conscious thinking about the process.

If this expert now transfers her knowledge to a person who never ridden a bike before, she can bring her knowledge into words or instructions to transfer it to the novice. This knowledge would be the explicit part of knowledge. The novice can read the instructions carefully, get on the bike and guess what will happen? The novice will not be able to ride the bike without losing the balance right at the start. He read how to use the handlebar and the driving speed to ensure balance. But the novice has to consciously think about the process while the bicycle starts tipping over. The novice simply misses the experience of the expert. This missing knowledge, which could not be transferred by words and instruction is the tacit knowledge.

The history of bicycling also offers a good example for self-transcending knowledge: Karl Freiherr von Drais who invented the running machine (and is therefore considered to be the godfather of the bicycles) was exposed to starving horses due to a climatic catastrophe in 1816 and the resulting crop failures. He invented the running machine, as he could presence transport issues due to a lack of horses and then saw an emerging opportunity for human powered, mechanized transport machines. Thus, he could sense a future before it existed.

2.5.2 What is learning?

A central question in scientific discussions revolves around the nature of learning. Does learning occur when new knowledge is acquired? Or does learning require the accompanied shift in action or change in behaviour (Easterby-Smith, Crossan, Nicolini, Fiol & Lyles, Weick, cited in Scott 2011)? This question has indeed practical implications, in particular in the context of innovation. If we consider learning purely as the acquisition of knowledge recognized as potentially useful (Huber 1991), how would this learning be sustained, without being embedded into action or behaviour?

Learners must have the ability and the motivation to detect and recognize a learning need. This perceived need is the driving force ”to move from contentment (I know that I know) to exploration (I know that I do not know) […] .This in turn is influenced by what they

already know or the complexity of their mental model" (Scott, 2011, p. 4). Inkpen and Crossan (1995) observed that the recognition of a need as well as openness to new learning are antecedents to acquiring new insights from others. Cook and Brown (1999) further noted that knowledge becomes valuable only as it is employed, combined and consumed. Also Nonaka (1994) stated "while tacit knowledge held by individuals may lie at the heart of the knowledge creating process, realizing the practical benefits of that knowledge centers on its externalization" (p.20). Thus, the combination of cognitive processes and their transformation into a new behaviour seems to be a mandatory aspect of learning.

In the context of organizational learning Crossan et al. (1999) state clearly: "Organizational learning links cognition and action (p.524). If learning only generates value by bringing knowledge into action, then learning necessarily involves the ability to collaborate and socialize (Wenger 2006).

Nonaka and Konno (1998) described this process of learning, or knowledge creation between individuals, groups and organisations in detail. They suggest in "the concept of *Ba*" that knowledge creation needs a shared, enabling space where individuals can exchange and relationships can emerge, whereas this space can be physical, virtual, mental or a combination of those. They called this space "*ba*", a Japanese word, which can be translated as "space". Knowledge (intangible) is embedded in *ba*, and will turn into transferable information (tangible), if separated from *ba.* Erich von Hippel described the same aspects and need in different words: "To solve a problem, the relevant information and the problem solving capability must be brought together - physically or virtually - at a single locus" (von Hippel, 1995, p. 429).

Nonaka and Konno (1998) describe knowledge creation as a dynamic "spiralling process of interactions between tacit and explicit knowledge" (p.42), the so called SECI process. They describe the SECI process of knowledge creation in 4 steps: socialisation, externalization, combination and internalization. The first steps, socialisation, is the sharing of tacit knowledge between two individuals. Nonaka and Konno point out that this step is called socialization, as the exchange of tacit knowledge is the result of joint activities. Individuals spending time with each other in the same space (*ba*), rather than purely swap information

(written or verbal instructions). The second step, externalization, is described as the conversion from tacit knowledge (highly personal knowledge) into explicit knowledge (information easy to understand for others). During this step an individual commits to a group by integrating its intentions and ideas into this group. Through dialogue the sum of the individual's ideas and experiences become integrated into the group's mental model. In the third step, the combination, explicit knowledge is transferred into more complex explicit knowledge. This involves collection of information from inside and outside the organisation, combining it with new knowledge and the spreading and systematizing of this new explicit knowledge within the firm. According to Nonaka and Konno (1998) this is where "justification - the basis for agreement- takes place" (p.45). The last step in the knowledge creation spiral, the internalization, describes the process of conversion of the (new) explicit knowledge base into the firm's tacit knowledge. For that to happen, explicit knowledge of the firm has to be embodied in "action and practice" (Nonaka and Konno, 1998, p.45) through training programs, strategy, innovation or other concepts. Through learning by doing, the individual can access the explicit knowledge of the organization, learn about the organization itself and his role within this organization. From this point, where newly acquired tacit knowledge occurs at the individual level, the knowledge creation process starts over again.

Crossan, Lane and White (1999) offer a similar model of knowledge creation in organizations, the "4I framework of organizational learning. The 4 described levels of learning are intuiting, interpreting, integrating and institutionalising. The processes of intuition and interpreting are taking place on the individual level and cover the recognition of a new insight and its explanation through dialogue and joint actions with other individuals. The integrating step is characterized by the development of shared understanding among group members and following coordinated actions through mutual adjustments. Those actions are turned into routines by Institutionalizing and embedding the learnings from individuals and groups into organizational rules and procedures.

An important aspect of knowledge transfer is described in innovation literature under the terminology "stickiness". Information and knowledge must be transferred from the point of origin to the point of problem solving activity. Depending on the complexity of the problem

or the accessibility of the information, this knowledge transfer can be smooth and easy to accomplish, or the opposite. Stickiness denotes difficulties experienced in the knowledge transfer process (Szulanski 1996; von Hippel 1994). This stickiness hinders the diffusion and distribution of knowledge and therefore challenges innovation.

Nonaka and Konno (1998) built on their SECI model by suggesting each of the 4 steps correspond with a specific *ba*. Each *ba* is supporting a particular conversion process and therefore accelerates the knowledge creation process. The *ba* supporting the described socialization step is called "Originating *Ba*" (p. 46). Originating *ba* is described as the place where the individuals share their experiences, feelings, values and mental models in order to empathize with other individuals. Therefor it is the place where "care, love, trust and commitment" emerge between individuals (Nonaka and Konno, 1998, p. 46). Physical face to face contact (within the firm, but also with external sources of knowledge) is described as the key requirement in this phase of knowledge creation in order to provide direct exchange and (idea) stimulation.

In the context of the front end of innovation, the *interacting ba*, the *ba* supporting the externalization step, is also of high relevance for a firm. Particularly, as the interacting *ba*, can be more easily actively (positively) influenced by smart decisions of the firm's leaders or managers.

The question of consciousness is another important aspect in the learning process. While the acquisition of new insights can be a function of conscious thinking, a result of a fortuitous incident or achieved by performing a manual task, most organisational learning theorists agree that learning requires conscious cognitive reflection (Crossan, Lane, & White, 1999). For this reflection, which is critical to the learning success of the individuals and thus that of the organization, very often no space or time is provided in a firm's organisational routine.

So beside ensuring the right mix of knowledge, capabilities and backgrounds in the composition of a project or innovation team to allow sharing and exchanging different mental models, it is also essential to enable a space, *ba*, to reflect on the individual's and the company's learnings. Successful companies such as 3M or Honda institutionalized the

"collective reflexion […] in the company culture" and "people engage jointly in the creation of meaning and value" (Nonaka and Konno, 1998, p.47).

Figure 3 shows the knowledge spiral and corresponding characteristic of *ba* as described above.

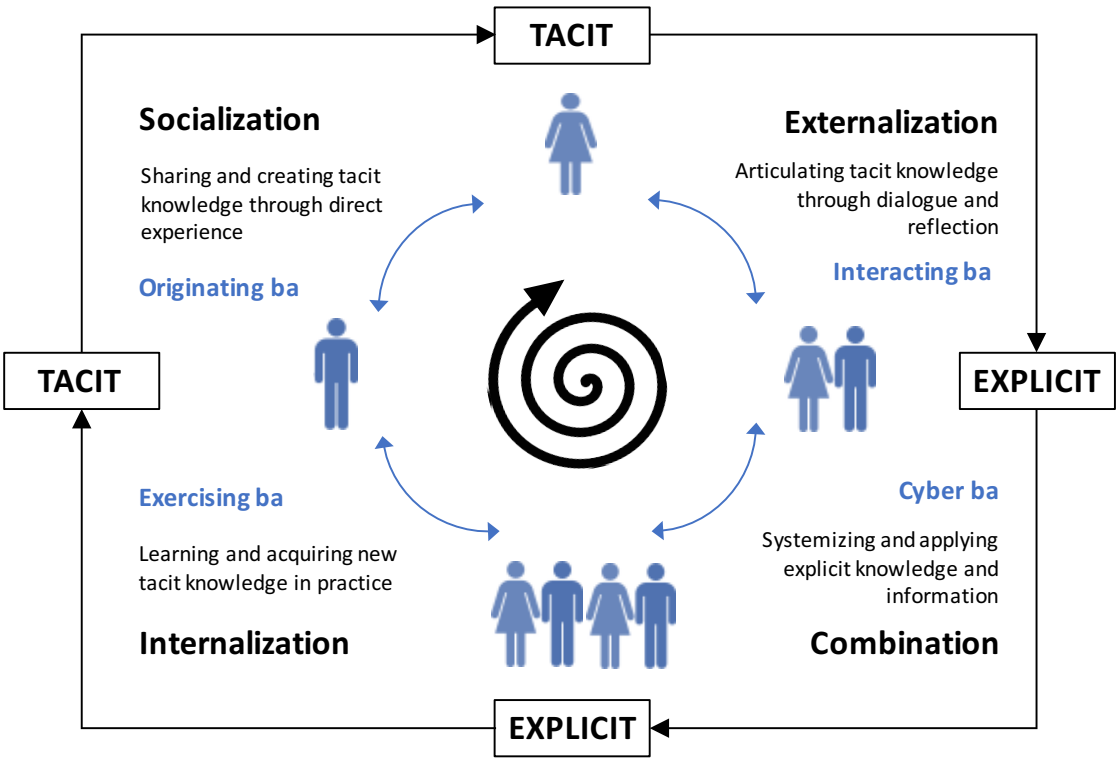

Figure 3: The knowledge spiral (adapted from Nonaka and Takeuchi 1995)

Nonaka and Toyama (2002) pointed out an important aspect: "knowledge does not just exist in one's cognition, rather, it's created in situated action". So *ba* offers the necessary context, the place "in which knowledge is shared, created and utilized […] where information is given meaning through interpretation to become knowledge, and new knowledge is created out of existing knowledge through the change of the meanings and contexts" (Nonaka and Toyama, 2002, p.1001). Thus, organizational learning has to do with constantly embedding knowledge into the organization's procedures, routines and culture and a constant reflection of its meaning for the firm. Leifer and Steinert (2014) described those aspects in the context of *Design Thinking*. "Team members learn from each other and the team's prior knowledge, reflecting upon and improving informal practices" (p. 155), a process

known as Triple Loop Learning. In this regard they also emphasize the importance of a shared, dedicated space and prototyping (action, learning by doing) which results in a faster and better innovation performance.

2.6 Problem solving

Referring to my previous point, generating new knowledge or combining existing knowledge in new ways is the base of innovation. Felin and Zenger (2014) describe innovation as the process "by which existing knowledge and inputs are creatively and efficiently recombined to create new and valuable outputs" (p. 915). So, innovation can be described as a process of search through which firms or individuals must find the right knowledge to solve a specific problem. Incremental and radical innovations differ extensively in their complexity and structure and will therefore need different ways of information search and problem solving strategies (Felin and Zenger, 2014, Reid and Brentani, 2004)

If a complex problem involves "a vast array of highly interdependent elements, choices, and knowledge sets that must be creatively recombined to compose valuable solutions" (Felin and Zenger, 2014, p. 916), then radical innovation is per definition a complex problem. Previously, I outlined that radical innovation has a high technical and market uncertainty on a macro and/or micro level. Those are highly interdependent influencing factors. Due to the level of newness of a radical innovation, knowledge is often ill structured and the nature of the interdependencies may not be fully understood. Furthermore, the location or source of specific knowledge relevant to the innovation problem is often unknown (knowledge is hidden or distributed). So, directional search, simple trial and error will not do the job and more sophisticated search approaches must be chosen. Felin and Zenger (2014) suggest a theory based search for highly complex problems with a high level of hidden knowledge. By "identifying and synthesizing the relevant knowledge that the firm seeks to explore" (Felin and Zenger, 2014, p.917) a theory is composed based on that knowledge and can be evaluated later through testing. This search became more complex as the growth rate of human knowledge increased and it is still increasing dramatically. Advances in information technology and access to knowledge "have resulted in a surfeit of information that managers

[and innovators] are required to sort, interpret, prioritise and act on" (Hodgkinson et al. 2009, p.278).

As Bill Joy, Sun Microsystem's founder correctly observed: "No matter who you are, most of the smartest people work for someone else". Thus, the ability to exploit external knowledge is critical to a firm's innovation success. Social interactions between members of a firm and external sources of knowledge facilitate both the search for information and its interpretation.

2.6.1 Absorptive capacity

The challenge with external knowledge is the difficulty to differentiate relevant knowledge from irrelevant stuff. In respect to radical innovation, the context of this work, this means to recognize knowledge linked to a technology, product or market which may not exist yet. Cohen and Levinthal (1990) describe this *absorptive capacity* of the firm as the ability "to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (p.128).

Research shows that firms which operate their own R&D or in-house manufacturing are better in recognizing and using external relevant knowhow as those tasks provide the necessary background knowledge for both, recognizing and implementing external ideas (Cohen and Levinthal, 1990). Thus, absorptive capacity, as well as insights, creativity and learning, needs prior related knowledge to build on in order to assimilate and use new knowledge. Psychologists explain this phenomena with the concept of associative learning: the memory (knowledge storage) is developed by linking new ideas and experiences to pre-existing concepts. In a nutshell, that means human brains were not designed to recall information in isolation.

In an uncertain setting, such as radical innovation, where it is unclear from which particular knowledge domains potential useful information will emerge in future, diversity is highly important. Cognitive diversity will balance the subjective nature of intuition, experience and mind-set and will therefore increase the probability that somebody has the

right prior knowledge to recognize the value of new incoming information. (Cohen and Levinthal, 1990).

Hence, relying on a small number of gatekeepers (interfaces to external sources of knowledge) may not be sufficient to increase a firm's adsorptive capacity and innovative performance. Furthermore, in large companies the communication channels within the sub-units of a firm and cross functional interfaces may be as important as the linkage to external contributors. As the development of communication networks takes time to develop, a firm must invest in its absorptive capacity early. If this is not done the cognitive distance between the company's employees and outside sources of knowledge becomes too large.

The firm's knowledge base may end up being too distant to appreciate or access emerging technological opportunities, as its value can simply not be recognized. Cohen and Levinthal (1990) suggest that "organizations with higher levels of absorptive capacity will tend to be more proactive, exploiting opportunities present in the environment, independent of current performance" (p. 137). Thus, the firm's task is to ensure it builds up an ecosystem where individual employees can access and exchange distant sources of knowledge inside and outside the company.

It likely needs a mind change in the measure of innovation success to understand that a firm "may conduct basic research less for particular results than to be able to provide themselves with the general background knowledge that would permit them to exploit rapidly useful scientific and technological knowledge" (Cohen and Levinthal, 1990, p. 148).

2.6.2 Sticky knowledge

As mentioned in chapter 2.5.2, sticky information is a threat to the exchange of information and knowledge and hence can affect problem solving in several ways. Von Hippel (1994) refers to a high stickiness when the cost of transferring information to solve an innovation related problem is high. This high cost accrues through the necessary transfer of information from the current location to the place of the problem-solving activity. The difficulties of transferring knowledge lies in its tacit aspect (Polanyi, 1958).

Szulanski (1996) built on the work of other researches and identified following sources of internal stickiness: (1) the source lacks motivation, or is simply unwilling to share information due to several personal reasons. (2) The source is not perceived as reliable. If the source seems unreliable, not trustworthy or not knowledgeable the transfer of knowledge from this source will be challenged and resisted by recipients. (3)The recipient lacks motivation to accept knowledge from the outside. (4) The recipient lacks absorptive capacity, mainly due to missing prior knowledge. (5) The recipient lacks retentive capacity. That means knowledge is transferred, but not retained within the group/ organization as the recipient lacks the ability to institutionalize the new knowledge and revert to the previous status quo. (6) Causal ambiguity describes the difficulties to transfer knowledge, because of its characteristics. Those characteristics can be the impossibility to determine the exact success factors for transferring that knowledge or the fact that the knowledge is embodied in highly tacit human skills. If the past usefulness of a particular knowledge is not proven yet the object of interest is (7) unproven knowledge and the transfer will be difficult. Potential recipients will less likely engage and may react negatively. The (8) barren organizational context such as the formal structure or systems in place, poor sources of coordination and expertise or the wrong behavioural attributes can make knowledge transfer difficult as well. Transfer of knowledge needs numerous social interactions between recipient and sources of knowledge. Missing intimacy will hinder the ease of communication and will result in an (9) arduous relationship, not advantageous for knowledge transfer.

He conducted a survey with 271 observations and used canonical correlation analysis of the data set to identify the major barriers to internal knowledge transfer. Surprisingly and against conventional wisdom (people generally refer to a lack of motivation), the main barriers were knowledge related factors such as the recipient's lack of absorptive capacity, causal ambiguity and an arduous relationship between the source and the recipient (Szulanksi, 1996).

The experience shows that transferring tacit knowledge is far from easy. That underlines the importance of a proper knowledge management strategy if a firm wants to achieve radical innovation. At this point it is crucial to distinguish between knowledge management and

information management. Good knowledge management will focus on enhancing the social interactions in order to enable as opposed to controlling knowledge creation and knowledge exchange.

2.7 Research gap and question

The literature examined demonstrates that many influencing factors and other aspects of radical innovation have been the (isolated) subject of prior research. Certain aspects were investigated in detail and confirmed in quantitative studies. Nevertheless, there is only scarce literature providing a holistic view on the dependencies and interrelations of those aspects, in particular from the social interactive perspective. Hence this research aims to develop a conceptual framework based on the review of existing literature to explain the mechanism by which social interactions forms radical innovation. By providing conclusively justified explanations of important underlying mechanisms and interdependencies among enabling factors this work tries to address the following question:

How do social interactions form the fuzzy front end of radical innovation in large firms?

A review of the existing literature will be the method of choice to identify the influencing factors. The identified factors are then tested by means of a case study of a disruptive innovation in a large firm.

The framework should enable managers and also innovators in large firms to better understand the mechanisms in radical innovation processes. This knowledge may help them to influence the underlying causes directly by building a strong innovation ecosystem, rather than trying to manage the resulting outcomes.

3 Theoretical framework

Figure 4 depicts a framework describing how social interaction forms radical innovation via several components and mechanisms.

The underlying key premises and relevant assumptions of the framework were laid out in chapter 2. The following graphical illustration should help to visualize those various interdependencies and mechanisms.

3.1 Graphical illustration of the framework and its mechanisms

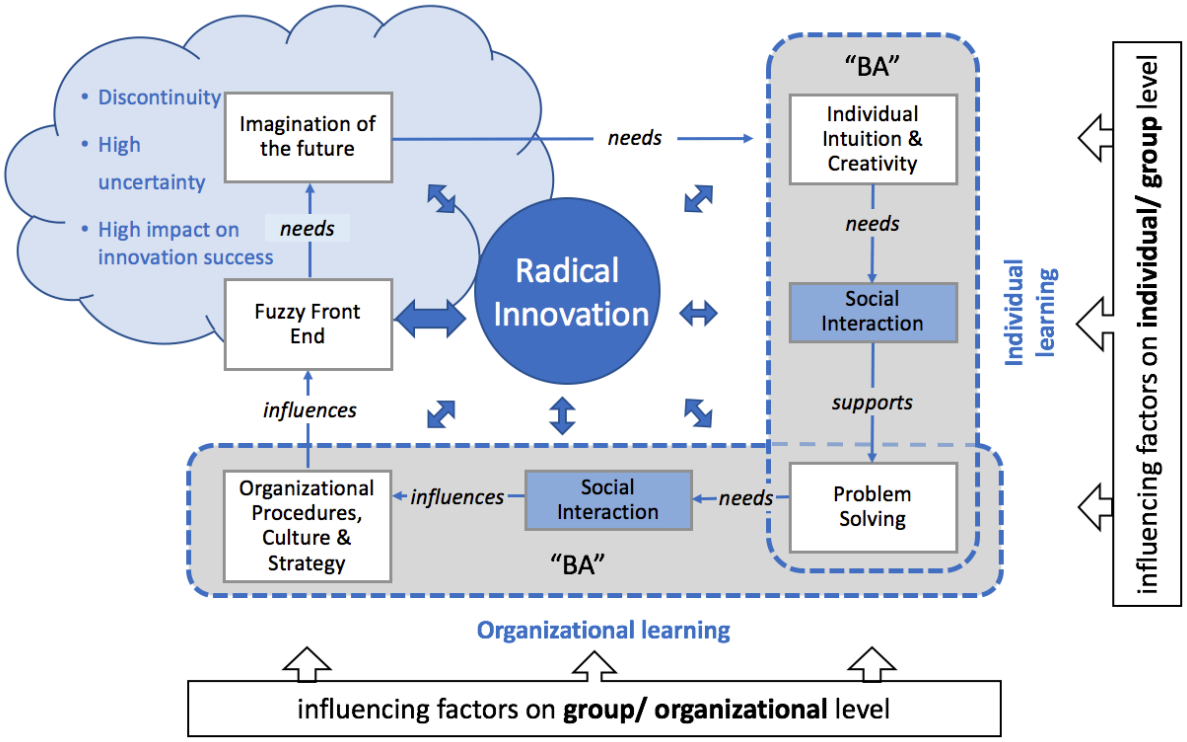

Figure 4: Framework of dependencies in the radical innovation process

The framework reflects, as laid out in chapter 2.2, that the fuzzy front end of radical innovation depends heavily on a company's ability to imagine a future that does not exist yet. The fuzzy front end and also the imagination of the unknown future is characterized by a high uncertainty level. In the case of radical innovation, the high uncertainty is accompanied by discontinuity of the existing reality.

The ability to imagine a future not yet embodied is possessed by individuals, as previously explained, and not by organisations. As illustrated in figure 4 and stated in chapter 2.3, imagination of the future requires intuitive and creative individuals. Social interaction enables the exchange of knowledge among individuals inside and outside the firm. This exchange of knowledge and information supports the problem-solving process, a key element of successful radical innovation. The social interaction between intuitive and creative individuals on one hand and peers with relevant knowledge on the other hand enables problem-solving. This problem-solving is embedded in the process of individual learning. "*Ba*" is the framework

or setting which facilitates this learning by providing shared time, space and meaning among the individuals and groups of individuals, for both individual learning as well as organizational learning. Several influencing and enabling factors were identified in the literature research, which influence the respective elements "*Individual intuition & creativity*", "*social interaction*" and "*problem solving*" and are discussed in more detailed in the next section of this study.

By systemizing the newly acquired experiences, impressions and findings which were exchanged among individuals and groups in the course of a problem-solving task, new learnings are brought back into the organization. This embedding of outcomes of the social interactive processes influences the organizational procedures, a mechanism called organizational learning. Further influencing factors were identified in the literature research which influence the organizational learning via the components "*problem solving*", "*social interaction*" and organizational *"procedures, culture and strategies"*. Also, those factors acting in the context of organisational learning are the subject matter of the next section.

As previously explained, the fuzzy front end has the strongest influence on the success of radical innovation. However, the influencing factors are not only crucial in the fuzzy front end and its elements and mechanisms, but take effect beyond the front end of innovation. Although uncertainty will decrease with advancing progress of the radical innovation project, new and unexpected threads or roadblocks will likely emerge and will require situation specific problem-solving activities similar to those in the fuzzy front end.

3.2 Social Interaction acts through following factors

The literature research revealed several factors influencing individual components of the radical innovation framework described in chapter 3.1. Table 2 assigns each identified factor to the relevant element of the framework, where relevant means an interdependent relationship. A factor which is already mentioned in one component list is not listed a second time with another component.

Table 2: Influencing factors on important components of the radical innovation framework

INDIVIDUAL INTUITION & CREATIVITY		
personal traits →	extraversion →	enthusiasm
cognitive & creative ability	openness to experience →	willingness to explore
divergent thining	conscientiousness	curiousity
prior knowledge & expertise	neurocitism	proactivness
recognize a pattern/ opportunity/ need		
intrinsic motivation		
care, trust, commitment		
tolerance for ambiguity		
freedom to follow own interest		
incubation periode (time)		

SOCIAL INTERACTION
inspiration
access to external knowhow
exchange and reflection with others/ feedback
access to "Ba" (time & space)
sense making
share values, norms, mental models & goals
test of concept/ idea
information sharing
diversity (cognitive, functional & technological)
built relationships
joint activities/ actions/ face to face contact

PROBLEM SOLVING
flexibility
strategic renewal
absorptive capacity

ORGANIZATIONAL PROCEDURES, CULTURES & STRATEGIES
motivation to innovate
resources /financial, time, personnel)
risk taking & failure acceptance
encouragement
stimulating work environment
Ambidexterity
consitenty (approach)
learning culture
absence of stress

No aspect of radical innovation seems to be simple and straightforward; the same is true for the influencing factors. The literature review has shown that most of the factors turned out to have multiple dependencies, either with other influencing factors or directly with other components in the framework, or both. Based on the literature reviewed it is impossible to quantify objectively the absolute strength of each relationship between factors and framework elements. The visualization of the dependencies gives additional information, as it indicates clearly the corresponding complexity. Figure 5 illustrate the relation network or interdependencies of the identified factors. The factors act *because of* and *through* their dependencies.

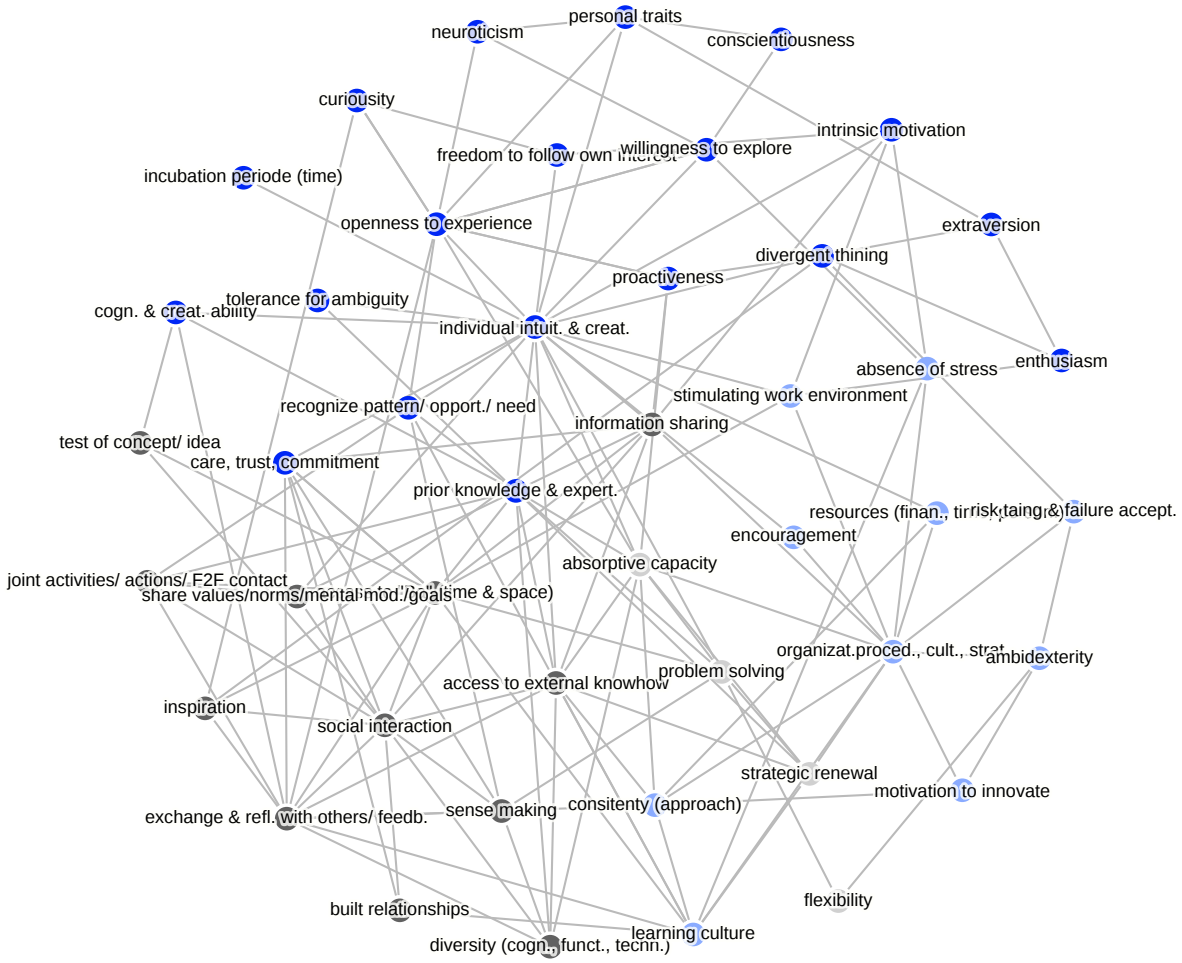

Figure 5: Influencing factors interdependencies

The colours of the nodes of the illustration in figure 5 correspond with the respective colours of the components of table 2 for easier orientation.

Figure 5 leads to the conclusion that a single or a group of influencing factors obviously cannot be read in isolation when it comes to increasing a firm's radical innovation performance. Nevertheless, to increase the understanding why and how certain factors influence components of radical innovation and interact with other factors, an isolated view of single factors or group of factors is recommended.

4 Methods

4.1 Expert interviews

The identified factors were subsequently tested in qualitative expert interviews. The three expert interview partners were selected upon their exposure and key contribution in the fuzzy front end of a radical innovation project, the ConSigma™ development. All interviews were conducted via Skype and lasted 31 minutes (interview 3), 46 minutes (interview 1) and 68 minutes (interview 2). The interviews have been recorded, transcribed and processed by deductive coding. An operative coding scheme was used where each of the four components of the framework stand for one category (individual intuition and creativity, social interaction, organizational procedures cultures and strategy, problem solving). Each code matched a factor and was allocated to one of the categories, according the factor's allocation in table 2.

In a further, but independent analysis step, each transcribed interview was analysed by inductive coding to see if further factors, not identified earlier in the framework, would emerge.

The interview questions addressed (1) the market and business context at the fuzzy front end of the project; (2) the personal perceptions and individual strategies/ attributes of the interviewees to handle the fuzzy front end in this project; (3) the process and influence of social interaction with internal and external peers and finally (4) the consequences or learnings of the project on an individual as well as corporate level. The full list of interview questions can be found in the appendix A. The transcripts are available on request.

The 3 expert interview partners were all employees of GEA, the company who pursued the ConSigma™ development:

Interviewee 1, held the position of the group's technical director when he started working on the ConSigma™ project. He retired end of May 2017 from the same position, but stayed involved in several innovation supervisory boards within and outside of GEA. He was considered as the main driver and visionary at the front end of the ConSigma™ project. Interviewee 2, was a development engineer in the innovation team, mainly responsible for bringing the conceptual ideas into engineered prototypes. Today he is development manager,

working on further developments of the continuous coater within the ConSigma™ product lines. Interviewee 3, was Managing Director of the GEA site in Wommelgem, BE (formerly known and mentioned in the interviews as “Collette”) when dealing with ConSigma™ first. As Executive Vice President he oversees today the technology centers at GEA and chairs in the steering board for GEA’s global Innovation Management initiative.

Interview one and two were held in English language, the third one in German. Citations from the third interview were translated into English by the author. Citations from the interviews are marked with I1, I2 and I3, according to the respective interview partner.

4.2 Project background and qualifying the samples

The radical innovation project the interviewees participated in was the development of GEA’s ConSigma™, the first commercial continuous oral solid dose (OSD) manufacturing line in the pharmaceutical industry.

GEA is one of the largest suppliers of process technology equipment for a range of industries including among others the food, chemical and pharmaceutical industry. As of March, 31st 2017, the 17,000 people operating worldwide generated revenue of about EUR 4.5billion. GEA is listed on the German MDAX stock index and included in the STOXX® Europe 600 Index.

ConSigma™ covers the so called secondary pharmaceutical manufacturing, the conversion from powder to tablets. For more than 50 years OSD (“tablets”) were produced in multi-step, batch processes. Figure 6 shows a comparison of concepts of a typical pharmaceutical batch versus continuous process (Lee et al., 2015)

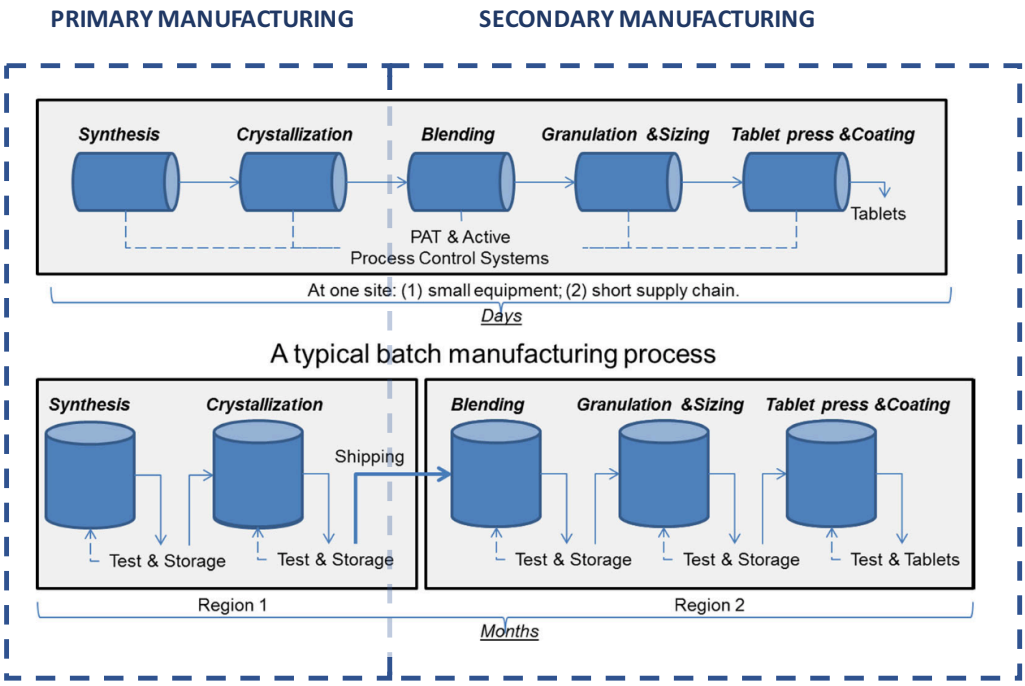

Figure 6: A conceptual integrated continuous manufacturing process (adapted from Lee et al., 2015)

In the traditional batch process each process step had a clear defined, understood and controlled start, end and quality release criteria. Each break (process stop) and intermediate storage cause inefficiency and delays, as well as increase the risk of defects and errors (Yu, 2016). The change towards a continuous process concept not only made substantial technical innovation necessary, but required a totally new understanding of underlying assumptions (how to define a "batch" if there is no batch anymore?), process control and analytical techniques. In a highly regulated environment, such as the pharmaceutical industry, a manufacturer is obligated to follow guidelines and regulatory decisions in order to be able to produce and commercialize a pharmaceutical drug.

Following Garcia and Calantone's (2002) definition, a radical innovation requires technological discontinuity, a "paradigm shift in the state of science or technology embedded in a product" (p.119) and a marketing discontinuity, "new market places to evolve and/or new marketing skills for the firm" (p.119) on a macro and a micro level. ConSigma™ needed all of that to succeed, which justifies why the project was chosen as an example of radical innovation: new technologies needed to be invented in order to overcome the engineering problems of a continuous production line. New scientific innovations were needed to develop

analytical technologies that allow a sufficient inline process control. GEA's and external engineers, managers and finally the sales force needed to be convinced to believe in and support a risky project with unclear outcomes. All in all, a new market needed to evolve where the huge benefits of a continuous production concept were well understood to overcome the high economic risk of delay or hinder regulatory approval of a drug manufacturing process. That means in the pharmaceutical setting that the whole ecosystem including regulatory bodies needed to accept new concepts and adapt their current measures of good manufacturing practice.

The development at GEA started in the late 1990s. In 2017, about 20 years later, continuous OSD manufacturing is accepted as superior manufacturing technology due to the lower cost of goods sold and improved drug quality, although the majority of drugs are still produced in batch processes. It was mainly the big, innovative pharmaceutical companies which started yet developing new processes based on a continuous concept. In 2016 the FDA for the first time allowed a manufacturer to switch from a batch manufacturing process to a continuous manufacturing process (Prezista, a drug for the treatment of HIV-1 infection by Janssen). This was only the second continuous process approved, after Vertex received FDA approval in July 2015 for the continuous production of its cystic fibrosis drug Orkambi (Yu, 2016). Despite the slow adoption of continuous manufacturing concepts to date, FDA is seeking to encourage pharmaceutical manufacturers to move to continuous manufacturing concepts and governments all over the world are funding research centres to push continuous manufacturing of pharmaceutical drugs.

5 Findings

All influencing factors listed in table 2 could be identified during the interviews. 39 out of 41 factors were extracted from all 3 interviews. The remaining two factors, incubation period and absence of stress, were mentioned by two of the interview partners. The reason for that may lie in the different functions of the interviewees in this case study. Their distinct contribution to the innovation project likely influenced their focus. Interviewee 3, for example, did mentioned that a certain time passed when people discussed the idea without action upon (factor "incubation period"). However, he did not indicate any relevance of this

step for the innovation project. Now, for the senior management position he held, this incubation period was eventually not of relevance for his tasks. The same interviewee did also not mention absence of stress. As managing director during this period of change it is plausible to consider that he did not experience absence of stress.

It became visible during the interviews that an influencing factor can act in a positive way to promote radical innovation (e.g. openness to experience), or can influence in a negative way and hinder radical innovation (e.g. neuroticism). Additionally, the absence of an innovation enabling factor can hinder or hamper radical innovation. All interview partners described hurdles they faced in their innovation project. Many of them were caused by people, groups or a setting which obviously lacked (some of) those enabling factors. Occasionally the interaction between factors could be observed. Sometimes without giving a clear indication which of the factors acted as the cause and which were the effect.

> *"It was an idea at the right time, or a demand at the right time. Which was the cart, which was the horse is open to debate" (I2)*

As all influencing factors were identified, I will focus to analyse only those findings in more detail, which offer either complementary aspects to already identified factors (new relations, new mechanism, etc.), or lead to new factors identification, or were pointed out frequently and thus seems to be of high importance for the radical innovation success in this case study.

Individual's influence

The importance of the individual's personal traits in the fuzzy front end seems, as expected, very important for the success of radical innovation. Despite the three interviewees were of different character, they all clearly showed their openness to experience, their curiosity and willingness to explore:

> *"For me actually, doing something brandnew is pretty much the only obsession I ever had out of working" (I2)*

> *"It started with the factor curiosity. How far can we go, what advantages will we see"? (I3)*

Although they were fully aware of the uncertainty and roadblocks to come all three were open and willing to explore continuous processing in pharmaceutical manufacturing. I found it particularly interesting that none of the interviewees showed doubts about the innovation direction. In two of the cases this can be explained by the prior experience and knowledge of the innovators. The interviewees had experienced the benefits of continuous manufacturing concepts in other industries. They could see the industry's need and the upcoming opportunity, thus it seems apparent to them that one day the industry will demand continuous processing.

> *"Although the structure of the industry and the regulation of the industry was not ready, there were still individuals who had ideas that things could be made better. There was a level of dissatisfaction with the way things were being done and the recognition that Pharma was old-fashioned and needed modernizing" (I1)*

> *"I think that one of the things I have looked at was the level of change I have seen in the petrochemical industry I've been in. I have been involved in a huge change, both in terms of technology, and in the way people were managed. Moving from very simple, old-fashion control to modern process control. I've been involved in quite complex, mathematical modelling of process control and had seen how much benefit in money that I had saved" (I1)*

The third interviewee had no prior direct involvement in continuous processing. Nevertheless, he could recognize the need to change his firms existing strategic positioning based on key experiences with customer and the reflection upon that. He experienced the limitation to differentiate his firm's offer, as batch processing equipment had become commodities equipment.

> *"The organisation knew how to build the equipment and make it work, but we had no deep scientific process understanding about the underlying mechanisms. […] We had several key experiences with Pfizer[…] which created the setting in which we concluded: OK, we have to think about entirely different topics […] There are new opportunities for us, we could have a completely different business model where we can distinguish ourselves and get out of the trap of no differentiation" (I3)*

That felt need for change paired with a general openness encouraged him to take the recognized opportunity and push this disruptive innovation. Thus, complementary to the various literature examples prior knowledge and experience is not only confined to technical, application or market concepts, but can trigger radical innovation even if it comes from a very general business knowhow or prior experienced threat or economic situation.

The inductive coding analysis revealed another factor on the individual's level, not being listed in the framework originally. There seems to be more than extraversion, openness to experience, commitment, intrinsic motivation and tolerance for ambiguity which helps individuals to peruse disruptive innovation. Despite the fact that all of those factors are necessary and could be identified in the interviews, they do not fully explain the confidence, persistence and courage the innovators showed in the case study, in particular when confronted with resistance from all sides:

> *"I was the crazy guy who would stand up and present this stuff […]and they'd go, "Yes, one a day, you're crazy." One would say, "Yes this is good stuff." And then they would say, "Yes okay, well it might happen. I won't hold my breath." And all that tough stuff. But you had to do it with enough science and confidence and pseudoscience that they sort of couldn't undermine you" (I1)*

> *"First, there was reluctance. There is something new and a.) it will take resources from other projects and b.) is there a market for that at all? But I think that's just the normal reaction on something totally new. […] Why shall we innovate? We are fine, we are growing! That was the environment" (I3)*

I propose the missing factor is self-esteem. Self-esteem is not described in the big 5 personality traits, although it is strongly linked to basic dimensions of personality. As there is no generally valid definition of self-esteem within in the scientific personality research, I follow the concept of self-esteem as a two-dimensional phenomenon. The first dimension, social worth, refers to one's self liking, often a result of other people's feedback. The other dimension, self-competence origins in one's reflection between past intentions and successes. If they correlated often, this can lead to experience of oneself's efficacy and power

(Tafarodi and Swann 1995, Ramsdal 2008). I will deliver some theoretical background on self-esteem in chapter 6 and also discuss the conclusions about self-esteem in more detail there.

Social interaction

The importance of social interaction on the radical innovation process was pointed out in many examples in this case study. Notably in the very early stage social interaction covers not only peer to peer inspirational and information or knowledge exchange aspects. Moreover, it provides encouragement and acknowledgement of the idea and the person behind this idea. It does that by identifying other open thinkers and help building relations to them.

> *"I would approach the issue with one or two radical thinking customers. […] Well, the first point is to recognize that you're not crazy. Or at least if you are crazy, there's two of you who are crazy. You're not alone. Then you start to recognize that it's okay to talk about this stuff with other people, and you find those people who are open and engaged, and those people who as soon as you mention it, close down" (I1)*

This reassurance of a disruptive innovation idea by others was confirmed to be important in order to achieve diversity and creative input in the problem-solving process itself. On top of that the case study revealed that it also gave a certain legitimation to the idea. In the case of the ConSigma™ development, influencing customers were engaged at a very early stage. This interest from outside enabled the innovators to overcome internal resistance:

> *"We would have never managed to work on this idea alone without customer's interest. The internal opposition would have been much too strong. Classic situation. The new idea would have been conceived right from beginning as competition to our existing basic business" (I3)*

This legitimation of the idea through recognition by externals even appeared in the case of external recognition through a competitor. One interviewee referred to a situation where a small competitor picked up on the continuous processing ideas at a very early stage:

"They were driven by one owner who could make very quick decisions […] He was more agile in the marketplace in that respect and prepared to spend his own money. But he legitimized the discussion [within GEA]" (I1)

The case study further revealed that the social interaction not only build peer to peer relations, but led to a network effect. In the context of disruptive innovation where exploring individuals are always confronted with resistance from their environment, the social relations with like-minded people are valued. Trust, once created in a project will last and will leverage cooperation and exchange in other projects, as both peers value and need the open exchange. Interviewee one referred to Mike C., an important external source of inspiration and external development partner of this project.

"We got talking about it [continuous processing] because he came from a chemical industry background, I came from a chemical industry background. I can remember we were working together on a traditional project, and literally standing together doing the test work on a new piece of equipment. It wasn't formal meetings, it was the sort of discussion you have in a lab while you're doing something else, while things are progressing. And it created a sort of a space in which you could have informal conversations" (I1)

This interaction and exchange of ideas and concepts helped both parties to finally convince their respective companies to start elaborating that idea. This collaboration opened new relations and allowed to participate for example in conversations with authorities (FDA). As mentioned earlier without complementary maturation of the ecosystem, such as the regulatory landscape and process analytical technologies, continuous manufacturing could not have taken off.

"I was looking for evidence of support and was digging it out and therefore, you sort of end up building a confirmatory bias because you're obviously looking for people who will support it. But you are starting to build a movement and of course, you're not the only one. […]I mean if you're wrong, then you will be the only person building the movement- But if you're right, what happens is other people are doing it at the

same time and then you collide with each other and all over sudden you go, right, we are all pulling in the same direction" (I1)

So just like the social interaction in a peer to peer or formal development group setting, the new network helped to test the idea, purely by the number of people who started getting interested. The informal network brought exposure to further peers, but also visibility. When the original development cooperation with Mike C.'s employer slowed down due to strategic changes in his firm and the resulting decline of support for this project, new customers showed interest instead.

"Then other companies came on because obviously, as soon as we had something that looked of interest to anybody, they start other people to bring in and showed the same thing too. Very rapidly we thought, well, this idea has legs" (I2)

All three interviewees referred many times to the importance of joint activities, face to face contact and prototyping (test of concept) to enhance social interaction, to create trust and enthusiasm and exchange information and experiences.

"Customers coming in and doing test work and getting excited […] it was a lot of development and talking and enthusiasm over a beer" (I1)

"… you try to get informal settings. I mean one of the reasons to go to site from troubleshooting […] would be to make the contacts so you could talk with-- and then having done that formal business you can afford to have the informal conversation. I think from a personal level what you do if you go in on a traditional level troubleshooting or a support they hopefully see some value in what you are doing in the conventional environment and then trust you when you start to talk crazy shit" (I1)

Rather than observing, as expected, that social interaction is a kind of necessary enabling vehicle or prerequisite of problem solving activities, the active and conscious use of social interaction as an enabling tool to overcome innovation related issues was noted in that case study. First, GEA's innovators used diversity to overcome functional fixedness. While the actual prototyping was done in a production unit in Belgium, the respective concept

development was done mainly by a group in UK. That way at a very early stage knowledge was transferred in both direction between developers and production. The interviewed innovators appreciated that they can focus more on the concepts of each innovation aspect rather than solving every tiny mechanic detail.

> *"That transfer obviously, brought with it, problems. There were always mistakes and errors made. […] giving a separate set of eyes and brains was the opportunity to go over. I think it was overall an advantage. I wouldn't wish to suggest that it all ran perfectly smoothly and nothing ever does, but it was quite good" (I2)*

Again, there was a lot of face to face contact between both groups in front of a new prototype. That way the peers could exchange their knowledge, immediately test the ideas in action and reflect upon.

> *"I was very often driving to Belgium with actually the dryer and the granulator, and all sorts of things in my car" (I2)*

Not only was the functional diversity within the company used, but GEA also made sure that the feedback from end users was integrated into the early stage development.

> *"…we operated a mechanism. We did enough and no more than to show whether the idea was viable. Then we brought Dr. C. along, to see how he reacted to it" (I2)*

Dealing with risks

As pointed out earlier risk taking and acceptance of failure are strong influencing factors on radical innovation success. Risk taking in the context of radical innovation and its high uncertainty is to a certain extend betting on an idea. Nevertheless, the study revealed that active risk management can be a part of risk taking. Figure 5 shows the links between the factor *risk taking and failure acceptance* to organisational culture as well as to individual's attributes. The study indicated an additional link to social interaction as a way to reduce uncertainty and a method of conscious risk taking.

The first indication revealed in the case study was GEAs approach to discuss and reflect its strategic direction with customers. It was not a standardized "voice of the customer

questionnaire" type of interaction, but an ongoing and open communication with users[3]. This allowed the innovators to recognize that their internal discussions led in a wrong direction.

> *„…and in that environment, we had internal discussions about whether fluid bed or one pot technology is conservative or progressive. We got in contact with customers, and they told us, this is all good and well, but we are already thinking two steps ahead" (I3)*

> *„...and Mike C. was a catalyst here, [so we concluded] actually in Pharma we are on the wrong track" (I3)*

GEA did not rely on some customers' feedback about a new product wish list, but the deep level conversation, the exchange of knowledge and exchange of experience with key users allowed a profound understanding of the customer's pains and drivers. This in turn allowed the innovators to reflect their strategic assumptions and let them realize the need for a strategic change long before the market in fact demanded that change. This gave them the time to nurture the idea and start developing without the time pressure to deliver an innovation a few month later.

> *"I talked with my immediate boss and said, "I think we can do something", and he was - he'd also come from a different background. He also could see the potential, and on a number of occasions when we were with customers, we would just mention these ideas and see what reaction we got" (I1)*

This approach reduced the risk, because it gave the innovators not only time to convince internal stakeholders, but also the time to mature ideas, work on prototypes and test them again with customers.

> *"Only after one or two years intensive discussions without a business case this [idea] become discussable within the organisation" (I3)*

[3] customer and user are in many market not unified in the same person, however due to the high cost of legal pharmaceutical manufacturing and other market dynamics a user typically is also a potential customer in this industry.

„The whole trick was that Astra Zeneca, Pfizer and GSK[4] showed strong interest. That way we finally got the management on our side" (I3)

The innovators at GEA were aware of the fact that they need the exchange with externals not only for idea generation, but for idea and concept testing, and to share and exchange their mental models. They saw the risk of falling in love with their own ideas and loose the capability of objective evaluation.

"Clearly, the concerns are that you can go a long way with a bad idea. And you only get a very short period of time in any development or invention, when you are truly innovative" (I2)

"I think is a very important bit of managing the whole process to re-evaluate what you're doing and let go of poor ideas or trials. Which ideas should not see the light of day. The closer you get to something, obviously, the more difficult is it to see from a distance" (I2)

Another risk management approach identified in this case study was related to the financial aspects of radical innovation at the fuzzy front end. GEA innovated in little steps, invested little amount of money to test each concept with external and internal peers, reflected upon it and defined the next step based on the previous results. The innovation team did a lot of inexpensive prototyping to test concepts and ideas quickly. That way they never risked a huge amount of money at once. They made sure to capture the learning from each step. The project did not have a defined budget in its early days. A small team with limited equipment had the freedom to work on that idea.

"I asked when I needed it [money]. I was told, you don't know how much budget you need, I don't know how much budget we can afford. Let's work it out as we go along. And that I think I found to be quite a good way to work because it meant, I didn't create bullshit budgets. I would develop something and say: look, this is what I think we need to spend to get to the next stage, can we afford to do it ? (I1)

[4] GSK: GlaxoSmithKline

"We have to get to the point where we can show something working without spending a lot of money. If we have tried to do it in a traditional way, the overheads and the costs would have gone through the roof, the time would have gone through the roof and people would have said, let's stop spending money on this, this is a waste of time" (I1)

This approach needed trust between the managers, development team and users (who came and tested). It took a lot of face to face communication and reflection, a lot of social interaction between the stakeholder. Although turbulent restructuring initiatives took place within GEA in the time of the ConSigma™ development, the support for this project was continuous and wasn't stopped at any time. Interviewee one, asked about the trust he received from his line manager, replied:

"I think we had a pretty good level of mutual respect. Yes, I think he thought it was not a bad idea and was willing to give me a bit of support. I suppose there's an element, you've got to have some degree of credibility" (I1)

Noteworthy to mention that none of the interviewees at any time felt a serious commercial risk for the firm or any personal or career risk. The following comments recorded in the interviews clearly shows the trust the individuals felt not only in their respective managers, but in their company. Thus, I suggest there is a relation between the factors *risk taking and failure acceptance* on the organizational level and *care, trust, commitment* on the individual level.

"This would not have killed the company, there would not have been drastic consequences. […] it was a kind of parallel universe to the existing business, and the existing business at that time was relative good" (I3)

"There have been other projects where that have failed or proven to be non-viable even after quite some period of time. That has not resulted in a disastrous fallout, the cutting off of heads. […] You could not work in such an environment where your-- where an idea had to succeed because most ideas don't" (I2)

"We did not invest too much money before we had got interest. There was a process whereby we tried at all times to share the investment with a risk but the enthusiasm from the customers. We also tried to use research money etcetera. We were trying not to risk big money" (I1)

Ba- a place for social interaction and learning

During the interviews, it became very obvious that this project's ba was a small pop up laboratory, nearly garage styled room where the innovators would play around with their prototypes. They called this place fondly *plastic fantastic lab,* in allusion to the prototypes made of plastics instead of stainless steel, the standard material in the pharmaceutical industry. Several statements pointed out the importance for both, informal open exchange of ideas and knowledge on one hand and a physical space for joint actions on the other hand. In particular the need for a space where thinking, communicating and reflecting outside the narrow boundaries of a fixed agenda in a corporate setting was mandatory in the early days.

"I think where ConSigma™ was really born, was in the end room"(I2)

"That's where clients came to see what was going on, where we could learn about the process, and make those development. That's really where it happened" (I2)

"The fact that it was very little but for the most part it had the necessary services and that you could be pretty independent" (I2)

One could even feel the pride when the interviewees talked about this place. I didn't get the impression in the interviews that this place was consciously established with the target to create a place for exchange. This place and its function evolved more naturally while the project progressed.

"[Customers] absolutely love coming and running a brown paper and sticky tape proof of concept, completely non-pharmaceutical process. Where they can disobey all the rules that they have to abide by in their own highly regulated facility. They get a great kick, out of them doing this kind of work. That only lasts for a certain period of time. But, you can get guys really excited" (I2)

"Those are the times where you can afford to take risks with ideas and say, "What about this, what about that?" Bounce stuff around. You don't often do that in a corporate setting. I would say that, at that stage, both our company and most of our customer companies, did not have spaces- I don't mean physical spaces, I mean organizational spaces- pools people who would relax in an environment" (I1)

Learning

The last aspect of the case study I want to examine is the relation between social interaction and (organizational) learning.

The ConSigma™ project was as discussed partly driven by the recognized need for the firm's strategic renewal. This strategic renewal without any doubt took place and GEA is today recognized as the technology leader in continuous pharmaceutical solid dose manufacturing. GEA has invested in a multimillion Euro pharmaceutical test centre, open in May 2017 on the birthplace of ConSigma™. Customers can use the facility to optimize or develop their process on continuous equipment. The question I tried to investigate during the interviews was how much of the learning got manifested within the organizational procedures or culture. In which way a new radical innovation would profit from the past experience.

"I think it increased that kudos of our company within the industry massively […] people saw GEA as a real technology leader" (I1)

"The influence has been vast. I'm struggling to think of the company as it was in the preceding two or three years, and the company as it is now" (I2)

The people direct involved in the ConSigma™ project clearly saw the whole development from the early days, how they overcome the threats and what huge impact it had on the site. They could also tell about the learnings which will last, learnings they had based on the experience and social interaction in that project. Furthermore, they also clearly recognized that this is not the end of a journey, but an ongoing process.

"We had some fights, we had some interesting interactions with academics who were also saying, this is not fully understood yet; we were saying, no, we understand that

but we're just going to do it. There was a period of time when we learned that to experiment and to do is better than to talk and present and debate. I think its gave some of us some confidence to do more" (I1)

"We must never assume that it is the lasting solution. It's just a step along the way"(I2)

However, all three interviewees agreed that the wider organization did not benefit from that learning. Additionally, the innovators seemed not convinced that in a different setting, with involvement of other individuals, the outcome would have been the same or will be similar successful in a future setting.

"I also think there are some to think that this sort of activity needs more regulation. And I still have this problem that I think that they are those who believe that you can manage this activity rather than support this activity. They don't understand the difference. They don't seem to get that if you support this you have a much better chance of making it real whereas if you simply try to systematize it you probably end up in a situation where you will not create that many more successes" (I1)

"There was an attempt I think by traditional management to want to both repeat it, repeat the success and to believe that they could manage that process" (I1)

A reason for that may lay in the fact that in the former GEA organisation the units acted independent from each other and were considered as silos. Individuals hardly had exchange with colleagues outside their units and organisational procedures between the unit did not exist. So there were neither processes in place to transfer information in form of instructions nor procedures to enhance social interaction by exchanging knowledge and experience.

"In those days and during the development it [the project] exist under a bell jar. Beyond the borders of the Pharma Unit, actually nobody at GEA noticed more than the name of the project and that customers where involved" (i3)

„It would have been nice to handle that [project] in a setting like we design it currently" (I3)

Yet, interviewee three states that his learnings from the ConSigma™ project definitely influenced the direction of GEA's new innovation management system, a corporate wide, board supported, initiative for which he is one of the driving forces today. So eventually the wider learning is just happening by individuals like him bringing new processes, procedures and mind sets back into the organization. At least his conclusions are promising:

> *"You cannot design something like that on a drawing board and bring it ready into production […] all that processes we try to describe and enable in the innovation management system: OK, here is the idea, how do we get the right people together, we look outwards, not inwards; how do we get the idea manifested, how do we get it tested, quickly without moving a lot of stainless steel, without interacting with the whole ERP[5] procedures, the whole organizational routines. ConSigma™ worked, because Trevor and his group, a handful of freethinkers, run for a moment in the next hardware store to get the parts they needed. It was not about going to the purchasing department, make a list and wait for 3-6 weeks until the last part appeared. […] this is the declared intention of the organization. Surely there is the intention on one hand and the reality on the other" (I3)*

Table 3 and Figure 7 reflect an updated version of the influencing factors and their network. The changes include the new factor *self-esteem* and the expansion of the factor risk taking & failure acceptance by adding the aspect of risk managing. The new factor is called *risk taking, managing & failure acceptance* Also the newly identified relations between the factors were updated in the network.

[5] ERP: enterprise resource planning

Table 3: updated overview of influencing factors

INDIVIDUAL INTUITION & CREATIVITY		
personal traits	extraversion	enthusiasm
self- esteem	openness to experience	willingness to explore
cognitive & creative ability	conscientiousness	curiousity
divergent thining	neurocitism	proactivness
prior knowledge & expertise		
recognize a pattern/ opportunity/ need		
intrinsic motivation		
care, trust, commitment		
tolerance for ambiguity		
freedom to follow own interest		
incubation period (time)		

SOCIAL INTERACTION
inspiration
access to external knowhow
exchange and reflection with others/ feedback
access to "Ba" (time & space)
sense making
share values, norms, mental models & goals
test of concept/ idea
information sharing
diversity (cognitive, functional & technological)
built relationships
joint activities/ actions/ face to face contact

PROBLEM SOLVING
flexibility
strategic renewal
absorptive capacity

ORGANIZATIONAL PROCEDURES, CULTURES & STRATEGIES
motivation to innovate
resources /financial, time, personnel)
risk taking, management & failure acceptance
encouragement
stimulating work environment
Ambidexterity
consitenty (approach)
learning culture
absence of stress

Figure 7: updated Influencing factors interdependencies

6 Discussion and conclusion

This paper aims to enhance managerial and innovator's understanding of the way social interaction forms the early stages of radical innovation. Therefore, this chapter is separated in two sections. The first section 6.1 will focus on adding further information and discussion based on the findings of the case study. The second section 6.2 will suggest recommendations for managerial innovation practice to reflect the outcomes of that work.

6.1 Theoretical implications

The insights generated in that study show that prior knowledge and experience of individuals are of high importance to imagine a future and pursue radical innovation

successfully. Unfortunately, it is not predictable which knowledge and experience will be needed for the next disruptive innovation.

The study has shown that knowledge diversity and its exchange via social interaction are complementary ingredients that favour not only idea generation but also provide support for innovators and legitimize a disruptive idea. Thus, companies must learn to actively handle diversity within their company, consciously built and use knowledge networks with academics, users, suppliers and other external and internal peers independent of a certain innovation project. In particular the insufficient leverage of existing knowledge due to missing exchange and social interaction between sub units and division of large firms is often an unsolved issue.

Domain relevant knowledge and experience is linked to previous professional skills, but even the best assets won't support radical innovation if the individuals' personal traits and the environment for social interaction are not favourable. As shown in the case study, and supported by literature (Sosa, 2011) the most important interaction in the early stage of innovation seems to be informal conversation. Hasan and Koning (2017) noted that a "complementary *"match"* between the traits of the focal individual and peer moderate the degree of social influence" (p. 3). Whereas he identified an innovator with high openness, exchanging with an extroverted peer to be a good match. A setting like this is not a unilateral transfer of knowledge, both individuals benefit from the exchange. Hasan and Koning's (2017) study even showed that knowledge generated by such an individual will increase the knowledge shared by the whole team. This mutual benefit explains a finding in the case study, that social relations once established, stay a source of exchange in the long run. Luckily, Perry-Smith (2006) showed that those ties in the knowledge network must not be tight; actually, weak ties are shown to be favourable for idea creation, which makes the creation of social networks in a real life organizational setting an easier task.

As mentioned earlier, the study indicated that self-esteem is another important personal trait triggering radical innovation. Resistance is a constant companion of every innovator, in particularly when dealing with disruptive innovation. Self- esteem has two dimensions, both are helpful in the fuzzy front end of innovation. The first dimension, the individual's cognition of its own social worth is always related to prior learning about other people's feedback about

oneself. (Cooly, cited by Ramsdal 2008). Ramsdal (2008) describes this dimension as the "moral evaluation of one's characteristics and actions" (p. 334). I suggest this strong embedment of *knowing* that a certain action is *right* helps to pursue a radical idea even against the external resistance. Interviewee three pointed out the responsibility he felt as a managing director to act, as he was fully aware that the current strategic direction can't be sustained in future. That feeling of *doing the right thing* helped him to beat the resistance he experienced within his firm. The second dimension of self-esteem refers to the concept of self-competence. It refers to the relation between one's own intention and past results. If this relation leads more often to success, one realizes his or her own self efficacy and power.

Shepard (1967) noted an important aspect of self-esteem linked to innovation:" For the successful innovator, too, the subjective risk lies in not innovating. He risks his sense of self-worth if he must settle for compromises or for less than full personal effectiveness and contribution" (p. 472). Interviewee one confirmed Shepard's suggestion exactly when asked about motivation and fears:

> *"I think it was much more a fear […] that it was a loss of personal opportunity,* ***not*** *to do it. That we'd look back and say, "That was something you should have done."(I1)*

Thus, the independence of the innovators self-esteem from organizational targets may also explain why traditional reward and punishment system in large organizations show little effect on radical innovation. Intrinsic motivation surely shows its influence in that respect as well.

Despite the missing organizational learning effect in the case study, it showed clearly that without social interaction, institutionalization does not take place and organizational learning does not happen. It is not enough to just distribute the news about an innovation success in order to learn as an organization and increase the firm's innovation capability. This simple spread of information clearly happened in the case of issue, and a picture of a ConSigma™ line was prominently positioned on the front-page of GEA's 2016 annual report, accompanied by a paragraph pointing out that example of GEA's innovation strength and the innovation prices the product line had won.

6.2 Managerial implications

"Although discontinuous innovations claim to be the root of only 10 percent of all new products, there is strong evidence that when successful, these types of new products pay off more than proportionally" (Cooper, Ettlie, Ettlie and Rubenstein, Kleinschmidt and Cooper, Mansfield and Wagner, Griffin cited by Reid and Brentani, 2014, p.172)

I want to avoid readers focusing on a certain factor rather than the factor network and its dynamics. Which factors should be emphasized in a firm's innovation attempt will depend on the specific firm. Each organization will see different gaps in their radical innovation setup. Furthermore, the firms current culture, its technological maturity status, the industries or markets the firm is serving and many other aspects will influence the firm's innovation approach. Nevertheless, I will suggest some universally valid recommendations based on the findings of this study:

There should be no illusion that at the front end of radical innovation a manager or leader will know which prior knowledge or expertise will be needed, which individuals will have the knowledge and network needed to let the innovation see the light of day. But a good manager, leader or corporate innovator should prepare the ground early on by investing in the firm's absorptive capacity. The earliest point to influence that is a conscious approach when hiring new employees. The individual's attitude and personality, as well as the diversity within the teams should be of focus when new people are hired.

Recommendation 1: hire employees showing advantageous personal traits and ensure diversity within the teams.

Although knowledge itself is a valuable resource of a firm, only its conversion into capabilities brings tangible value. Thus, a firm's culture, norms and routines should emphasize and enable social interaction to allow knowledge to be exchanged with internal and external peers, independent of a particular initiative or campaign.

Radical innovation requires per definition a disruption on the macro level, thus at least the disruption of the industry. History shows us many examples of radical innovations which were based on an outstanding technology, but only due to the change of the whole ecosystem

the innovation could disrupt the status quo. Thus, it is highly important to identify as early as possible internal and external peers with various backgrounds and influencing opportunities and foster social interaction among them in order to allow radical innovation to succeed. As stated during the interviews in the case study:

"I think it would be extraordinarily difficult to conceive a system in the under wrappers, in the dark, in the privacy of our own laboratory. And bring it to a state of readiness, and then, then launch it on the market" (I2)

That does not mean that a firm should blindly run after each opportunity to innovate. Social interaction can and should be a tool to manage innovation related risks. Open innovation, lead user projects, design thinking and many others innovation concepts help to increase the knowledge pool by integrating external sources of knowledge as well as lower the risk and cost of radical innovation.

To fully leverage the company's innovation capabilities, firms should actively allocate time and space for shared reflection within teams and among teams. Organisational learning, a basis for future innovation, will not take place without established procedures or learning culture. Face to face contact is very important to contextualize tacit knowledge and there is little evidence that radical innovation can succeed without this social exchange. These informal social interactions are often seen as a pure cost factor and in times of economic turbulences are typically hampered or stopped. Other tools, such as storytelling can be used additionally to leverage learning effects. Crossan et al. (1999) noted the significance of storytelling for organizational learning by providing richer understanding of the complexity of a practice which in turn supports problem solving.

The literature review as well as the case study pointed out the importance of *ba* as a place of exchange, trust creation and knowledge generation. Enabling context and enabling condition- the nature of *ba* – must be properly understood by managers to avoid the pitfall of establishing just a fancy "start up styled" office place.

Recommendation 2: enhance and support meaningful social relations inside and outside your firm.

Intuition, creativity and social interaction cannot be enforced, hence the same is true for innovation. But managers can nurture certain behaviours and leverage enabling factors to increase the probability of radical innovation to emerge. Thus, managers must accept to decouple the investment in radical innovation from a certain innovation project. Investments in social interaction as well as in basic innovation projects when new technologies emerge should be seen as an elementary and mandatory prerequisite in order to participate in the game of disruptive innovation. Managers and innovators should keep in mind that it takes a long time to build absorptive capacity as well as knowledge networks and this process cannot be enforced to speed up. Thus, a consistent approach is very important for radical innovation's success.

Recommendation 3: radical innovation cannot be enforced, but enabled and supported continuously.

Conclusively, I believe the most important underling managerial issue in the context of radical innovation is the inability of most managers and organizations to simply accept uncertainty as an integral part of the fuzzy front end. We can reduce uncertainty, but we cannot eliminate it.

> *"Rather than seeing uncertainty as a threat that needs to be pseudo quantified or abstracted away we invite you to embrace ambiguity and to leverage it in order to create better innovations faster. The key lies in letting your innovation teams be truly creative and in focusing on iterative learning and redesign rather than on optimizing on concrete, but potentially ill-fitting requirements" (Leifer and Steinert 2014, p.141).*

6.3 Limitations and further research

This research streams across different perspectives and disciplines, thereby providing a simplified overview of existing literature on all influencing topics. Further holistic and quantitative research will be needed to get a clearer picture of the influencing power of specific enabling factor groups compared to each other.

Another interesting aspect for future research is the impact of electronification on our communication habits and the resulting social interaction. How do online communities without face to face contact and modern communication technologies affect our way to build social relations or exchange (tacit) knowledge in the context of radical innovation.

Moreover, the leverage effect of managerial and organisational procedures and cultures on the respective innovation influencing factors should be of scientific empirically interest.

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Appendix

Appendix A

Table 4: interview questions (Guidance)

#	Question	interview support guidance (for the interviewer guidance only)
1	Can you describe the situation before the Consigma Idea came up? What was your role, the business environment/ challenges/ settings?	
2	When/ how did you hear about the idea/ did you have the idea (ConSigma) the first time?	describe situation
3	How did you feel in this situation?	what knowledge/ experience did help/ hinder the idea?
4	What were your next steps?	knowhow exchange?How did you get support? How long did it take to share the idea etc? (what happened inbetween) proactive behaviour? When did the first action happen / what was it?
5	What motivated you/ what scared you?	
6	Have you been convinced of the success ?	How did you deal with the doubts? was the organisation ready to absorb the new information/ ideas? how did you deal with the uncertainty?
7	How did the organsation (other team members) deal with the uncertainty in this situation?	ambidexterity
8	Which support did you get?	by whom ? institutionalized or did you ask for? was the support consistent? (did it matter?)
9	Which roadsblocks did you face?	How did you deal with them ? Who did fight you and how did you deal with that? (judge the ideas) How did you convince others of this idea?
10	Where and when did you tyically exchange with team members/ external supporters/ managers?	Ba?/ certain time, certain space? How important was reflection (alone/ with others) for you?
11	What would have happened if the project would have failed ?	personal consequences? business cosequences?
12	How did this innovation influences the organisation?	new thinking? procedures? stragegic influence? new position in the market? Do you think this project made new, future radical innovations easier?
13	How did this innovation influence you?	career personal relations learnings
14	from an overall point of view: which words would you use to describe the experience/ the time during this project	
15	personal information Age past carreer (functions, markets, education) What hobbies do you have ?	what makes them interesting for you? openness/ diversity?

Appendix B

Figure 8: travel between UK and Belgium with new prototypes

Figure 9: Plastic Fantastic Laboratory

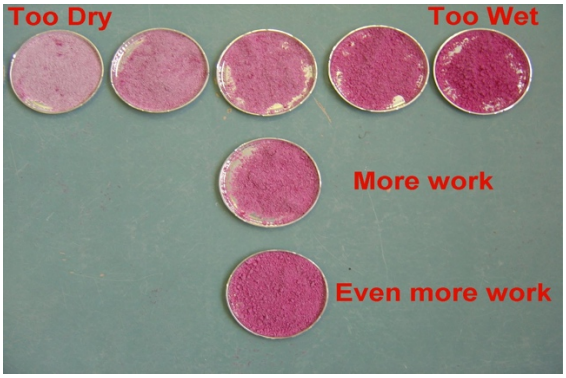

Figure 10: results of early tests with prototypes