

The learning dynamics of external–internal knowledge
and exploitation–exploration: the case of SMEs’
learning-capacity building

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ABSTRACT

The research in this thesis provides an understanding of the growth of the firm from the co-evolution of its learning and technological trajectory by focusing on the micro components of learning and the process of capacity building. It aims to explain the degree of complementarity, interdependency and co-evolution within the process of **knowledge integration and learning** over the firm's technological trajectory. In doing so, it searches for the process of capacity building, emphasizing the interaction between **knowledge reconfiguration** – i.e. whether the source of knowledge is passive, active or interactive – and **its orientation** – i.e. whether it is explorative or exploitative. In brief, the thesis analyses the link between knowledge integration, technological learning, capacity building and technological transformation.

Three bodies of literature frame the analysis. First, from the literature on knowledge management, the main problems of coordination regarding knowledge transfer – i.e. whether it is tacit or explicit – are discussed. Second, publications on both organizational learning and dynamic capability are considered together to enable the firm's learning dynamics to be understood by distinguishing the mechanisms, the processes and methods used by firms to develop common ground in their interpretative system – these being cognitive and behavioural processes. Lastly, the absorptive capacity construct is examined in terms of the different levels at which the firm approaches external knowledge and develops its learning experience.

Accordingly, taking a process and micro view of learning, the analytical approach emphasizes the **learning schemes**, defined as the vehicles through which the action of mobilizing component knowledge into capabilities and routines occurs. Based on their differences and similarities regarding knowledge source and orientation, these learning schemes define six categories of learning capacity: formative, adaptive, transformative, inventive, created and renewed. The way these learning capacities are developed over time defines the firm's learning trajectory, presenting a functional relationship with its technological trajectory.

The research deployed an historical in-depth two-case-study method. The first case is a nursery seedling firm (NSF) within the fruit industry and the second case supplies ingredients for the food industry (ISF). The data were developed from annual review reports and project documents combined with semi-structured interviews with key individuals of the firms.

The cases provide evidence of the firms' learning-capacity building and co-evolution of their **knowledge-integration and learning system (KILS)**. The evidence shows that what really matters is how firms develop, at a certain point, a simultaneous and complementary interaction among these learning capacities. This process creates what are defined as a 'sense of opportunity' and 'technological flexibility'.

Moreover, the evidence reveals that the oscillation between 'path-dependent' and 'path-breaking' changes is not linear along the trajectory. Thus, a rather complementary and iterative dynamic between the six learning capacities throughout the learning trajectory and technological trajectory is exhibited.

The contributions of this research are relevant to firms categorized as established engineering-based SMEs within market contexts identified as 'moderately dynamic' with disperse and erratic 'technological opportunities'.

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Intentions and motivations usually give you the strength to keep moving despite all possible obstacles. Based on my personal experience a PhD is mainly a process in which your will is repetitively tested in ways that both reasoning and perspectives of the world are challenging. When I started and even before I just had a brief idea of how this process will be able to shape my mind set and take me away from how I used to perceive things around me. Now that I have finished I cannot be sure what means to do a PhD, but what can I certainly know is that I have learnt a bit more about how to see life. More than anything this process was for me a way to educate my mind and this is how I finally have understood this journey. So, I could say that my initial intentions were surpassed by far by the final results.

This process has also thought me about consistency. Deciding to have a consistent life could be a hard way to go, probably utopic and considered unrewarded especially because it could go against many social agreements which are mainly driven by economic goals. At least at this point I'm pretty sure that being consistent is not just an option but also a way to think and act in life. And so, thinking and acting as an academic means being consistent in the pursuing of knowledge to address something for the good of society.

This way to take this learning process was certainly enabled by the Freeman Centre and CENTRIM's community, which I was lucky enough to be part of. Then, I'm very grateful to have spent these years surrounded by a great group of people who were truly committed to what they believed and taught me not by lessons but through their own way of living and perceiving the world of academics how meaningful life can be when a path to science is taken. Then, beyond ontology, epistemology, methodology and theories in innovation it was consciousness, respect for your own and others ideas and reasoning what matters the most. Being critical and ethical is the lesson I appreciate the most from these years in CENTRIM, which open up a question: What kind of scientist -if I considered one myself- I would like to be?

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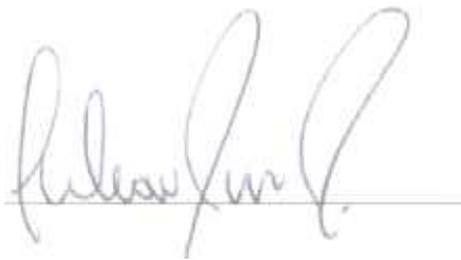
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LIST OF ACRONYMS

CIAT	International Centre for Tropical Agriculture
COLCIENCIAS	Administrative Department of Science Technology and Innovation
CORPOICA	Columbian Agricultural Research Corporation
EMBRAPA	Brazilian Agricultural Research Corporation
E&D	Engineer and Design
FLM	Functional learning mechanisms
HACCP	Hazard Analysis Critical Control Points
ICA	Columbian Agricultural Institute
INVIMA	National Institute of Surveillance of Drugs and Food
INTAL	Science and Food Technology Institute
ISF	Ingredient Supplier Firm
ISO	International Organization for Standardization
KILS	Knowledge-integration and learning system
LS	Learning Schemes
MLM	Metal learning mechanisms
NSF	Nursery Seedling Firm
R&D	Research and Development
SMEs	Small Medium Sized Enterprises

DECLARATION

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to his or any other university for a degree, and does not incorporate any material already submitted for a degree.

A handwritten signature in black ink, written over a horizontal line. The signature is cursive and appears to be 'Helen J. M. G.'.

Signed

10, October 2014

Date

1 INTRODUCTION

The research for this thesis attempts to explain further the way in which knowledge integration occurs as an iterative process shaped by the learning dynamics of the firm and mobilization of capabilities. Previous literature such as absorptive capacity and dynamic capabilities has provided some insights on these phenomena but has lacked an integrated and complete view with regards to the coordination problems related to the transfer and appropriability of knowledge and the gaining of learning capacity over different transitions periods in the firms' life cycle. So, the research in this thesis offers a routine based and a bottom-up perspective that take into account the interaction between tacit and explicit knowledge, individual and collective learning as well as cognitive and behavioural changes. As a result the research deals with how firms by challenging their interpretive system are able to make trustful technological transformations through the dynamics of knowledge integration.

The research emphasizes the importance of the micro-foundations of learning by observing the actions that firms undertake to expose themselves to new information and know-how. Two factors, which have been taken separately, are highlighted in the view that the research for this thesis proposes. First, the research argues that the way firms develop their internal knowledge drives the way they are able to create interactive processes to get access to external knowledge –i.e. a balance between external and internal sources of knowledge-. Second, the way in which firms interact with the external environment makes them realize the importance of developing productive opportunities, rather than just focusing on improving the performance of their current capabilities and routines –i.e. a balance between exploitation and exploration-. In this sense, learning-capacity and capabilities building is the result of an interactive process between the ways in which knowledge is internally created and the selection and integration of the knowledge developed elsewhere over a firm's evolution.

Traditional approaches such as the behavioural theory of the firm (Cyert and March, 1963), transaction cost theory (Williamson, 1975) and the resource-based view of the firm (Wernerfelt, 1984) evidenced to some extent the importance of strategic decisions

and learning by focusing attention on the integration of distinctive resources to gain advantage of the external business environment (Augier and Teece, 2009).

However, the debate became more complex and explanations to define which resources were more relevant started to be the main concern of researchers. Analytical distinctions have been made between knowledge, skills, capabilities, and tangible assets, and even new constructs came into the picture, like routines (Nelson and Winter, 1982; Barney, 1991; Easterby-Smith and Prieto, 2008). But the recognition of the rather dynamic character of those assets shifted the analysis towards the characteristics of knowledge and learning in a wide variety of organizational and industrial contexts. Ever since then, there has been an interest to develop theories and compile explanations about how knowledge, learning and capabilities interact and accelerate the firm's development (e.g. Nahapiet and Ghoshal, 1998; Kenney and Gudergan, 2006).

The link between knowledge, learning, capabilities and routines has been largely exhibited in a variety of empirical studies (e.g. Hamel, 1991; Leonard-Barton, 1992). Some perspectives highlight how learning acts as the glue between knowledge and capabilities but have narrowly focused on its problem-oriented character, as remarked by Nonaka (1994) and Lei et al (1996). Nonetheless, the literature converges on two main points. Firstly, organizations should have the conditions to convert knowledge into firm-specific capabilities and routines, and secondly, although the link between knowledge, learning and capabilities is clear in practice, it is so complex an interaction that organizations keep struggling to make it work effectively and outcomes are still blurred.

The intrinsic problem between the three concepts of knowledge integration, learning, and capabilities lies, as Kogut and Zander (1992) have commented, in the fact that beyond the analytical distinctions they cannot be treated independently. In practice and theory there should be a dynamic and consistent movement between the three concepts throughout the organization's existence (Argote et al, 2003).

However, in order to understand the rather complex phenomenon in which knowledge evolves within organizations over time, attention has been focused on one of the three concepts or characteristics. The literature on innovation, for example, has mainly

concentrated on the process of knowledge integration in the context of product development and as related to capabilities. The literature on knowledge and organizational learning has stimulated a shift in interest from the understanding of knowledge transfer to the organizational learning mechanisms that enable the integration process. Other literature – for example on absorptive capacity and dynamic capabilities – has focused on the renewal process of the firm’s capabilities through the ability of the firm to combine external with internal knowledge. All these types of literature are examples of the search for explanations to identify which assets are more important for the firm’s evolution and survival and what is the best way to progress along the right learning and technological trajectory.

According to all these approaches organizations exist and survive because they are able to combine a broad range of knowledge specialists. These specialists make the best use of a group of technologies to bring social benefits, which in the case of firms refer to markets. From the learning perspective firms also exist because they are able to move as fast as the industrial environment does to meet market and demand needs. Thus, firms are not steady over time, meaning that the knowledge and technology¹ of the firm are the result of its learning dynamics.

Overall, this research has focused on four issues that emerge from the literature on knowledge creation and integration; in this thesis it is proposed that these issues have the potential to obstruct the bond between the following aspects of knowledge creation in organizations: (a) the integration of new knowledge, (b) the learning mechanisms and processes and (c) the resultant outcomes in changing capabilities. The research proposes that for this link to work firms should challenge these four issues all together.

¹ Technology is an embodied knowledge object that offers a set of solutions, in which the causes, the consequences, functions and applications as well as the implications for specific types of routine are well known for any production environment. Technology can take different forms. The most characteristic takes the form of devices; it can also take the form of a technique or a final product to be used. Also technologies can be defined in terms of their complexity. The most complex include a group of devices and techniques. It is implicit within the term that as it increases in complexity, it requires more specialized and skilled personnel. Also the stage of knowledge of the technology and its proximity to the frontier determine its complexity.

The first issue refers to knowledge configuration. The research proposes that firms' interpretative systems are built through a variety of sources where internal and external knowledge are clearly more interactive than tends to be acknowledged.

The second issue concerns knowledge orientation; firms develop the conditions not only to exploit new knowledge but also to go ahead and explore knowledge that might be part of future technological and market opportunities. The research proposes that the interaction between exploitation and exploration could be sequential or iterative based on how a firm's learning trajectory evolves over time and how it comes to understand its strategic position in the industry and interprets the direction that its trajectory can take.

The third issue is the overemphasis of aspects of the macro-components of learning and organizational conditions for the process of the integration of knowledge and learning. The research proposes that focus should be placed on the micro-components of learning. Nevertheless, as also proposed in the thesis, firms' knowledge integration and learning should certainly emerge by developing an alignment, instead of a hierarchical condition, between these two levels.

The fourth issue is connected with the interpretative system of the firm; it is recognized that the knowledge of a firm is made up of a combination of tacit, explicit and codified knowledge that resides in the individual or collective memory of the firm, and in turn, this combination affects their function in integrating new knowledge. In this respect this research argues that integration of any knowledge creates tensions between how individuals or groups of individuals understand the routines and how they believe those routines should be shifted towards a specific technological direction. The link between knowledge integration and capabilities differs then depending on how firms are able to encounter the learning process. The research therefore proposes that the problem of transferability should be focused on how different types of knowledge are involved and the extent of the cognitive and behavioural changes required for knowledge integration to be effective.

These four issues combined suggest that firms should be able to see knowledge integration and learning not just as a single event but as an evolving process in which they are able to create a sense of opportunity by knowing what and how to learn. As a result, causes, current actions and consequences as well as interactions, sequences and iterative patterns matter for what might be defined as the knowledge-integration and learning system (KILS) of firms and its corresponding (effective) technological transformation. Knowledge integration and learning then become evolving processes through which firms might gradually shape their interpretative system so that they could understand how to respond to competitive challenges in the face of new technological and market demands. The research for this thesis differs from the knowledge integration, learning and capabilities related literatures (e.g. absorptive capacity and dynamic capabilities) and their corresponding analytical frameworks by challenging and integrating these four issues together in a single framework. As a result, the research distances itself from previous studies by proposing an integrative, bottom-up, action-based and historical approach for the understanding of the evolution of knowledge integration and learning of the firm.

The research, therefore, aims to answer the following overarching question:

To what extent does the integration of external and internal knowledge for either exploitation or exploration explain the organization's learning-capacity building and its functional relationship with its technological trajectory?

To enable an understanding of knowledge integration and learning by focusing on knowledge reconfiguration and orientation, the analytical and conceptual framework that has been developed for this thesis seeks to offer a stylized explanation of the underlying characteristics of the micro-components of learning, aiming to answer the following supportive questions:

To what extent does the combination of different FLMs enable the organization's learning dynamics?

To what extent do different learning capacities (sources and their orientation) trigger the organization's technological transformation process?

To what extent do the efficiency, coherence and flexibility of the learning trajectory influence the scope and outcome of the knowledge-integration process?

How do the decision-making processes and patterns of growth explain the scope and outcome of the technological learning dynamics?

How do the MLMs explain the scope and outcome of the technological learning dynamics?

How do industrial differences (e.g. agro and food processing) affect the pattern of the organization's learning and technological trajectory?

Drawing upon the literature on organizational learning (Argyris, 1976; Fiol and Lyles, 1985; Levitt and March, 1988), knowledge management (Nonaka, 1994; Pisano, 1994; Grant, 1996a), absorptive capacity (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van den Bosh et al, 1999) and dynamic capability (Teece and Pisano, 1994; Teece et al, 1997), the framework offers a window that enables observation of how organizations integrate and diffuse knowledge into their routines. Moreover, building from an evolutionary perspective (Nelson and Winter, 1982; Dosi, 1988) it traces the relationship between the learning and the technological trajectories along the firm's life cycle.

The framework assumes that learning occurs through actions, which involve not only the cognition of individuals but also collective meaning (Wenger, 1998), with the intention to change behaviours – and therefore routines – through a process of 'sensemaking' (Weick, 1995).² These intentions represented through events are defined

² New knowledge and the intentions to learn, which are represented through specific events, are most likely to be initiated in the cognition of individuals but as Teece et al (1994) have suggested, they tend to become "intrinsically social and collective phenomena" (p.15). The position of these individuals (e.g. experts and/or key managers) determines their ability to move knowledge forward through power or persuasion and bargaining (or both) to modify the interpretative system (Daft and Weick,

here as 'learning schemes'. Defining the learning schemes (through learning events) as the units within which knowledge integration and learning can be observed brings about a discussion which refers to the organization as a social structure of shared perspectives in which actions are a response to the organizational context but are based on individual interpretation, and it is the individuals who finally search for new interpretative systems. As noted by Brown and Duguid (2001), "...what individuals learn always and inevitably reflects the social context in which they learn it and in which they put it into practice" (p.201).

Learning schemes refer therefore to the efforts that organizations make to acquire and internalize knowledge from elsewhere into their production systems. As discussed above, integration is complete when incremental, modular or radical alteration is made (Henderson and Clark, 1990) and when the technology in question is used to exploit its own potential. Hence, the learning schemes link the functional learning mechanisms (FLMs) with the learning process – i.e. through processes of reflection, assimilation and implementation – and the methods proposed by Hislop (2003) – i.e. socially based methods and formal communication-based methods. The learning schemes are the representations through which knowledge integration and learning occurs, the learning events being the observed unit of analysis.

Once a specific knowledge's property is assigned to these learning schemes, they represent the building blocks of the 'learning capacities'. **Learning capacity** is defined by the ability of the organization to integrate different types of knowledge from a variety of sources with the aim of modifying current technological capabilities and routines to fit into the industry or create productive opportunities. The learning capacity represents the second level of analysis.

The firm's learning capacity has been traditionally acknowledged in the literature as 'absorptive capacity'. Nevertheless, it has been primarily associated with the firm's ability to obtain knowledge from R&D, which tends to neglect other learning and

1984). As a result learning could be collectively constructed if persuasion takes place or collectively accepted if it is introduced through power instead. In both situations the interpretative system tends to be socially embedded into the routines and new cognitive processes take place.

technologically related events. Where previous instances of learning capacity have been recognized in the literature, a path-dependent condition of learning and capacity building could be traced.

Therefore, unfolding the concept of absorptive capacity based on all the different types of learning event over the firm's life cycle, and emphasizing the orientation and the extent of knowledge configuration, can distinguish a learning capacity taxonomy. Whereas the first group of learning capacities refers to knowledge exploitation, which are (1) formative, (2) adaptive and (3) transformative, the second group relates to knowledge exploration, defined as (4) inventive, (5) created and (6) renewed.

Each level of capacity might determine a transition period faced by an organization over its technological trajectory. This means that one level of capacity is developed upon the previous one. Incremental and path-breaking changes, either at the capability or routine level, are expected over these transition periods linking each level of capacity with its corresponding scope and outcome in terms of technological transformation.

In this sense the process of innovation within an organization it will be more broadly perceived and defined as the cumulative use of embedded alongside external knowledge either to solve technical problems or to produce changes in capabilities and routines that shift the organization to diversify its technological or market opportunities. Innovation is understood, then, as the technological transformation process³ that an organization is able to follow in order to fit into the industry; therefore it takes into account the scope and the trajectory of the related technology and market. And so, beyond of what firms can possible achieved in terms of the development of new products, services and technologies, when they engage with innovation should deal with the problem of coordination, in which firms constantly challenge their interpretative system and are able to move and appropriate knowledge of different forms and nature.

³ For the sake of the research, technology (information and know-how) has been associated with component knowledge, distinctive in three types following Van den Bosh's (1999) suggestion: "knowledge related to products or services, knowledge related to production processes and knowledge related to markets" (p. 552).

An historical in-depth two-case-study method was selected as the most suitable strategy to carry out the research. Four main factors were used to guide and provide the rationale for the selected method. **First**, the main research question searches for how and why the dynamics of knowledge integration, learning and capabilities interact from the perspective of the orientation and sources, rather than only looking for associations – i.e. the ‘what’ types of question. **Second**, an approach based on both the sequence and history of learning events was planned for the purposes of understanding the evolution of those dynamics. **Third**, from the theoretical discussion it was anticipated that a multilevel analysis – going from the micro-characteristics of knowledge and learning to the macro-related features – would be undertaken (Foss et al, 2010). **Fourth**, the availability of cases was limited due to choice of the setting and population; from the case selection process only two firms were found.

The research followed a deductive-inductive sequence of inquiry. As the research is positioned within an established theoretical framework, the initial conceptual and analytical assumptions were developed from the knowledge management, organizational learning, dynamic capabilities and absorptive capacity literatures. However, as the process of observation and analysis followed an integrative perspective combined with a longitudinal approach, new constructs (e.g. learning schemes) were validated and different analytical interactions such as the one between the learning capacities and the development of capabilities were revealed. Some other assumptions emerged from the analysis like the understanding that the knowledge integration and learning system should be viewed from a single conceptual approach (the literature has treated both systems as related but different) and the consideration that bottom-up logics for creating learning dynamics should be followed by firms for effective technological transformations rather strategic and up-down approaches; in other words to mobilise knowledge and learning, organizations should develop a dialectic and iterative system of interpretation in between operational and organizational routines.

Qualitative research and more specifically case studies have been widely discussed in the literature on organization and management not only because of their relevance to the understanding of certain phenomena, but also because the search for consistency and coherence is essential in order to have valid arguments. Most of the discussions

relate to how objective or subjective the reality can be, or how general or specific an argument needs to be for the purposes of making a contribution to knowledge. It is clear that case studies tend to be context-specific or exploratory or they serve the purpose of generating or building theory.

This research contributes towards this discussion by following previous suggestions (Yin, 1994; Platt, 1988; Lee, 1989; Leonard-Barton, 1990; Eisenhard, 1989a) in the sense that case studies not only require as much justification as possible but also need to bring about epistemological consistency. However, context-specific research, even if is theory-driven as this study has been, requires a more dialectic dialogue between the intentions of the research, theory and the reality it seeks.

To approach the analysis of knowledge integration, learning and capabilities, the research proposes to focus the attention on SMEs in an emerging economy⁴, the selection of which followed a strategic and systematic procedure. The firms from which the evidence was taken are characterized as established Small and Medium Enterprises (SMEs) and engineering-oriented. As well as demonstrating that they had the intention to learn, these two SMEs also showed that they had looked forward to moving from a mature, single technology to an emerging, complex technology. These two factors in particular meant they were valid cases from which to collect the evidence, which would then be subjected to analysis in a market context considered moderately dynamic. In

⁴ While the technological capability literature in emerging economies (Bell, 2007; Dantas, and Martin, 2011; Dutrénit, 1998; Dutrénit, 2009; Figueiredo, 2002; Figueiredo, 2008a; Figueiredo, 2008b; Figueiredo, 2010; Hobday, 2005; Hobday and Rush, 2007; Kim, 1980; Kim, 1997; Kim, 1998; Kim and Nelson, 2000; Liu, Qian, and Chen, 2006; Marin and Bell, 2010; Oliveira Vera-curz, 2006) is recognised as important, what the literature has to say about knowledge integration, learning mechanisms and learning capacities in the development of local markets and users demands turns out generally to be limited. This literature emphasises in the following aspects: i) It mainly focuses on how firms acquire foreign technologies, ii) it centres the analysis on building on and categorising of capabilities and operational routines rather than the evolution of learning dynamics, iii) It is located in the process of catching up and the paths that firms should follow to be competent in using dominant design technologies, iv) This literature generally observes either large firms in emerging economies or what have been called latecomer firms or the building of capabilities of multinational subsidiaries in developing economies and v) it considers external demands as the main motivation for upgrading technological capabilities neglecting local user requirements as a fundamental source of learning and capabilities development. All these aspects although relevant differ from the approach that the research in this thesis takes.

this sense these two SMEs were distinguished as atypical and defined as high growth SMEs.

The SMEs were selected from a database specifically developed from R&D projects presented for grants to the national governmental organization in charge of the support of scientific and technological development in Columbia called COLCIENCIAS (Administrative Department of Science, Technology and Innovation: acronym is in Spanish). From this database a specifically defined population of firms was selected.

The case study strategy has enabled a rich and detailed analysis of how the micro-components of knowledge integration and learning – i.e. learning schemes – interact over a long period of time, and in turn this has led to a better understanding of the causes and consequences of the process of building up capacity and capabilities.

The first SME is a firm whose economic activity consists of raising nursery seedlings, specializing in the fruit industry, positioning the firm at the bottom of the fruit value chain. It sells certified plants of perennial fruit trees⁵ to farmers with commercial orientation. The firm was a pioneer in the industry, which is made up of SMEs. The second SME is a firm whose economic activity consists of supplying ingredients – e.g. improvers of flavour, colour and textures, additives and preservatives – to the food processing industry specializing in human consumption.

The KILS in both SMEs was observed through the same analytical and conceptual framework, with an emphasis on the learning schemes. The analysis of the evidence emphasizes how the interaction between the orientation of knowledge and its configuration responds to the process of learning-capacity building; defining in this way the importance that knowledge integration and learning have for the firm's strategic orientation and development.

In both SMEs the learning and technological trajectories were traced from inception. In the case of the nursery seedling firm (NSF), 409 learning events were reported grouped

⁵ Perennial refers to a plant that lives for more than two years. Fruit trees such as mango, guava, citrus and avocado are perennial in nature.

into 17 different types of learning scheme from 1983 to 2010. In the case of the ingredient supplier firm (ISF), 850 learning events were reported grouped into 23 different types of learning scheme. By looking at these learning events (that were chronologically organized and categorized according to learning schemes and the corresponding learning capacities), the cases provide a complete picture of the depth of the firms' KILS and throw new light on both how dynamic capabilities work and absorptive capacity is gained throughout a firm's lifecycle.

To collect this information from firms a combined set of documents as well as semi structured interviews were carried out to different key members of the firm over a period of two months. The historical information that covered 27 (NSF) and 27 (ISF) years respectively was gathered retrospectively, reflecting on the past and recent learning events of the firm. The study was also longitudinal as it relates different periods of the firm's life cycle with regards to the development of the learning capacities.

The thesis has three main parts: the first comprises the theoretical (chapter 2), conceptual and analytical (chapter 3) discussion; the second describes the methodology (chapter 4); the third focuses on the case studies from which the evidence was taken (chapters 5 and 6) and the cross-case analysis (chapter 7). Overall, the thesis is made up of eight chapters that are summarized below: the introduction (chapter 1), chapters 2 to 7 mentioned above, and the conclusions (chapter 8).

Following this introductory chapter, **chapter 2** focuses on the theoretical debate around knowledge integration, learning and capabilities. Drawing upon three streams of literature, it discusses the problems, and their implications, of knowledge integration in the evolution of the capabilities of the firm and how firms through learning overcome these problems and build their learning capacities.

The chapter first discusses knowledge in organizations; two factors are highlighted from the debate over how knowledge is integrated and the implications of this process for firms. The first emphasizes that the problem of knowledge integration is closely related to how the interpretative system of the firm is created. The second factor

stresses the distinction between architecture and component knowledge, arguing that although it has been neglected there is a dialectic interaction between these two levels of knowledge.

The following section concerns the debate over (1) the relative importance of the meta-learning mechanisms (MLMs) compared to the FLMs, and (2) the learning process as a means for bringing about cognitive and behavioural changes. Regarding the first point the section argues that more emphasis should be placed at the level of the micro-components of learning, suggesting that organizations should challenge the interaction of both types of mechanism instead of looking at them as one-directional processes to create and facilitate the conditions for knowledge integration through learning. The second point, in contrast, is more concerned with the effectiveness of knowledge integration, arguing that depending on asymmetries in the interpretative system within the organization's members and distance in the technology, different methods of learning should be pursued over the learning process to achieve the right cognitive and behavioural changes.

The third section focuses on the main point of the research in this thesis, which is about the interplay between internal and external knowledge and between exploitation and exploration of knowledge for the evolution of the firm's learning capacities. This section discusses the oversimplification that researchers in the field have tended towards by paying little attention to the causes and consequences of these interactions in the evolution of the firm's learning capacity. The chapter ends by describing the theoretical motivations and the main and supportive research questions.

Chapter 3 develops the analytical and conceptual framework that has shaped the arguments behind the research. Consistent with the discussion of the literature, the framework aims to specify what is defined in this thesis as the KILS.

First, the chapter discusses the implications of the learning scheme as a construct to define the micro-components of learning. By taking this approach the research suggests several aspects of the KILS. First, learning in organizations occurs through the actions (learning events) they take to expose their interpretative system. Second, these actions

happen at an individual level or through social interactions. Third, these actions mobilize component knowledge by combining different types of knowledge – i.e. automatic, conscious, collective and objective (Spender, 1996; Lam, 2000). Fourth, the learning process deals with different cognitive and behavioural responses to generate a result in the way routines are performed. And fifth, the outcome of any of these actions is likely to complement the others. This approach is motivated by an interest in the interaction of the learning events for the KILS.

The following section is centred on the link between learning and capacity building. Out of all the characteristics embodied in the learning schemes, the research for this thesis focuses on the reconfiguration of knowledge (i.e. whether sources are passive, active or interactive) and its orientation (i.e. whether it is exploitative or explorative) for the process of capacity building. Thus, the section proposes that firms develop different learning capacities based on their exposure to external knowledge and the additive effects of both orientations to knowledge over their lifetimes.

The next section acknowledges the association of the KILS with the technological trajectory describing what it means to have an effective technological transformation. The chapter ends by explaining all the integrative elements that make up the KILS, which include, besides the micro-components of learning, the MLMs and other characteristics of organizations like the organizational forms and their decision-making processes.

Chapter 4 describes the research strategy used to answer the main research question. The chapter goes beyond an explanation of the research methodology and frames the discussion on qualitative research methods by defining the philosophical discussions behind this type of approach so to as understand and interpret what happen within organizations.

The chapter is divided into two sections. First, there is a discussion about the foundations of the research design in the light of the literature on case studies methods; Eisenhardt's (1991) suggestion is followed – that case studies should be rationally bounded as much as possible by delimiting the features in which the theoretical

arguments from them will be taken. The section therefore considers the paradigmatic approach, the purpose of the research, the logic sequence, the typology, the replication logic, context setting, level of analysis and timescale.

Second, the research process is presented; it describes how the methodological justifications are represented through the sequence in which the research was undertaken. The research for this study was completed in eight phases and followed an iterative process – described as cyclical by Marshall and Rossman (1999) and Chatman and Flynn (2005).

The discussions on methodology in chapter 4 introduce the analysis of the two case studies, which are the result of the strategy used in the research for this thesis. **Chapters 5 and 6** present the evidence from, respectively, the first case study (nursery seedling firm) and the second case study (ingredient supplier firm). Both chapters follow the same structure, because the aim was to have a comparative narrative between the two cases. The first two sections are centred on the analysis of the evolution of the market and the technological context of the firms⁶.

The next sections describe the process of knowledge integration through the learning schemes and the their links with the learning-capacity building and the firms' technological trajectories. Each of these two chapters aims to offer the within-case analysis based on the conceptual and analytical linkages explained in the analytical framework (e.g. learning schemes, learning capacities and MLMs).

Chapter 7 presents the cross-case analysis. The chapter compares the two cases in terms of the conceptual and analytical construct. The cross-case analysis offers a refinement of the theoretical discussion (chapter 2) in light of the evidence taken from the cases to propose a stylized analysis of the link between knowledge integration, learning capacities and capabilities. The first section describes the similarities and

⁶ As both of the two SMEs were pioneers and leaders in their corresponding markets, their managers had a great level of understanding of their market and technological context. So, the sections in each of the case reports related to the market were constructed based on information collected from the managers and key members of the SMEs.

difference between the two cases in order to have a clear perspective on a comparison of their KILS.

The following sections focus on using the evidence from the cases to raise arguments over the main theoretical discussions posited in chapters 2 and 3. First there is a discussion of the problem of transferability and appropriability encountered by firms across the evolving process of the KILS. The following section analyses data from the two cases on the interaction between knowledge configuration and orientation for the development of the firms' learning capacities. The chapter ends by offering an integrated picture for the understanding of the co-evolution of the KILS in relation to the technological trajectory over the firms' life cycles.

Chapter 8 summarizes the findings in the research for this thesis. The chapter comprises a final discussion of (1) the main concepts proposed in the analytical framework and (2) how the KILS serves as a construct that combines discussions from the literature on knowledge management, organizational learning and capability to enable a better understanding of how firms deal with the process of knowledge integration, learning, capacity building and capabilities. An emphasis of the debate in this chapter relates the concept of 'absorptive capacity' with that of 'dynamics capabilities'. Finally the chapter discusses the limitations of the research, some managerial and policy implications and provides some guidelines for future research.

2 KNOWLEDGE INTEGRATION, LEARNING, CAPACITY BUILDING AND CAPABILITIES IN ORGANIZATIONS

2.1 Introduction

This chapter aims to offer a theoretical explanation of the nature of the link between knowledge integration, learning and capabilities from previous analytical and empirical works based on two main bodies of the literature – knowledge management and organizational learning. Other supportive literature such as absorptive capacity, exploration and exploitation, and dynamic capabilities are used to offer a broader explanation of the already extended and complex phenomenon. The examination of this literature exposes the analytical distinctions and discussions that frame the research, the empirical description and the later analytical and theoretical arguments.

The chapter comprises a series of arguments set out in next four sections. Section 2.2 discusses the problem of transferability and hierarchies of knowledge so to as offer the conceptual boundaries of the analytical discussion. Section 2.3 discusses one of the core arguments of the research regarding the mechanisms and the process of learning; in addition, the first explicative features are described – i.e. meta-learning mechanisms and decision-making processes. Section 2.4 discusses the relationship between knowledge integration and learning as seen through the lens of the sources and the orientation of knowledge. It also discusses the absorptive capacity construct by looking more closely at the influence of the state of knowledge and experiences: the argument is that organizations search for absorptive capacity through a variety of learning dynamics. Finally, Section 2.5 sets out the theoretical arguments that support this research and gave birth to the research questions that underpin the empirical investigation.

2.2 Organizational knowledge systems

The literature shows that researchers have recognized that firms have three main functions as repositories of knowledge. First, firms were just considered for their role as users of knowledge, but scholars then started to observe their second role in knowledge creation and their third role in knowledge integration. It must be said that organizations and more specifically firms are key to determining the dominant knowledge base in terms of technology and its direction within an industry.

This section focuses mainly on knowledge integration as the interest for this thesis is more closely related to the mobilization of knowledge that creates changes in the organization's state of knowledge. Two questions are behind this position: (1) to what extent all knowledge is transferred from that which is tacit to that which is explicit; and (2) how the result of what is finally integrated could be defined. Building on the literature on knowledge management, the following subsections frame the research by looking at the problem of transferability and the hierarchies of knowledge within organizations.

2.2.1 Knowledge integration: the transfer problem and knowledge conversion

Literature dealing with knowledge integration has focused on the distinction between tacit and explicit knowledge (Polany, 1966; Anderson, 1983; Nonaka, 1994). Tacit knowledge is created in the cognitive process of individuals with regards to how they interpret the system in action; explicit knowledge is created when practices and procedures are not just conventionally known but are also defined through objective codes of communication.

Knowledge integration, as discussed in this thesis, is concerned with Nonaka's (1994) fundamental question of how knowledge is created in organizations. The section considers the question: is the conversion of knowledge what matters the most, taking into account that organizations in the evolution and expansion of their interpretative system create the conditions to complementarily use both types of knowledge (ibid.)?

As a result operational routines are made and developed by combining tacit and explicit knowledge (Hamel, 1991). The section also deals with a second question: how can the integration of tacit and explicit knowledge be balanced to assure appropriability?

The main concern here then is knowledge transferability – i.e. from tacit to explicit and vice versa – within the organization (and between organizations). Scholars kept suggesting that despite all efforts there is always some knowledge in the firm that remains tacit. Nelson and Winter (1982) pointed out that the domains of both types of knowledge are blurred and flexible. Ever since then researchers have been preoccupied with the importance of this tacit knowledge, claiming sometimes that it might be the source of competitive advantage (Winter, 1987; Hall, 1993; Grant, 1996a). Hence, managerial problems have included those related to defining which type of knowledge is more critical for the firm, how to use that knowledge to create value, under which circumstances, and how it should be transferred.

Grant (1996) suggested that knowledge integration might be better understood as way of making the best use of complementary technologies through cross learning by organizational members. This approach focuses on coordination, which means, “establishing a mode of interaction” (ibid. p. 114) between and among tacit, explicit and codified knowledge to assure appropriability. So, knowledge integration is first interpreted as a process of knowledge conversion – i.e. between tacit and explicit and vice versa – (Kogut and Zander, 1992).

Therefore organizations and more specifically firms accomplish the role of knowledge-integrating institutions (Grant, 1996). This knowledge view of the firm states that the firm’s main task is the integration of the specialized knowledge of a variety of individuals. In other words, organizations and firms define the value and the rules within which the exploitation of knowledge is rooted for the development of capabilities and routines; knowledge is then validated when it is fully appropriated by firms. This perspective is distinguished by two assumptions based on Grant’s argument: “knowledge creation is an individual activity” and “the primary role of firms is in the application of existing knowledge to the production of goods and services” (p. 112).

Although this is an interesting conceptual approach, building on Simon's (1991) suggestion, it just considers that knowledge creation and integration are mainly spurred by (a) what the members of a firm know individually and (b) the hiring of new specialists.

This argument, however, does not pay much attention to routines as the place where the memory of the organization is located, as March (1991) has observed. Spender (1996) implied having two complementary positions in this respect. The first goes in line with the concept of coordination that sees knowledge integration as a managerial problem – this means that firms should be able to move individual knowledge around the firm whilst simultaneously preventing leakage of information (maximizing appropriability). The second argument suggests more focus on rules and routines where knowledge is embedded so to as have shared knowledge and constraints on individual members (ibid, 1996). Indeed, knowledge integration refers to the mobilization of tacit and explicit knowledge from and among individuals to make it part of the 'knowing' of the firm through the routines.

In this line of argument, Spender (1996) also proposed moving beyond the tacit and explicit type of organizational knowledge. He suggests that knowledge in organizations needs to be distinguished between individual and social as well. While individual knowledge moves with the person, social knowledge is embedded in the routines and remains in the firm. Based on his analysis four types of knowledge are identified: conscious, automatic, objective, and collective. In line with Spender's argument this research proposes that each of these knowledge types leads to different transfer and mobilization patterns, and therefore that the implications of each type for the firm might be explained by different theoretical approaches. But is also argued that when organizations integrate knowledge they look to combine different types of knowledge while assuring appropriability.

Transferring knowledge from individuals in either of the first two forms – conscious (explicit) or automatic (tacit) – depends on solving the agency problem⁷ (Eisenhardt, 1989) through power in the first case or persuasion in the second. Objective knowledge (explicit) is closely related to market mechanisms in which the value of knowledge can be regulated – i.e. institutional mechanisms. Collective knowledge (tacit), on the other hand, is related to the process of production translated into routines. The argument gives importance to individuals as learning agents (Nonaka and Takeuchi, 1995) but follows Nelson and Winter's (1982) presumption that firms have the ability to keep knowledge in their routines independently of their employees.

Lam (2000), using a similar categorization – i.e. embrained (explicit-individual), encoded (explicit-collective), embodied (tacit-individual) and embedded (tacit-collective) – added a controversial argument to the analysis. She argued that firms with a specific organizational form are able to take advantage of the conversion of specific types of knowledge over the others. Based on Mintzberg (1979), Aoki (1986) and Nonaka and Takeuchi (1995) typologies, Lam proposed a framework in which she discussed that different organizational forms vary not only in how they coordinate the conversion of knowledge in favour of the use of certain types of knowledge during their evolution and expansion process,⁸ but also because of the nature of the component knowledge they tend to create.

⁷ According to this author the agency relationships arise when (1) goals between the organization and the agent are in conflict and when (2) is difficult for the organization to have control over all agent actions.

⁸ In this framework organizations associated with 'professional bureaucracy' tend to create and convert most of the knowledge into embrained knowledge while organizations such as 'machine bureaucracy' are keener to rely on encoded knowledge. In the former type of organization, which is functionally segmented and hierarchical, knowledge resides in the more skilled staff who are also in charge of designing the work rules and job boundaries. So, coordination is achieved by standardization, and tacit knowledge is contained within the boundaries of individual specialization; "learning tends to be narrow and constrained within the boundary of formal specialist knowledge" (Lam, 2000: p. 495).

In the case of the 'machine bureaucracy' type of organization associated with encoded knowledge, specialization, standardization and control are the bottom line of the whole coordination system, and then it tends to be fragmented. Based on Lam's (ibid.) argument, all efforts in this type of organization are aimed at the codification of operating skills. The formal managerial hierarchy is the main agent responsible for the formulation of the procedures and performance standards – i.e. transferring tacit to explicit and codified knowledge – and the integration of knowledge. Tacit knowledge tends to be minimized and learning occurs through correction and monitoring. Based on this characterization these types of organization are not good at dealing with novelty and change.

Along the same line of argument De Boer et al (1999) stated, “organizational form has important implications for a firm’s ability to generate the type of knowledge integration process required by the context” (ibid: p. 382). Organizational form in this analysis refers to the infrastructure that supports the process of knowledge integration. Differing from Lam’s (2000) framework, and building on the framework proposed by Ansoff and Brandenburg (1971), De Boer et al (1999) used other types of organizational form, that is, functional, divisional, matrix and innovative forms. This latter distinction seems to offer a complementary explanation to that of Lam (2000).

Hence, the argument that specific organizational forms shape how knowledge and the learning patterns are combined seems to be supportive enough to be taken into account (Kenney and Gudergan, 2006). Some organizational forms favour a specific type of knowledge and place emphasis on certain ways in which it is mobilized across the organization. So, knowledge transfer might be distinctively pursued through the actions of specialized skilled individuals or collaborative practices and behaviours.

The empirical analysis in this thesis, while recognising the relevance of the organizational form for knowledge integration, stresses the rather dynamic character of organizations over time arguing that organizations and more specifically firms do not necessarily remain as one type during their life cycle; on the contrary they migrate to adjust themselves to technological and learning circumstances. It is argued that not all

On the other hand are the organizations that give more importance to tacit knowledge. In this framework embodied knowledge is associated with the ‘operating adhocracy’ type of organization and embedded knowledge with what Aoki (1988) defined as the ‘J-firm’.

The ‘operating adhocracy’ organization is not concerned with standardization of work processes and it is rather collaborative by having market-based project teams. Knowledge in this type of organization is considered embodied. Although individual knowledge is important, this type of organization aims to put together diverse know-how for experimentation, and interactive problem solving, coordination and learning occur as a result of this teamwork of individual experts from diverse specializations. This type of organization tends to change faster; it then creates problems of knowledge accumulation, but at the same time ‘operating adhocracy’ organizations are characterized by their innovativeness.

Finally, the ‘J-form’ organization that is best recognized for having team relationships and shared culture among its members is related to embedded knowledge. In this type of organization managerial hierarchical structure and non-hierarchical teams operate in parallel. Knowledge transfer occurs as a result of the temporary movement of individuals across projects teams who then return to their formal positions. According to Lam (2000), innovation in the ‘J-form’ of organization is more likely to happen incrementally rather than radically.

areas within the firm fit within one type of organizational form responding to one mode of knowledge conversion, configuration and learning pattern, and so different forms are likely to coexist within the same organizational context.

All in all, knowledge integration in this first approach implies minimizing the cost of mobilization of, and interaction between, different knowledge types accurately across the organization through coordination and by maximizing their appropriability. Researchers are still recognizing the complexity of this process; therefore, efforts have been made to distinguish individuals from organizations and to explain how transferability patterns might change from one firm to another.

As discussed by Kenney and Gudergan (2006) this research goes in line with previous findings regarding knowledge transfer in two senses. First, despite the efforts that firms should invest in keeping some knowledge in its tacit form and making other knowledge explicit, the interdependency of all knowledge types for the knowledge integration process is recognized. Second, knowledge transfer is very much linked to learning, and so, all the conditions affecting the learning dynamics of the firm enable its capacity for knowledge transfer.

In this subsection the concept and foundations of the process of knowledge integration have been discussed. The process has been initially explained from the perspective of organizational forms; nevertheless, further distinctions and explanations are added to enable a more complete argument for the framing of the research. The following subsection discusses another distinction to be taken into account related to knowledge hierarchies before discussing in further detail the implications of learning strategies for the knowledge integration process.

2.2.2 Knowledge hierarchies and the appropriability of the component knowledge

Based on the assumptions set out above about knowledge types, a complementary position to knowledge creation and integration which is hidden in this argument relates

to the mutual dependence between coordination and the production system – i.e. the process technology deployed (Lam, 2000). This concern brings up a discussion that is closely related to the functional relation of knowledge with regards to the process technology (Hughes, 1983, 1992; Callon, 1992 ; Pisano, 1994).

Knowledge integration, as has also been recognized, implies a process in which an advanced technology is implemented either as a replacement of, or for introducing, new operational capabilities as part of current routines. Based on this complementary view, integration is complete if an incremental alteration is made and if the technology in question is being used to exploit its potential. In a study on process technology, Pisano (1994) considered a project completed only after there was evidence that the implementation operated consistently as expected. Here the concept of appropriability rests on operational efficiency.

This recognition leads to the idea that knowledge is not an asset and is not static. Following Spender (1996), knowledge in the firm is better understood as “ [...] the processes embedded in the organization, which are represented through the *firm's* ability to cognize about them and behave accordingly” (ibid, 1996: p. 54, italics are mine).

Regarding this matter, De Boer et al (1999) proposed a knowledge hierarchy. At the top of the hierarchy lies the ‘architectural knowledge’ which is defined as the platform that firms create to enable knowledge integration; this knowledge is related to, for example, organizational forms, structures, hierarchies, interaction processes, incentives and communication capabilities. At the bottom of the hierarchy lies the ‘component knowledge’ referred to as the structure of production based on the technological settings of the industry; this knowledge is related to products or services, production processes and markets.

Hence change can be related to either the architecture or the components. However, the main challenge of knowledge integration as a management system, as it is discussed in this thesis, consists on achieving the right combination of architectural knowledge for the better performance of the component knowledge. In line with Wei et al (2009) the

thesis argues that coherence in the interaction between these two levels of knowledge in the organization can be achieved by mixing top-down or bottom-up approach. Indeed, the thesis proposes that the architectural knowledge is not static and it should also change as a respond to alterations in the component knowledge level.

In contrast to previous studies, the empirical focus of this research is on the component knowledge, and so a bottom-up analysis from component to architectural knowledge has been done. Research on knowledge management has traditionally focused on architectural knowledge claiming that knowledge integration is better explained in terms of the differences that exist between organizational environments that enable the creation of favoured conditions for socialization and interaction (see Kogut and Zander, 1992). Nonetheless, these approaches tend to neglect the relevance of individual and group actions, which brings about the cognitive and behavioural condition of knowledge integration. Although arguments can arise that knowledge creation at the component knowledge level is conditioned by how the architectural knowledge is set, there is still a great deal to be understood with regards to individual agencies and their direct actions on the component knowledge.

Moreover, specific events that are pursued to influence specific aspects of the component knowledge could be more critical to understanding behaviours than intentions and incentives which are features related to architectural knowledge. By then looking at the micro-components of knowledge⁹, coherence and consistency are more clearly assessed. Challenges in approaching the problem of knowledge integration and learning via their micro-components consist of making sense of aggregated sequences of events resulting in new ways to set up the architectural knowledge. In consequence the interrelation and dynamics between the component knowledge and the architectural knowledge is acknowledged.

⁹ Looking at the micro-components of knowledge integration has raised more methodological and epistemological discussions than ontological given the lack of information available at the level of the firm in terms of how a sequence of events can be traced over time (Rousseau, 1985; Becker and Huselid, 2006; Foss et al, 2010). In this sense explanations have focused more on the structure rather than on the agency of individuals.

Leonard-Barton (1988), who implicitly made a bottom-up analysis, focused also on the component knowledge. Her study exemplified knowledge integration in the case of new production technologies. She showed that integration happens when technology is implemented, in other words, when the new production technology gets started and runs into the daily routines. In this case she attested that integration is also a dynamic process of mutual adaptation between technology and the environment (ibid, 1988). By environment she meant the structure and practices of the existing organizational settings and industrial arrangements.

It is suggested in this research that knowledge integration happens as a dialectic interaction between technology and routines until the desired conditions are met.¹⁰ In this sense it deals with issues such as the character of the technological development with regards to its complexity (Kogut and Zander, 1992), uncertainties in terms of the outcome, design of the production system, engineering skills of the staff and organizational routine settings. So, additional questions related to the extent of change and alteration of the organization when knowledge is being integrated have also been at the forefront of investigation, which leads the theoretical argument to the second question, posted above, concerning what is finally integrated.

The assumption behind these questions links knowledge integration with change in capabilities, routines and performance (e.g. Carmeli and Tishler, 2004; Wei et al, 2009). As complicated as it sounds to provide evidence for this ontological relationship, an effective managerial solution to knowledge integration, as noted by Wei et al (2009), should tend towards achieving outstanding financial management through operational functioning and new business opportunities (Teece, Pisano and Shuen, 1997; De Boer et al, 1999; Kalczynski, 2005).

A careful reading of the literature on knowledge management implies that the scope and outcome of knowledge integration is hard to define from the organizational perspective. As a result, much focus has been placed on specific contexts such as mergers and acquisitions, new ventures and product development (considered below in

¹⁰ In line with Cyert and March's (1963) behavioral theory of the firm, the concept of satisfaction is considered more appropriate than efficiency to explain the outcome of change and growth.

this chapter as learning mechanisms). In dealing with this issue Grant (1996a) described effective transformation processes as having three different aspects: (1) efficiency of knowledge integration, (2) scope of knowledge integration, and (3) flexibility of knowledge integration.

According to Grant's framework, the **efficiency of knowledge integration** refers to how firms are able to get the best use of specialized knowledge from their staff members. In other words, knowledge integration is efficient if new component knowledge, which can be transferred from internal or external sources, has a direct impact on the operational routines and therefore enhances the firm's competence.

According to Grant (ibid.) three conditions are necessary for the efficiency of knowledge integration. First, there should be common ground in the knowledge base in the case of interaction between different specialists, which means similar cognitive understanding of concepts, experiences, and vocabulary. When knowledge integration implies the development of collective knowledge, even though asymmetries can bring a richer interpretation for taking advantage of new knowledge, if they are too wide with regards to the technical implications and values of the new knowledge, the outcome of the process tends to result in ambiguities. Second, routines in which knowledge is integrated should be frequent and stable enough to act as repositories of new information and know-how. Lastly, the structure of the organization should guarantee the transfer and mobilization of knowledge without much communication.

The **scope of knowledge integration** refers to the requirement of different specializations to face the complexity of the component knowledge. In the words of Grant the scope is related to "the breadth of specialized knowledge" (ibid.: p. 380). Finally, the **flexibility of knowledge integration** relies on the ability of the firm to extend its existing capabilities either through the implementation of additional types of knowledge (e.g. when a chemical firm introduces a microbiologist in an attempt to modify the inputs of production) or through reconfiguring existing knowledge into new types of capabilities (e.g. when a staff member is rotated from one function to another).

When referring to component knowledge, this analysis implies that knowledge integration is not necessarily a straightforward process. In this sense successful knowledge integration is more likely to occur when organizations are able to understand the managerial characteristics of the process beyond the engineering-related features as Pisano (1994) had previously suggested. Knowledge integration also happens when any alteration of the technology is preceded by adjustments in the organizational settings (De Boer et al, 1999; Lam, 2000; Kenny and Gudergan, 2006). This position contrasts with the view of knowledge integration in which technology is just assumed from the perspective of the developer and is forcibly put in place by them.

In strict terms knowledge is considered integrated when the perceived returns from the new knowledge exceed the value of the routine (e.g. Grant, 1996). Consequently, appropriability is defined to as the ability of the firm to receive higher returns. However, as Grant (1996b) recalled from Rosen (1991), it is difficult to explicitly identify in organizations (which are systems with many imbalances (e.g. Tsoukas, 1996)) from which knowledge specifically the returns or values are taken – e.g. tacit or explicit – and so as Grant also acknowledged, organizations are challenged to identify how an optimal investment will be achieved by new knowledge.

This discussion opens the door to what has been defined as the ‘states of knowledge’ of production and the relationship between knowledge integration and performance (this relationship is given the term ‘rent’). Appropriability of knowledge in this sense is mediated by three aspects: the knowledge that organizations have of their production systems, the way in which technologies are available for the firm disposal and the existence of appropriate routines to receive the new knowledge that allows firms to take the best from it. But also because of the imbalance that organizations face across functions, rent might be better considered as an overall concept for the firm’s organizational routines.

Alternatively, regarding knowledge integration and performance, Leonard-Barton (1988) in a study of 12 technological implementations distinguished three types of misalignments in the knowledge-integration process: the first is technical, the second relates to what she calls ‘delivery systems’ and the last refers to values.

The **first misalignment** refers to the technical features of the technology. According to Leonard-Barton it can happen in two ways. On the one hand, it occurs when technology is still not ready to meet targets and there are still some scientific and even technical misunderstandings that need to be clarified. On the other hand, it can happen when the knowledge related to organizations' operational routines is unpredictable and erratic rather than proceduralized and organized. And so, technological implementation (c.f. as a form of knowledge integration) can have a negative effect or might not be as beneficial as expected if there is a lack of understanding of the routines.

The **second misalignment** can happen through what Leonard-Barton calls the 'delivery system', which is defined as the technical attributes of the system through which the technology is delivered to users. Blueprint manuals in the case of equipment acquisition, training for the implementation of a new technique or the engineering support for a software implementation are some examples of delivery systems. The misalignment occurs when the technology is not well understood and so is not adequately integrated into the routines and could be either rejected, underused or sabotaged.

To explain the **third misalignment** related to values, Leonard-Barton distinguished two interrelated performance criteria: significance of the technology for job performance and the nature of the impact. While the significance could be qualified as either high or low the impact could be negative or positive.

Significance refers to how the routines are altered by a new technological implementation. According to the framework proposed by her, if the affected activities are core the significance is high, otherwise (i.e. for peripheral activities) the significance is low. The impact is reflected by financial measures but also by efficiency in production, status, improvements in the conditions in which the routines are running, the skills and quality, and could be perceived as positive or negative. Assuming that perfect alignment is impossible, coordination aims to reduce the negative impacts that any of the three misalignments could create in the knowledge-integration process. A decision to integrate certain knowledge is less likely to happen in situations of low significance and

negative impact, compared with those of high impact, because the routines lack the importance to justify the effort.

From this theoretical analysis of the literature on knowledge management, it could be argued that the more advanced the knowledge is for the firm involve, the less easy its integration. Among other conditions, Leonard-Barton (1988) highlighted the edgy character of new technology, compared to that in existence, particularly when the latter is distant from the technological frontier. And so, breaking the path-dependence trajectory, as will be discussed below, depends on a consistent process in which the learning capacities are developed over time, going back to the assumption that knowledge integration, learning, capacity building and technological renewal are interdependent phenomena and not just different faces of the same coin.

Once a given technological alteration is made, managers should deal with organizational and not just technical designs as has been supported in the above discussion. The effects of knowledge integration can be far-reaching, making an impact sometimes on the routines and functioning of an organization. Moreover, knowledge integration should happen continuously through different periods of time and across functions, and therefore different approaches to knowledge integration should be considered at different moments of the learning trajectory based on the state of knowledge of production¹¹ and the environmental conditions of the industry – i.e. technology and market.

To sum up, knowledge integration in this research is considered closely related to the approach that it is a managerial problem rather than a technological one. Therefore, the research in this thesis is based on the managerial view that an alignment between individual specialists, technology and routines should be undertaken. The research also follows the suggestion made by Spender (1996) in which theoretical approaches should be adjusted to the different types of organizational knowledge.

¹¹ Easterby-Smith and Prieto (2008) argued that in order to integrate knowledge and maintain an adaptive learning process firms must ensure that organizational resources and the operational routines are appropriate to the business context.

Acknowledging the implications of learning for the transfer of knowledge drawn from foregone discussions (e.g. Lam, 2000), this research attempts to explain further the way in which knowledge integration occurs as an iterative process shaped by the learning dynamics of the firm and mobilization of capabilities.

As discussed in the rest of this chapter, the research is in line with the argument that knowledge integration is mediated by how an organization deals with its learning strategies. Building upon the literature on organizational learning, dynamic capabilities and capabilities, the next sections discuss learning mechanisms and processes in which knowledge integration happens. The discussion considers that knowledge integration is also influenced by two characteristics: the sources from which knowledge is taken (c.f. traditionally seen as internal and external) and the orientation of that knowledge (i.e. exploitative and explorative).

2.3 A broader view of the learning systems

As suggested above, knowledge integration is mediated by learning. Learning as an explanation for strategic actions goes beyond the resource-based view and capabilities. Rather than just identifying critical resources and capabilities the firm should be able to create the conditions for its adjustments over time. Understanding of learning in organizations has therefore become the locus of knowledge creation and knowledge integration.

One learning perspective views organizations as highly constructive and democratized structures in which coordination and decision-making processes should be considered widespread across the firm. As recognized by Spender (1996) learning is less likely to be effective if knowledge is just legitimated by top managers, who also manage subordinates, as they do not know what and how to perform the routines and observe and invent them through the correct understanding of the environment – i.e. the production process. And so, learning becomes a socially constructed practice that combines a broad range of specialist knowledge to make the organization move forward

in the most appropriate technological direction regardless of its positions, status and politics.

Another learning approach to firms also highlights the importance of external sources for new ideas, for instance, coming from the interaction with consumers (Von Hippel, 1988). The main idea behind this approach is that the more exposed the organization is to receive knowledge, the better it understands the flow of knowledge that is critical to enhancing its performance, but also the better it will follow an effective and consistent transformation path. This aspect will be treated in more detail in later sections of this chapter.

Hence, in order to create value and be able to adapt resources and capabilities to respond to the dynamic changes of the market and technological environment, firms and organizations in general should move along paths of learning, taking advantage of their cumulative experiences and knowledge bases (Teece et al, 1997). These paths of learning allow firms to gain access to knowledge so they can compare and contrast their routines with those elsewhere, and either maintain their routines or change them (Levitt and March, 1988; Kieser et al, 2001; Holmqvist, 2004).

Following an earlier conceptualization of organizational learning, Levitt and March (1988) proposed three principles, which are routine-based, history-dependent, and target-oriented, from which learning should be seen. According to these principles any learning event that modifies a situation can be legitimate depending on how procedures are chosen from a variety of alternatives. Once the routine-based conditions are accepted, these authors also argued that adaptations are closely related to how the organization interpreted past experiences and its historical evolution of its routines. Finally, learning is a response to the expected outcomes compared to the observed ones. The effective uses of certain learning mechanisms are therefore expected to have an impact on procedures, being shaped by past experiences and responding to an intended performance. As result, the learning system of the organization should provide the means through which the routines are recorded in the collective memory of the firm and transmitted across time.

From this view two aspects became important for the organization's learning system as a means for knowledge integration: the learning mechanisms and the learning process. Although both the mechanisms and process are interdependent, as is argued in the following subsection, in order to have an analytical distinction they are treated separately. The mechanisms and the process, as interpreted from the literature, are considered a central part of the empirical and theoretical discussion of this research. The link between the mechanisms and the process is referred to as the 'learning schemes'.

2.3.1 Learning mechanisms for knowledge integration

One aspect in which knowledge integration is mediated by learning refers to the platforms used by the firm to mobilize either architectural or component knowledge within itself. Shrivastava (1983) defined these platforms as 'learning systems', which are described as the means by which organizations learn. Four characteristics define them: first, they work as the interpretative means by which relevant knowledge is used for decision making; second, they go beyond specific areas and functions; third, they are deployed through the current practices of the organization; fourth, all members of the organization broadly know the learning system even if it is not documented or explicitly verbalized (ibid, 1983).

Later literature used the term 'knowledge governance' to define these platforms. It is described as "the selected organizational structures and mechanisms that can influence the process of using, sharing, integrating, and creating knowledge in preferred directions and towards preferred levels" (Foss et al, 2010: p. 456). From these perspectives two types of learning platforms can be inferred. The first relates to what can be termed the meta-learning mechanisms (MLMs)¹² (Fiol and Lyles, 1985; Lei et al, 1996) and the second to the functional learning mechanisms (FLMs).

¹² Fiol and Lyles (1985) identified higher-level organizational learning, defined by Lei et al (1996) as the heuristics and insights that provide the conditions to solve ambiguous situations and enable and constrain the possibility for learning. The aim of this higher level of learning is to create new collective consciousness within the organization (Fiol and Lyles, 1985).

Scholars have mentioned the term MLMs in a different fashion as well. Kogut and Zander (1992) for instance make reference to the firm's organizing principles based on the presumption that knowledge is socially constructed, and so its mobilization is enabled by the social establishment and conventions, known as politics and culture. Henderson and Clark (1990) distinguished what they referred to as 'architectural innovations' from other types of innovation. These types of innovation as stated by De Boer et al (1999) have more implications for organizational conditions than the component knowledge and the technologies embedded within those components.

A general consensus regarding these types of mechanism is related to the means by which the organization develops common ground through practices of communication between and among groups to enable knowledge integration. It goes in line with the focus that Grant (1996) posited on the establishment of modes of interaction. In this regard Grant (1996a) acknowledged that integration at this level of the firm involves explicit rules and instructions or the sequential patterns of interactions already defined between individuals. While rules and instructions intend to codify tacit knowledge without having the risk of losing substantial amounts of knowledge, patterns of interaction aim to minimize the cost of communication.

De Boer et al (1999) developed a more distinctive framework regarding the so-called MLMs. Building upon the concept of combinative capabilities (Kogut and Zander, 1992) De Boer et al suggest that firms have at their disposal three different integration mechanisms: system capabilities, coordination capabilities and socialization capabilities. They found that these mechanisms have implications for the three dimensions of the knowledge-integration process – i.e. on efficiency, scope and flexibility – that have been described above (Grant, 1996).

System capabilities as defined by De Boer et al (1999) are used to enable the integration of explicit knowledge through the definition of *ex ante* rules and procedures. These are formal mechanisms represented through formal language, codes, working manuals and information systems. The aim of these types of mechanism is to reduce the need for further communication among subunits and positions within the firm; they can be considered as the memory for managing routine situations.

In contrast to system capabilities, **coordination capabilities** as MLMs are related to the way people interact with each other.¹³ Interaction practices can be designed or just emerge spontaneously. These capabilities are developed through an organizational design that enables the participation of all members of staff in different parts of the organization; conditions to facilitate job rotation and the use of liaison devices are examples of the means through which coordination could happen. De Boer et al (1999) provide evidence of the link between these capabilities and organizational forms, stating that knowledge integration is higher when either staff of the organization at different levels of the hierarchy takes part in the decision-making process or when communication of information tends to be decentralized.

Another way through which these mechanisms can be considered, relates to the attractiveness of skilled workers, for instance. Individuals with better performance will migrate to those organizations that allow them to explore their full capacity, and so this will be perhaps just turned into a greater knowledge transfer within the firm.

The third suggested MLM for knowledge integration is termed **socialization capabilities**. The integration of component knowledge is facilitated through socialization when the organization is able to produce a shared ideology or a sense of identity convincing enough to move the firm forward as a collective entity through which reality is interpreted. In this context the culture of the firm is determined by the system of ideas that is also represented by the values that lie behind the behaviour of all members.¹⁴ One negative aspect is that a strong organizational identity might result in losing perspective with regards to changes in the technology and market, as was implied by De Boer et al in their comment on the work of De Leeuw and Volberta (1996).

¹³ Argote et al (2003) observe that organizations should provide the conditions to develop the opportunities to create knowledge from experience and trial and error, for instance. Also, organization managers should provide the practices through which the physical and psychological distance between individuals gets reduced. As a result the organization will create the opportunity for its members to learn from each other.

¹⁴ The system of incentives (McEvily et al, 2000; Osterloh and Frey, 2000; Orlikowski, 2002), for instance, sits well with this type of mechanism, although is not mentioned by these authors. The incentives might guarantee that individuals search for the enhancement and sharing of their knowledge while making sure that it is protected for the sake of the organization.

In addition to the MLMs, the learning system is also constituted by the FLMs. These mechanisms can be considered as the means by which component knowledge is acquired with the intention of having a direct and indirect impact on the technology and the production system – i.e. on the state of knowledge. Drawing upon Kogut and Zander (1992), it could be argued that these functional mechanisms are nested within the organizing principles or MLMs and are used to modify the component knowledge. The FLMs resemble the intention through which component knowledge is moved from one site to another.

Kogut and Zander (ibid.) suggest that knowledge acquisition through these types of mechanism, should distinguish information¹⁵ from know-how. Information refers to that standardized knowledge that can be commonly understood by those who have the required technical training. Know-how, on the other hand, is defined as the accumulative practical skills needed to perform any routine in an efficient way (Von Hippel, 1988). This difference makes clear what technology implies – i.e. information – and what is finally integrated into the firm – i.e. know-how.

This distinction defines the scope that each FLM has over the production system with regards to the learning process. As will be discussed later, knowledge mobilization in terms of information and know-how is linked to the interaction between cognition and behaviour. And so, the FLMs deal with the transfer of information with the aim of redefining the process by which routines are structured or can be better modified (know-how). Nevertheless, it does not always seem to be the case.

According to Lipshitz et al (2002), these mechanisms should be prompted in a way that guarantees behavioural changes and the usefulness of future knowledge and avoids worthless knowledge. For this to happen these authors suggest two conditions that learning throughout the FLM should meet. First, learning should address valid information and know-how, which means that interpretations are not subjective and biased towards an individual interest. Second, all learning events should be implemented.

¹⁵ Information refers to the data that is understood and interpreted for a specific purpose or function, which is converted into technology, at which point it becomes part of a routine.

Karsnlüoglu and Easterby-Smith (2011) for instance provided evidence of two forms in which the FLM could be performed. These are participative learning systems and expert learning systems. The former enable knowledge sharing across all areas within organizations in which different members deliberately pursue their learning initiatives, providing easy access to knowledge through participative methods. In contrast, organizations undertake expert learning systems if individuals who occupy directorial positions are the ones who pursue the use of learning mechanisms. These individuals act as key brokers of the organization's knowledge. While expert learning systems are associated with bureaucratic organizations, in participative learning systems, initiatives are flexible and independent of authority. According to these authors "...organizations that are more successful in their innovation and change efforts have highly participative learning systems" (p. 15).

FLMs – such as product development, equipment acquisition, hiring of skilled people, the contracting of consultants (e.g. Bessant and Rush, 1995; Hislop, 2002), introduction of management systems (Karsnlüoglu and Easterby-Smith, 2011) and experimentation or research and development (R&D) – as Dodgson (1993) suggested, represent examples of a variety of vehicles in which knowledge is acquired through learning. According to the evidence provided these mechanisms could take a range of characteristics that can be described by their degree of explicitness, formality, systematization, and sophistication (Shrivastava, 1983; 1981).

Experimentation, for instance, has been the focus of attention of many scholars. According to Lei et al (1996) experimentation as FLMs could be considered in two distinctive ways. The first is more technical and engineering-oriented and the second is more scientifically oriented. Experimentation in both senses is also distinctive according to the outcome: the first mainly focuses on the design part – i.e. product design – and the second on the structure of the process (Pisano, 1994).

Experimentation has normally been considered and acknowledged as an accurate way, although slow and costly, to gather information (e.g. Dosi, 1988; Von Hippel, 1988). Evidence offered by Pisano (1994) on research process development suggests that

firms with higher states of knowledge, which means having detailed understanding of the operational routines, are keener to allocate resources to research. Pisano also observed that the state of knowledge of the production environment explains why a firm takes on research activities. Furthermore, research is more likely to happen in firms characterized by a rich scientific knowledge-base rather than firms where technology is more of an art than a science (ibid, 1994).

On the one hand, as Ulrich and Eppinger (2000) have recognized, technical and engineering experimentation are used to generate and facilitate feedback about how routines in certain production environments work before an alteration is made. According to Lei et al (1996) firms that use this type of experimentation process improve their capacity for defining and solving problems. Based on Pisano's (1990; 1994) proposed framework, this particular learning mechanism is defined as learning-before-doing.¹⁶ Experimentation of this type is considered incremental. In terms of intra-organizational arrangements engineering experimentation creates the conditions for close interrelationships and the setting up of ad hoc teams among key actors who have various functions within the organization (Lei et al, 1996), thereby facilitating the flow of knowledge and information.

On the other hand, scientifically oriented experimentation is regarded as a learning mechanism in which firms tend to explore technological divergences either in products or production systems. These types of experimentation as suggested by Tushman and Anderson (1986) are part of the search for technological and market breakthrough.

Hence, while engineering experimentation is prompted to improve the firm's learning capacity for problem solving, scientific experimentation is considered a strategic action for gaining sustainable competitive advantage (Henderson and Clark, 1990). According to Lei et al. (1996) the combinative use of both types of experimentation is an important facilitator to refine the firm's core competence, and therefore its long-term survival. The important aspect of doing experimentation of both types is that it enables the

¹⁶ Pisano (ibid.) argues that the use of experimentation can lead to a good learning strategy when the state of knowledge of production is quite sufficient to understand and predict how any other technology will fit and affect the operational routines. However, he proposed that without good predicted conditions learning-by-doing might be a better learning strategy.

continuous creation of new frames of reference and heuristics needed to create over time, new managerial logics (Prahalad and Bettis, 1986; Knott and Posen, 2009).

Another stream of research has focused on **product development** (e.g. Pisano, 1990; Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Iansiti and Clark, 1994). Researchers have claimed that the development of a new product might generate changes across the whole production environment but more importantly that it allows access to, and interaction with, knowledge from different sources into the organizational routines, especially from customers. Some scholars even consider product development as an organizational process, given its importance for the organization's strategic development. Also the nature of the sequence for this process might change from industry to industry in terms of the starting point, the sources, the timing, regulations involved and access to market. The argument is that product development is a clear example of how to mobilize knowledge within, as well as into, an organization.

Hence approaching product development as a learning vehicle implies it is seen as a process rather than just as a result which refers just to figures of market acceptance and commercialization. One of the problematic aspects with this process could be the starting point. Whether it begins with recognition of the potential of the production system or an identification of a market need, product development probably implies an engineering or design modification. In some situations it might signify different systematic links between other organizational processes and routes to market.

Another type of learning mechanism emerged with the increasing **use of information technologies** by organizations. In principle the implementation of information management systems, as noted by Hislop (2003), served the purpose of improving the levels of coordination, storage of information, and communication between teams and functional areas. In terms of knowledge integration, information systems acting as an FLM facilitate knowledge transfers especially from embedded to encoded knowledge. The main managerial challenge when implementing information systems is to convert component knowledge into architectural knowledge.

A well-known FLM relates to the **recruiting of new workers** with the required skills either for improving or modifying the knowledge base of the firm (Kogut and Zander, 1992). According to Song et al (2003), due to the complex nature of external knowledge acquisition, organizations normally search for valuable knowledge through the hiring of individuals. The hiring of experienced or qualified individuals seems to be a learning mechanism that brings new technological interpretations on how to perform the routines and, as also argued by Kim (1997), it permits further knowledge building.

However, leveraging external knowledge and learning through the hiring of experienced and qualified individuals depends on both the coordination mechanisms of the hiring organization and the asymmetries in the capabilities of individuals in relation to the organization. From an evolutionary perspective, Song et al. (2003) argue that organizations that are less path dependent than others are better able to get knowledge from expertise that is distant from the hiring firm (i.e. the more path dependent an organization is, the less likely it will gain access to such knowledge). However, their evidence also suggests that the new expertise should not be related to the core technology of the hiring organization.

Training could be also identified as an FLM. This mechanism has become an important means to transport relevant knowledge; nevertheless, its effectiveness depends on the way in which training programmes are pursued within organizations. Whether it then has implications for cognitive or behavioural changes could be related, as Karsnlüoglu and Easterby-Smith (2011) have suggested, to the content of the training (i.e. on-the-job, quality, technical, behavioural), by whom the training is decided, how is delivered (i.e. in-house, by predetermined external bodies, by various external bodies) and evaluated.

Management system implementations such as the quality systems certifications (e.g. ISO 9000, ISO 22000) have also been evidenced as effective learning vehicles (e.g. Karsnlüoglu and Easterby-Smith, 2011). The processes in which these systems are implemented imply not just changes in the way routines are integrated but how they are performed as well. However, this mechanism represents a competitive advantage just in those organizations in which the market environment values improvements in quality, food safety (for the food industry) and hygiene, for instance, or when the

regulatory framework demands these certifications.

The **acquisition of technical devices** for the improvement of the technological conditions of the production system has been also widely addressed within the literature on learning and innovation. According to Flowers (2007) one of the aspects evidenced by literature is that in order to get assertiveness with regards to the technical acquisition of devices, organizations have sought to improve their knowledge of, and ties with, their suppliers.

Flowers characterized the firms that buy technology as buyers-users and buyers-producers. The former tend to buy the technological devices to use them to improve their operational routines. On the other hand, buyers-producers buy technical devices to integrate them within their own products.¹⁷

Although knowledge coming from technical acquisitions tends to be described as codified – meaning the characteristics of the knowledge are more easily transferred – organizations face several challenges in the learning process, which are increased if such acquisitions are not frequent learning events. Under this assumption, Flowers observes that “firms who make frequent acquisition...may seek to develop the ‘intelligent customership’” (p. 325) – a pattern that is associated with the development of the firm’s absorptive capacity.

These are some relevant examples of the type of FLMs that organization could use for knowledge integration and learning. Although each of these FLMs deserves broader analysis, for the sake of the argument the purpose here is more illustrative. Each of these learning mechanisms has been traditionally used as a window to represent a broader phenomenon of organizational learning as a strategy for empirical research.

Although many insights have helped with the understanding of learning strategies and dynamics in organizations, little is known about how the interactions between them happen in a wider spectrum of the organization. The literature – e.g. on dynamic capabilities – has normally included discussion of each of these mechanisms

¹⁷ However, the analysis proposed by Flowers (2007) refers to high technology capital goods.

independently, but little is known about their systematic and systemic interaction. Dodgson (1993) argued that the use of these FLMs “might vary over time with industry, technology, and product life cycle” (p. 386) and, as will be acknowledge below, the use of these mechanisms to be effective should be aligned with the alternatives that firms have at their disposal to growth (goals).

Although the research focuses on these FLMs, from an organizational perspective it is more important to understand the extent to which there is interdependency between the MLMs and FLMs. Popper and Lipshitz (2000) have observed that it is through the consistency between the MLM¹⁸ and FLM that effective learning is more likely to happen. This is a discussion that has traditionally concerned earliest works within the already established organizational learning community. Researchers within this stream of the literature distinguished learning in organizations in terms of two processes: single-loop learning and double-loop learning (Argyris, 1976).

Single-loop learning refers to the learning that happens within the status quo. Double-loop learning relates to learning that has an impact on the organizing principles. The FLMs as considered within the literature could be linked to single-loop learning; nevertheless, as has been argued, the frequent use of these functional mechanisms will eventually leverage the organizational norms, and so double-loop learning will occur by the means of MLMs until the heuristics of the organization match the new production system in place. This becomes a process that continuously moves across the organization’s existence.

According to the review by Foss et al (2010) most of the literature focuses either on the MLMs or the FLMs. However, their review proposed a more iterative approach that might occur between the FLMs and the MLMs¹⁹ (see also Lipshitz et al, 2002).

¹⁸ Related to the MLMs, Popper and Lipshitz (2000) refer to the normative systems of shared values and beliefs.

¹⁹ Earlier analysis of single- and double-loop learning (Huber, 1991) suggested that more empirical research should be done in order to understand if these two distinctive learning systems are actually dichotomous. According to this author, systematic empirical research might not find these two systems distinct in practice.

Once a historical perspective is undertaken, the MLMs are considered explanatory for the firm's learning system, offering evidence of the link between the micro and the macro aspects of the learning process at different moments in time of the organization. Based on this discussion this research states that neither FLMs nor MLMs act independently of each other for the knowledge integration and learning system of the firm.²⁰ The next section aims to offer a complementary argument by understanding the relationship between FLMs and the so-called learning process.

2.3.2 Learning process

Another distinction made within the literature on organizational learning refers to the diffusion of knowledge, technology and innovations within the organization (Rogers, 1962). This diffusion implies recognizing learning as a process that leads to either cognitive or behavioural changes, as Fiol and Lyles (1985) suggested. These two distinctive changes bring about a broader definition associated with a process of improving actions, their effectiveness (through better knowledge and understanding) and future actions as well as with the organization's ability to respond to environmental and organizational changes.²¹

This view of learning, i.e. regarding its role as part of knowledge integration, has been considered as the ability of the organization to recognize the difference between actual routines and their potential for improvement (Dosi and Marengo, 1993; Iansiti and Clark, 1994), which Szulanski (1996) defined as the moment when needs and the identification of new knowledge meet – i.e. the initiation process. This claim highlights the importance of the process of learning starting with the understanding of the routines. The potential for learning then is limited or enabled by the state of knowledge

²⁰ Agyris and Schon (1978) acknowledged earlier in the literature on organizational learning the interdependency between the MLMs and FLMs. They stated that when organizations engaged in both single- and double-loop learning to detect and correct mistakes within the present policies and objectives as well as looking forward for solutions that involve modifying norms and policies, they carry out what is called deutero-learning.

²¹ This research focuses more on behavioural, rather than cognitive, development, as has been illustrated throughout the chapter. Nonetheless, as will be empirically discussed, from a historical perspective a dialectical influence might happen.

of the production environment, as has been recognized along the lines throughout this chapter.

Definitions of learning closely related to changes in the states of knowledge emphasize the understanding of reasons beyond learning actions (Hedberg, 1981). Once it is known that learning departs from recognition of what and how things have worked, the other concern consists of understanding how to anticipate all thinkable situations before alternative operational routines are put in place. In other words, the knowledge-integration process involves the decision to anticipate needs (see discussion on implementation in Szulanski, 1996), meaning a selection method to find out, among all the possible technological choices, the right match with the production environment. Pisano (1990) acknowledged this part of the learning process as 'learning-before-doing'.

Learning also occurs as a result of a reaction to online feedback. Another approach has traditionally treated learning as a problem-solving process, which can be interpreted as a dynamic in which the organization, once it understands the routines through experience, is able to identify the difficulties in its production environment and react according to the circumstances. This occurrence of learning has been defined as 'learning-by-reacting'. This initial spark to react is normally initiated from external alerts, for instance customers' feedback.

Levitt and March (1988) and later Pisano (1990) and others (e.g. Von Hippel and Tyre, 1995; Eppel et al, 1996) also put forward evidence of a more traditional approach to the learning process, which places emphasis on actual practice. This instance of learning has been categorized as 'learning-by-doing'. Improvements under this consideration are the result of cumulative experience of production skills, increase in production scale and experience of individual workers (Levitt and March, 1988). Organizations in this case follow an experience-learning-based approach (Argote and Miron-Spektor, 2011). Following analogies with Szulanski's (1996) model, any integration takes root when new knowledge is being used, which refers to the ramp-up stage.

The deployment of a specific routine as a result of a learning process, as noted by Levitt and March (1988), departs from the three considerations of learning (learning-before-

doing, learning-by-reacting, learning-by-doing). Any of these departing points of learning might define the characteristics of the process and its knowledge-integration pattern, which imply transferability and appropriability. In this sense the evolution of routines and capabilities as an outcome of the learning system is viewed as a process in which knowledge is “acquired, processed, disseminated and stored” (Shrivastava, 1983: p. 16).

In consequence, learning entails the mobilization of knowledge from both individuals and within the organization (Senge, 1990; Dodgson, 1993; Akbar, 2003). Scholars from this perspective have concerned themselves with whether learning is a cognitive or a social process that happens either through individual cognition/practice or through interaction (Akbar, 2003). So, the complexity of the learning dynamic goes beyond the mechanisms, as acknowledged in the previous section, and also involves the sequence in which learning might occur and through which it is operationalized within organizations.

Dibella et al (1996) suggest that the learning process enables knowledge dissemination. Organizations establish either an atmosphere in which knowledge through learning flows and evolves informally and fluently or a structured and controlled approach in which learning is formally induced. In this sense Hislop (2003) implicitly refers to the methods of the learning process. His framework distinguishes the socially based methods from the formal communication-based methods; the first rely on intensive social interactions and the second are primarily based on documentation and education.²²

With socially based methods, the emphasis is on knowledge being embedded into routines and in the practices that people follow; communication of the methods is subjective and socially constructed between relevant individuals. Formal communication-based methods take account of the fact that relevant knowledge can be

²² To provide evidence of the importance of these two distinctive methods for the learning process, Hislop (2003) focused on how an information management system was implemented. Following a case-study method he observed five different firms. For the socially based methods he focused on intensive team working, and personal communication. In the case of the formal communication, methods such as formal education, training, and dissemination of encoded information in documents were observed.

communicated objectively through prearranged means. Although Hislop's study favours the social interaction methods, he also acknowledges the complementary effects between both types of method and the need to use both of them in whatever learning mechanisms or context – i.e. by means of management information systems. Leonard-Barton (1988) used the term 'delivery system' instead; she describes methods as the formal and informal devices through which knowledge is transported.²³

Along the same line of argument, Prencipe and Tell (2001) introduced the concept of the 'learning landscape'.²⁴ They argued that firms used certain methods to mobilize knowledge through the learning process for experience accumulation, knowledge articulation and codification. So, the learning landscape is defined through how firms favour more informal and practice-based methods (experience accumulation) over more formal socially (knowledge articulation) and structured (knowledge codification) methods and vice versa. The researchers built on these distinctions to argue that although firms combine different forms of knowledge, they tend to approach certain methods because somehow they have preferences to as how to convert knowledge – as Nonaka (1994) once suggested – to tacit, explicit or codified forms.²⁵

Hence the nature of the knowledge component as well as the characteristics of the coordination process defines the methods firms use to mobilize and learn. Akbar (2003) observed that despite the interrelationships that exist between all types of knowledge, there are differences in the way in which each knowledge type is transferred. As a result the learning dynamics are distinctive as well. For instance, the learning of explicit knowledge uses methods such as training,²⁶ workshops or logical deduction. In contrast

²³ As acknowledged above, if the delivery system is inadequate for the integration process it creates what Leonard-Barton (1988) calls a 'misalignment'.

²⁴ Six firms were used as case studies for the analysis in a variety of industries. Two were from the defense sector (one being on navigator learning landscapes – favouring knowledge articulation), and the others were from aerospace (explorer landscape – favouring experience accumulation), flight simulators, the power generation industry and large software systems (exploiter learning landscape – favouring knowledge codification).

²⁵ Their argument and claims were made within the context of project-to-project learning. This is an important distinction as their main point is how firms reflect between project-based events to improve the sequence of their learning dynamics over time rather than the sequence of learning within and across events.

²⁶ Referring to the work of Thompson et al (2000), Argote et al (2003) state that training as a relevant method for the learning process contributes to increase the individual's ability to transfer capabilities

to explicit knowledge, tacit knowledge is internalized through methods like experience, trial and error, practice (learning-by-doing) and direct observation.

In the case of product development, for instance, Koch (2011) suggested that the use of team projects – as a method of facing the learning process from the perspective of knowledge integration – is better for achieving innovative performance. In this case, Koch presumed that the autonomy of the team members and their diversity and dedication are important factors when methods for team projects are chosen. Also, her argument implies that in the case of product development, team projects facilitate the transfer of both tacit and explicit knowledge in contrast to other methods based on isolated process of individual rationing or trial and error. This is another example where socially based methods are favoured over formal communication-based methods.

Hence although having a sequence of the knowledge-integration and learning process, as Szulanski (1996) suggested in his model, is ideal to assure effectiveness and avoid causal ambiguity²⁷ and unprovenness,²⁸ organizations tend to be more chaotic, and diverse learning patterns, starting from different moments and following different learning cycles, might be part of the firm's knowledge-integration and learning system. It would be expected that over time firms become more conscious of the implications of the learning process and start mobilizing knowledge in a more rational sequence from initiation to implementation.

That firms learn which methods are best to mobilize knowledge is an important aspect for the learning system of the firm besides those described above (Section 2.3.1) regarding the MLMs and FLMs. Indeed, the understanding of the learning process along with the methods help to put in perspective the scope of the knowledge integration,

from one routine to another. This can be also extrapolated to the transfer of capabilities from external sources for the implementation of these capabilities into routines. It is suggested that training serves as a bridge (i.e. it enables assimilation) for the transfer of explicit knowledge in order to produce cognitive and behavioral changes.

²⁷ Causal ambiguity occurs as a result of imperfection in the understanding of how the routines are used and the way in which new knowledge could affect its efficiency and use (Szulanski, 1996).

²⁸ Unprovenness is considered to apply to that knowledge which does not have a proven record of usefulness. As Szulanski (1996) observed, engagement and legitimacy of unproven knowledge are difficult, and therefore its implementation is difficult.

whether the learning process is followed by a pattern of reflection (i.e. learning-before-doing), reaction (learning-by-reaction) or practice (learning-by-doing).

Accordingly, the research for this thesis is based on the understanding the learning process in terms of knowledge integration. Consequently, the learning process is defined from the moment in which new component knowledge is identified to the moment it is considered part of a certain operational routine. Additionally, the research recognizes the event and sequence of events that allow knowledge integration to happen. The intention behind the research is not just to capture isolated events but rather it is to consider (1) how an event relates to its predecessor and (2) how new knowledge is transferred and diffused through learning so that it serves the strategic purposes of the firm.

So, what matters most is how the firm is able to behave appropriately according to the type of FLM it is using, and how the firm is able to combine all possible methods along the learning process – i.e. using processes of reflection, assimilation and implementation. And so, examining the learning process through the lens of the social and formal communication methods that organizations might deploy (such as workshops, personal assistance, practices, meetings, conferences, virtual share points, mailing lists, rational sequences, and trial and error) could offer a complete picture of the hidden reasons why some learning dynamics are efficient (Grant, 1996a) and others are not.

With regards to the scope and outcome of the learning process, whether the organization follows a specific pattern or uses certain methods, it is essential (as Fiol and Lyles (1985) noted) to make a distinction between cognition and behaviours. Implementations – i.e. changes – as a result of the learning process, as these authors suggest, happen when the understanding of the meanings and conceptual schemes of the system is systematically modified at the cognitive and behavioural level. As Szulanski (1996) has observed, implementation is achieved when satisfactory results are assured at the routine level. By viewing the learning process through the lens of the functional learning schemes, cognitions, behaviors and practices are put into perspective as part of the coordination and knowledge-integration process.

Moreover, sometimes many actions are required to generate behavioural changes, but the extent of these behavioural changes do not necessarily correspond to the same degree of cognitive changes and vice versa (e.g. Huber, 1991). While behavioural changes are linked to the FLMs, the extent of cognitive development could be linked to both MLMs and FLMs. And so, effective knowledge-integration implementations as referred to by Grant (1996b) and described above will also depend on how the changes in desire (either behavioural or cognitive) are consistent with the learning process and methods, and follow either a systematic or discretionary pattern.

2.3.3 Decision-making process and the learning system

Integrating new knowledge in the form of technology might be conditioned by some uncertainties that force conscious organizations to be aware of how to deal with the implications of learning and its dynamics. According to Leonard-Barton (1987) two types of uncertainties can be identified. One type of uncertainty is related to the rate of change and the degree of competence of the environment, as Lipshitz et al (2002) have acknowledged. The second is referred to as what is defined to as ambiguity of the information and know-how –see also Popper and Lipshitz (2000) –. This ambiguity occurs when even though the final value of the learning event is perceived there is not much clarity of the outcomes.²⁹

If it is recognized that technological implementation could result in different meanings and values and there is no clear way to assure how in certain circumstances the environment is understood and the expected outcome achieved; both conflict-sharing processes and experimentation could be, as Leonard-Barton (1987) has argued, legitimate ways of dealing with a gradual introduction of technology. Clearly, the closer the technology is to the technological frontier the higher the likelihood to perceive risks in the knowledge integration regarding these types of uncertainty.

²⁹ According to Dodgson (1993) the greater the uncertainty *perceived by organizations*, the greater the need for learning (italics are from the author). One of the goals of learning is to reduce the level of uncertainty.

Even though the evidence presented and analysed by Leonard-Barton (*ibid.*) was collected from the process of software development and implementation, in the case of interactive collaboration between developers and users, these two uncertainties could also fit with the explanation of how firms might encounter learning dynamics in the case of other types of learning events to integrate a different type of knowledge (technological alteration).

Uncertainties can be reduced if the firm's investments in knowledge and learning, as Kogut and Zander (1992) have acknowledged, are motivated by the combination of current capabilities and future commercial and technological opportunities. These authors argued that any given technology has in any moment in time decreasing returns from which there are incentives to develop new but related skills. In other words, their argument refers to the options that the firm is able to accumulate for future developments. Reduction of uncertainties becomes an important feature for an organization's learning motives, adding a more complex rational association that explains learning efforts beyond the traditional view (which is related to the stimulus-response pattern), and which gives a sense of opportunity to the organization's decision-making process.

Consequently, investment in knowledge and technology as a result of reduction of uncertainties goes hand in hand with the organizational characteristics that relate to the decision-making process. The underlying argument states that the organizing principles behind the decision-making process shape the extent to which knowledge is shared and integrated as well as the learning system. Building on the literature on organizational learning, Shrivastava (1983) developed an understanding of the role of different types of decision-making process in determining how actions are undertaken. In a study of 32 business organizations he identified six types of pattern for decision making that explain differences in learning systems.

The distinctions he made offer an explanation of how differences in decision making influence the way in which learning dynamics are pursued at the level of the FLMs. He defined a decision-making taxonomy for the learning system based on two dimensions. First, an individual-organizational dimension moves from the conception of a decision-

making system that relies on the perception of one or a few critical individuals to that in which decisions are considered more independent of individual managers' inputs and tend to be more objective. The second dimension is defined through the process from which the decision-making system is arranged; according to the author it could be evolutionary or designed, the former being the result of historical practices and the latter occurring as a result of the analytical and planning specification of needs.

By combining these two dimensions, Shrivastava defined the following decision-making patterns: (1) one-man institution, (2) mythological learning system, (3) seeking culture system, (4) participative learning system, (5) formal management system and (6) bureaucratic learning system.

In the **one-man institution** (i.e. individual, evolutionary), decisions over the learning dynamics in the organization rely on one individual. This person acts as the key broker and critical source of the organizational knowledge, filtering and controlling the flow of information. Interpreting the analysis from Argyris and Schon (1978), Shrivastava (1983) argued that within these organizations decisions are biased towards the perceptions and limitations of this individual and the decision-making process is based on tacit acceptance by other staff members.

In **mythological learning systems** (i.e. group, evolutionary), learning dynamics are pursued through superstition based on stories of individuals or groups. Organizations with this characteristic create divisions and ambiguities; knowledge and information within them are communicated in different ways according to whom these myths offer advantages or disadvantages. According to Shrivastava's findings, these situations determine how decisions are made over the learning dynamics and knowledge sharing.

In contrast, the **seeking culture system** (i.e. organizational, evolutionary) is bounded by a culture where inquisitiveness and curiosity are encouraged. Individuals are empowered to continually search for knowledge relevant to their functions. Organizations that share this learning system create the conditions for knowledge sharing and the constant movement of relevant information through networks. Additionally, individuals of this type of organizations develop sufficient knowledge to

have influence over certain decisions. Moreover, information used for decisions taken goes through a validity process by using legitimate means.

Participative learning (i.e. individual, designed) is similar to the culture seeking system. In this fourth system Shrivastava referred to the organizational practices of forming ad hoc committees, working groups or teams to find alternative solutions to strategic and technical problems. As this author recalled from the empirical evidence, this system “reflects a management process which has institutionalized participation in decision-making” (p. 22). The working groups enable the diffusion of knowledge and information as well as the development of common understanding among staff members so they share assumptions on critical issues. The shortcomings, however, are associated with the time needed for the process and the possible conflicts that individuals might face in responding to different committees’ requirements.

The fifth system is that of **formal management** (i.e. group, designed). It is based on Shrivastava’s own evidence, and under this system the organization establishes systematic procedures to guide decisions and actions. The process of decision-making is the result of combining experience with managerial techniques. Examples of these procedures as defined by this author are strategic management mechanisms, management information systems or project management.

Finally, the **bureaucratic learning system** (i.e. organizational, designed) is based on regulated procedures and a high level of control of information, and so the decision making process relies on established policies that are objectively defined. In other words, the type of information and its purpose are already defined for any situation.

Decision-making processes are also linked to strategic orientations taken by organizations to redefine their growth alternatives. According to Lei et al (1996), decisions over strategic orientations also provide the basis for defining the learning conditions of the firm and the motivations to search for dynamic capabilities. Decisions over growth alternatives depend on the assessment of what current and required skills and technologies are already available, and what are required, to enable the chosen strategic orientation. For instance, Lei et al (ibid.) described two possible alternatives,

one referred to as the search for new technological applications, and the second related to the positioning of new lines of business and what they identify as 'global diversification'.

The most common and continuous approach to growth is when organizations look to advance their technological production systems so to as improve the efficiency of their routines; therefore, they look to advance their market competence. But, frequently organizations also try to take all possible market opportunities by using their current technological settings. As a result firms might be able to open up other segments or market niches. Dodgson (1993) defined this strategic orientation as learning that responds to the need for adjustment in times of great uncertainty. A breakthrough might occur by combining both alternatives or even by looking for geographic diversification. It is argued then that decisions regarding the strategic choices for growth are key determinants for the dynamics of the learning system at any point in time. Also, organizations are not static and these alternatives are changeable over time. In summary, learning effectiveness also consists of matching the alternative for growth with the path for learning.

Regarding the organization's life cycle, Dodgson (1993) suggested that during initial and early stages of technology, product development and diffusion, the FLMS focus on overcoming uncertainties. In later stages, when the organization is well established and positioned, learning efforts aim to achieve benefits of scale. Beyond this period, if the organization still survives, the focus is on regeneration.

From this perspective it is suggested that differences in decision-making processes are assumed to be one of the factors that explain why knowledge integration and the learning system are prompted in one specific direction. The relative importance and existence of any of these types of decision-making pattern as well as the growth alternatives are discussed below by reference to empirical evidence.

It is argued whether or not the organization, over its evolutionary process, is able to modify its decision-making system to enhance the alignment and consistency between its learning system and its strategic intentions. This argument questions how firms are

able to move along the individual–organizational dimension or from an evolutionary to a designed dimension. The research in this thesis argues that along the life cycle organizations are able to match the MLMs with the FLMs to meet the competitive requirements. Moreover, the empirical evidence is examined to see whether an organization combines more than one type of decision-making system for different learning purposes.

2.4 Locus of knowledge integration and technological learning

Knowledge management has focused on the mobilization of different types of knowledge and the combination of different bodies of specialized knowledge (e.g. Hislop, 2003). In a complementary manner, the literature on learning as acknowledged above recognizes the importance of mechanisms, actions and processes (cognitive and behavioural). Later conceptualization on absorptive capacity (Easterby-Smith et al, 2008; Lichtenthaler and Lichtenthaler, 2009; Sun and Anderson, 2010) and the dynamic capabilities of the firm (Helfat et al 2007; Augier and Teece, 2009) brought together both knowledge integration and learning.

Subsequently, scholars from these two streams came to highlight the importance of the organization's evolution of its internal knowledge along with its ability to recognize and select external knowledge. While the literature on absorptive capacity has focused on past learning experiences, the literature on dynamic capability has been more about how the operational routines can be modified (Winter, 2003).³⁰ Nonetheless, both types of literature agree that it is through the coevolution of knowledge and learning that organizations survive and preserve their competence level.

Along with the configuration of internal and external knowledge, theoretical and empirical evidence have highlighted the relevance of the interaction between exploitation and exploration. In line with the argument of Easterby-Smith and Prieto, (2008) this thesis proposes that the combining effect of all these aspects of knowledge

³⁰ Dynamic capabilities have been also linked to the FLMs (e.g. Gulati et al 2002; Ali et al 2012). Most of the empirical evidence on dynamic capabilities focuses on product development, highlighting its importance as a learning mechanism for knowledge configuration and technological adaptation.

gives the true nature of the system of knowledge and learning of the firm from an evolutionary perspective. The research in this thesis then recognizes the state of knowledge with regards to the routines, the organization's accumulative experience – i.e. path dependence – and the identification of technological and market opportunities (Teece, Pisano and Shuen, 1997).

This section focuses first on how the literature deals with the relationship between internal and external knowledge. Second, it highlights the relationship between exploitation and exploration. The literature search illustrates how knowledge can be integrated and combined in a number of ways, and that there is a need for more than one learning capacity. Thus, by the end of the section, a broader understanding of the absorptive capacity is offered.

2.4.1 Knowledge reconfiguration: the interplay between internal and external knowledge

The argument that sourcing knowledge externally to develop capabilities for adaptation and innovation is faster and less costly than knowledge sourced internally (e.g. Mansfield, 1985), has been increasingly important to address how organizations are able to take technological and commercial opportunities developed elsewhere (Chesbrough, 2003; Laursen and Salter, 2006). When introducing the knowledge-based view of the firm, Spender (1996) opened a discussion – quite new at that time – about whether organizations could be considered boundary-less open systems which tend to establish a “dynamic organic relationship with other knowledge-producing and applying entities” (ibid.: p. 47).

Empirical evidence has shown how organizations have recently moved their learning processes from just internal sources towards the use of external ones (Hagedoorn, 1993; Duysters and de Man, 2003; Nooteboom et al, 2005; Chesbrough et al, 2006); this has gradually become a more common practice, especially in industries that are knowledge-intense such as nanotechnology, information technology and biotechnology (Powell et al, 1996; Gilsing and Nooteboom, 2006).

The motives for firms and other organizations to interact have already been identified in the literature. Drawing on 'transaction cost economics' (Williamson, 1975), other authors have argued that the driving force behind the search for external knowledge is related to the reduction of the trade-off in the process of knowledge flow by spreading the cost and risk of the learning process and innovation.

One of the earliest and most widespread views put forward to explain why firms get, and interact for, external knowledge is the resource-based view of the firm (RBV) (Wernerfelt, 1984). In this paper, Wernerfelt described how firms that have been more interconnected with other actors within the technological, industrial and market system are able to reduce the levels of uncertainty that are associated with knowledge integration. The RBV has claimed that firms are not self-sufficient, and efficiency is achieved by having an interactive dynamic with the environment.

In addition, Lei et al (1996), drawing upon the work of Reed and de Fillippi (1990) and Barney (1991), suggest that arrangements with external partners offer a perspective on a firm's own learning efforts and contribute towards, for example in the case of a competitor, the evaluation of the degree of 'causal ambiguity' related to others firms' competences (Lei et al, 1996).

Most of the motives previously described underlie the importance of external knowledge; however, this interaction is more complex than mere cost considerations or resource complementarities. Factors such as transfer of know-how among parties, accessing other firms' capabilities and/or improving the firm's own capabilities and learning (Bessant and Francis, 1999; Bessant and Tsekouras, 2001) could be very important outcomes as well (Kim and Inkpen, 2005; Ozman, 2009).

One of the first approaches towards analysing the role of knowledge that is external to the firm was defined by questioning the limits of the firm in terms of its knowledge (Grant, 1996). The firm is limited by vertical and horizontal boundaries.

Vertical boundaries are determined by the extent to which firms need to integrate previous and successive production sequences in the value chain for better

performance. Otherwise both (previous and successive) sequences could be developed in two different firms. Horizontal boundaries are explained by gaps between the knowledge domain of the firm and its product domain. If the firm has all the knowledge required to produce its products, it is technologically self-sufficient. However, this is not really the case and perfect congruence does not exist, and so as Grant noted “firms tend to form around product-knowledge constellations” (p. 120).

The need for knowledge in vertical boundaries creates the conditions for integration and imperfect congruence between a firm’s products and knowledge domains, opening up the opportunities for knowledge trading to take place through, for example, strategic alliances. The general idea is that firms exist because of their internal knowledge but more importantly because they rely on their ability to capture external knowledge. Nonetheless, as Zander and Kogut (1995) have indicated, the ability of the firm to acquire external knowledge is defined by the nature of that knowledge (i.e. whether it is tacit or explicit, its complexity and the learning mechanisms used for its transfer), as well as firm-specific capabilities and previous learning experience (i.e. prior knowledge) (Cohen and Levinthal, 1990).

The concept of knowledge source was initially expressed in terms of the preference that an organization has to create and integrate knowledge from its own experience and capabilities –this being internal knowledge – in contrast to the integration of knowledge that is created externally; the concept is also about the conflict that may arise when a firm has to make a choice between using internal and external knowledge (Dibella et al, 1996).³¹ This appreciation defines how organizations favour internal over external knowledge, and vice versa, for the integration of new knowledge.

³¹ Dibella et al (1996) found different patterns with regards to knowledge sources in developing learning capabilities as part of their field study. In the case of a car manufacturer, the acquisition of knowledge was internally oriented although the organization maintained external links with universities, research centres and suppliers. In contrast, the other firm relied entirely on its own knowledge to develop its technological capabilities. In the nuclear energy firm, learning from external sources came in the form of events with not a clear relation between each other, and the mobile phone company used external knowledge only to identify trends for the development of new products. From these cases it could be argued that internal knowledge is always required for developing capabilities while external knowledge is optional and used more for seeking information. Moreover, none of these cases favoured a balanced approach towards knowledge sources.

What has been underlined in this chapter is that the cumulative knowledge internally developed by organizations shapes their attitude to and understanding of external knowledge integration. This relates to the path-dependent characteristic of the learning and technological trajectory and the relevance of prior knowledge for seizing new technology (Tsai, 2001). The literature on absorptive capacity (e.g. Cohen and Levinthal, 1990; Lane et al, 2006) shows that researchers have recognized these two characteristics of knowledge reconfiguration.

It is clear up to now that in order to survive firms should reconfigure their component knowledge over time. However, this reconfiguration (as has been acknowledged from the perspective of knowledge integration) has implications for how organizations understand problems of transferability, coordination and appropriability.

Moreover, reconfiguration is not just a matter of the internal knowledge system; it also implies an identification, selection and implementation of technological opportunities outside the boundaries of the firm. Thus, this reconfiguration implies the integration of appropriate external knowledge. The concept of appropriateness is implied by what is being defined as the state of knowledge of the production system. In addition the firm is able to understand the future trajectory if it understands its current routines. Reconfiguration is therefore considered as the combination of internal and external knowledge (Helfat et al 2007; Capron and Mitchell, 2009).

Nonetheless, in contrast to the previous approach of the literature on absorptive capacity (AC) and dynamic capabilities (DC), the research for this thesis expands on the concept of knowledge reconfiguration by linking knowledge integration with learning and capabilities. Knowledge reconfiguration is understood beyond the assimilation and transformation part of the AC, which also relates to the sense of opportunity in the case of DC, with more attention being paid to the implications for the implementation process. In line with proposals from Robertson et al (2012) this research is concerned with compiling the integration of internal and external knowledge, emphasizing the realized absorptive capacity (Zahra and George, 2002) and the seizing of opportunities, which also means that this thesis is concerned with the underlying aspects behind the application of new knowledge.

Firms are assumed, as was described earlier in the chapter, to be the sources from which tacit and explicit types of knowledge are selected. Drawing on evolutionary theory (Nelson and Winter, 1982), this selection process comes from the interaction of the internal knowledge and capabilities with the external economic and social context of the firm. Finally firms stored both tacit and explicit knowledge and in the operational routines. Arguing that knowledge generation occurs by these sorts of interaction (Nonaka and Takeuchi, 1995 highlights that it is important for firms to be able to create a bridge between their prior knowledge with the knowledge produced elsewhere³² for the development of capabilities.

According to Kogut and Zander (1992) the firm's knowledge goes beyond its boundaries; it is also bounded by the information that other actors around it possess. However, they also argued that the access to this external knowledge is mediated by how transactions and cooperation are conducted as well as the development of long-term relationships as had already been noted by Von Hippel (1988). The last aspect is of particular importance if it is also assumed that knowledge transfer among organizations is leveraged by the way in which common language and shared codes are developed.

Along the same line of argument, Holmqvist (2004) observed that organizational learning involves inter-organizational and intra-organizational dynamics. Inter-organizational learning, as considered by Czarniawaska (2001), is based on the idea that the process is undertaken during social bargaining where the experience of the parties involved is combined. It means that it is not a matter of a simple copying of experiences from one organization to another, but rather of the exchange of complementary experiences, probably as suggested by the vicarious learning approach (Huber, 1991) for gaining knowledge from collaborative agreements.

On the other hand, as Lane and Lubatkin (1998) have suggested, intra-organizational learning is understood as an extension of inter-organizational learning. It is considered

³² Building on Von Hippel's (1988) ideas, Hislop (2003) argued that the reconfiguration of distinctive and heterogeneous components of knowledge involves the interaction of the firm with a range of different actors such as equipment suppliers, consultants and designers.

complementary when organizations decide to share knowledge and align themselves with other organizations' experiences for their own benefit, and when they adjust their practices (Hamel, 1991; Larsson et al, 1998; Kim and Inkpen, 2005; Easterby-Smith et al, 2008; Ozman, 2009). In any case, according to Simonin (1997) external knowledge should match somehow the firm's previous knowledge and have a relation with its future intentions.

Even though recent literature on organizational learning has recognized analytically and empirically the relation between inter- and intra-organizational learning (e.g. Sammarra and Biggiero, 2008), the process of how shared knowledge is further integrated (cognitively and behaviourly) to make changes and adjustments to routines is still not clear.

In contrast, Grant (1996b) has suggested another way of understanding the interaction between external and internal knowledge integration. He proposed a framework in which he described three ways to source knowledge, these being defined as internalization, market contracts and relational contracts. Accordingly, firms need what Grant (1996b) defined as 'flexibility of knowledge integration' so that they can continue to combine existing knowledge with new knowledge.

Internalization has already been discussed in the chapter; it refers to all the mechanisms (MLMs and FLMS) that are at a firm's disposal to mobilize knowledge across functions and hierarchies. It also provides the basis for knowledge derived from sources beyond the boundaries of the firm. Again the complexity is simplified to a problem of appropriability and valuation (ibid). This knowledge tends to be tacit and embedded with individual expertise.

Drawing upon Demsetz's (1991) framework, Grant stated that knowledge integration from **market contracts** is only suitable if that knowledge is already embodied within a product or service such as technical devices, software or ingredients. This type of knowledge normally takes the form of already-made technology and could be exemplified by blueprints, technical specifications or standardized design, and so, this knowledge is open to imitation by any firm under transaction arrangements (Lei et al,

1996). External knowledge under formal market institutions is considered universal, generic and relatively easy to obtain by market transactions and arrangements (e.g. Doherty, 1992; Lei et al, 1996).

According to Grant's (1996b) argument, if buyers need access to the knowledge embodied in the product or services, market contracts for knowledge integration tend to be inefficient. Also, any knowledge coming from external sources through contracts requires that firms previously had an internalization process.

Relational contracts can take the form of strategic alliances, joint ventures, joint projects or another form of inter-firm network. This way of interacting with external sources for knowledge integration – in contrast to market contracts – applies better when the explicit knowledge is not yet available and so, requires background knowledge. According to Grant, collaborations are likely to happen when there is imperfect correspondence or there is uncertainty between knowledge inputs and products outputs.

Indeed, arrangements with external organizations when tacit knowledge is more likely in the interaction are not necessarily easy to manage. As was previously described this form of knowledge is firm-specific and hard to decipher. Lei et al (1996) highlighted the difficulties of transferring tacit knowledge from shared experience with different conditions, especially because of what they called 'causal ambiguity' (see Szulanski, 1996 and Simonin, 1999) – i.e. interpretations that make the imitation from and to other firms difficult.

There are two main advantages to using relational contracts for knowledge integration. First, firms get access to divergent specialist knowledge that would not otherwise be available. Second, when there is uncertainty regarding the benefits of the new knowledge the use of inter-firm networks tends to be faster than using a combination of internalization and market contracts. Nevertheless, once the uncertainty has vanished possible problems of appropriability might arise between partners. This way of sourcing knowledge has been evidenced in the case of biotechnology-applied industries such as human health, crops production and food processing (Liebeskind et al, 1996).

Hence, as has been noted in this chapter, the knowledge boundaries of the firm are rather blurred and what really matters is the recognition that knowledge integration involves a process of reconfiguration of distinctive and heterogeneous bodies of knowledge whether it comes from external or internal sources (Hislop, 2003).

Furthermore, most of the empirical analysis related to internal and external learning dynamics has been done in terms of comparison between them or has been done on each of them independently; so far, little has been done to take account of the complementary effects of both sorts of dynamics, which scholars have recently suggested as the way in which knowledge integration and the transfer problem should be addressed (Holmqvist, 2004).

Therefore, an initial aim of this study was to discuss the complex interplay between inter- and intra-organization learning. There are several aspects that have to be taken in consideration in order to understand better how the knowledge shared is further integrated and used within the organization. The next section will consider that there are also differences in the learning patterns according to the orientation of knowledge – i.e. whether that orientation is explorative or exploitative.

2.4.2 Knowledge orientation: exploitation and exploration

The orientation of knowledge has been traditionally defined as exploitation and exploration, the first meaning being used to refer to as those events which develop to improve the efficiency of the current production system and the second meaning to denote those events that are meant to create technological and market breakthroughs. March (1991) referred to exploitation as the development of new capabilities under existing operational principles, which allow the organization to improve the conditions of its current commercial activities. Exploration is understood as the development of new capabilities that tend to shift the operational system towards a different technological and market paradigm to develop productive opportunities.

Those who have researched exploitation–exploration propose that organizational survival in the long run requires a balance between the two orientations in the

adaptation process (Easterby-Smith and Prieto, 2008). There are difficulties in carrying out both orientations simultaneously; however, according to Holmqvist (2004) and Gilsing and Nooteboom (2006), organizations unable to do so might drop into what is called a 'competence trap' or the accumulation of undeveloped ideas (Levitt and March, 1988). Levinthal and March's (1993) seminal work stated that organizations should "engage in enough exploitation to ensure the organization's current viability and engage in enough exploration to ensure its future viability" (p. 105).

However, as well as aiming to achieve a balance, the argument should also be concerned with the identification of how and under which conditions these two orientations are iterative and interdependent – in other words, how exploitation-related events serve as a spark for the exploration process and how a learning sequence is developed to integrate knowledge from exploration to exploitation (Easterby-Smith and Prieto, 2008). Although the way organizations deploy both orientations has been acknowledged as a matter of strategic choice, it has also been recognized that the logic behind the choice is different. According to He and Wong (2004) the movement towards either of the two orientations differs in structure, methods and requires different behaviours from firm's members.

Whatever the motivations for an organization to undertake exploratory or exploitative processes, features such as the stage of the industry's life cycle or the technological trajectory and the growth phase of the organization engaged or product life cycle are also important considerations (Laursen and Salter, 2006; Ozman, 2009).

In order to relate the two knowledge-orientation processes within the frame of inter- and intra-organizational learning processes several authors have proposed different explanations, for example, the cycle of discovery by Nooteboom (2000). Holmqvist (2004) also proposed four processes: opening-up extension, focusing extension, opening-up internalization and focusing internalization.

The first process refers to intra-organizational exploitation that generates inter-organizational exploration. The second considers intra-organizational exploration generating inter-organizational exploitation. In contrast the last two depart from the

network dynamics and refer to, respectively, inter-organizational exploitation that generates intra-organizational exploration, and inter-organizational exploration generating intra-organizational exploitation.

In the opening-up internalization process, Holmqvist (ibid.) identified that organizations are not automatically able to generate new skills internally from knowledge that is inter- organizationally shared. In this case the donor partner in the alliance makes an effort to translate its experience into a language that could be understood by the recipient partner.

In the focusing internalization process, the author found that the collaborative events in which a firm is involved enhance its skills for exploitation afterwards (learning-by-doing). However, in order to internalize the shared knowledge in the inter-organizational process, the firm translates the external experience into its own scheme (interpretative system).

In both the situations described above, what is important for the process of integrating – internalizing-knowledge from an inter-organizational learning perspective – is the creation of understandable language between the members involved that allows the organizations to recognize what is relevant regarding the shared knowledge. This study recognized that achieving common grounds for a shared interpretative system was quite relevant for the effectiveness of knowledge integration.

Without this common understanding it is assumed that the interaction between inter- and intra-organizational learning processes is going to be null (Holmqvist, 2004; Laursen and Salter, 2006; Sammarra and Biggiero, 2008). In addition, Tsekouras et al (2006) found that key brokers between organizations in the alliance are also relevant for the effectiveness of inter- and intra-organizational learning processes.

Researchers who study networks and organizational learning have commented that the knowledge-orientation process, whether it takes place at inter or intra-organizational level, follows different learning patterns due to the resources and capabilities needed as well to as the singularities in the nature of knowledge (Nooteboom et al, 2005;

Vanhaverbeke, 2009).

According to Gilsing and Nooteboom (2006) networks in the context of exploitation take place in a consolidate dominant design, mean that knowledge tend to be more codified which implies that in terms of interactions there is a need more formal form of governance to avoid risk of knowledge leakage. However this characteristic of the knowledge flow could create more opportunities for constructing contractual arrangements.

In the case of exploration, the more radical the change the more difficult it is to specify the outcomes. In contrast to exploitation, the knowledge is more tacit, and therefore more informal instruments of governance like trust and reputation are more likely to be used; also, because of the emerging novelty, there is a greater need to have a certain frequency of interactions than in exploitative-related events (ibid.).

2.4.3 Searching for absorptive capacity (AC): the state of knowledge and experience

According to Lam (2000) the firm's learning capacity mostly depends on the continuous and changeable interaction between explicit and tacit knowledge over time. However, this interaction, as discussed above, is quite difficult because both types of knowledge differ in their knowledge-integration mechanisms (for codification), their methods for the learning process and their potential for appropriation.

Cohen and Levinthal (1989) proposed the concept of absorptive capacity (AC), which has since become a well-established approach to understanding learning in organizations in contrast to the traditionally accepted view of learning-by-doing. The absorptive capacity of the firm basically highlights the importance of knowledge produced elsewhere for the firm's adaptation process. Since then, researchers have been interested in the factors that contribute to the AC of the firm based on the claim that firms with greater absorptive capacity will perform better and survive longer compared with those with lesser or no absorptive capacity.

Two underlying aspects of a firm's absorptive capacity require further analysis apart from those already mentioned in this chapter: one relates to the state of knowledge and the other refers to the firm's learning experience.

Turning first to the **state of knowledge**: an important aspect of the learning capacity in organizations seems to be related to the understanding of the state of knowledge of their production (Cohen and Bacdayan, 1994; Pisano, 1994). This means having a clear recognition of the capabilities and routines within the underlying operations. Normally organizations achieve this understanding through their embedded knowledge and through their actual practice during production. In this sense learning processes such as learning-by-doing, trial and error, and online experimentation are likely to help overcome chaotic states (the latter being characterized by erratic growth, turbulent production and little time for rational planning). Consequently the learning-by-doing approach to learning, that was initially taken as contraindicated for the firm's absorptive capacity, is rather complementary and could even be considered as interdependent along with these other forms of learning.

In line with this assumption Pisano (1994) suggested that firms should start creating learning capacity by initially accumulating sufficient knowledge of the underlying technical features of the routines and their interactions. Although this is a capacity that firms should develop at first, once a firm goes down a path of continuously modifying the state of knowledge, the FLMs should be prompted so to as obtain and enhance the organization's knowledge of their production system. The argument behind this is that if the organization loses track of its knowledge about its routines, it is unlikely to get its future knowledge right.

Turning secondly to **learning experience**: this aspect of the AC of the firm is very much linked to how the experiences of a firm are accumulated over time. Experience accumulation should be considered in one way or another as beyond what individuals are able to store in their memories and so it overcomes the problem of individual turnover.

The question is: what are the contributions that previous learning experiences offer to the AC of the firm? One of the main problems in answering this question is related to how the assessment of learning from experience can be done when it is biased towards individual perception.

Levitt and March (1988) acknowledged the difficulty of recognizing experience in two senses: the first they called the 'ambiguity of success' and the second 'superstitious learning'. Success that is usually evaluated in terms of the relation between performance and outcomes is not that objective and depends very much on a specific interests of certain group members. Also, learning actions do not necessarily match the outcome; they are normally above or below the target. However, as these authors imply, actions are seldom perceived accurately.

Apart from the difficulty of acknowledging good or bad experience accumulation, there is the problem of how to record experience within the firm's memory, and even more problematical, what kind of experiences should be recorded for the sake of the absorptive capacity of the firm. Again, according to Levitt and March (1998), firms record those events that will be relevant for future actions and outcomes, but, as has been noted, that recording is also subjective. Although one part of that experience is embodied within the routines, the parts that help the understanding of how the routine was formed tend to be lost in translation or simply disappear from the organizational memory.

What is being argued here is that the recording of operational routines could be as important as the recording of the learning routines. As a result the way the firm's members are able to interpret and store in the memory of the organization these events contributes also to the firm's absorptive capacity beyond the fact these events actually happened. An interpretation of the work of Levitt and March (1988) is that the less inconsistent and ambiguous the organizational memory with regards to past learning events the greater is the actual and potential learning capacity. Thus, learning experience is not just about the recording of events, but also about assertiveness in the identification of the events and the process of selection of capabilities.

Indeed, as has been discussed throughout the chapter, the underlying assumption is that knowledge integration and learning is a process that might improve through cumulative experience. Nevertheless, this experience is sometimes perceived as erratic and at other times it is related to events that are perceived as rational and systematic, suggesting that consistent and orderly experiences of a variety of FLMs deployed across time contribute more towards the learning absorptive capacity than chaotic or random experiences.

The other part of experience relates to the frequency of use of certain routines, that is, whether they are deployed on relatively regular basis or not. According to Levitt and March (1988) this last feature also influences the extent to which experience is perceived and, therefore, the organization's learning capacity. In this case, the more regularly an event takes place through the firm's history the easier its retrieval. As a result the firm will be able to improve its absorptive capacity.

Nonetheless, in referring to the work of March (1991), Dodgson (1993) has argued that responses based on a delayed interpretation of a single event can only be taken as experience if the event has occurred relatively recently; this is especially because with the passage of time there are changes in the cognitive system of individuals, and political convenience that might also influence how that experience was valued.

In this sense Weick (1991) argued that learning from experience in terms of frequency also occurs when organizations have the same response to either the same or different stimuli; otherwise they might follow what he calls a 'non-learning pattern', no matter how frequently the actions take place.

Thus, the assessment of experience to define the firm's learning capacity also implies the observation of how learning events tend to be collected from the organizational memory in the cases in which the firm needs to respond to situations already experienced in the past. According to this view, organizations follow a learning pattern from experience just as they recognize and collect information from similar past events. However, in line with Schilling et al's (2003) observation, it is argued in this thesis that

diverse experience, if consistent, could be more beneficial for learning than identical experience.

Moreover, what is also argued here is that the ways in which the FLMS are deployed do not necessarily lead to the same path towards the firm's absorptive capacity, and in such cases, the FLMS should not be considered equally. As discussed in previous subsections, knowledge integration and learning differ according to the source (i.e. internal or external) and the orientation (i.e. exploration or exploitation) of knowledge. It is therefore suggested that the interaction of these two aspects (source and orientation) by the means of the FLMS shapes the way in which the absorptive capacity of the firm is achieved.

Along the same line of argument, DiBella et al (1996) have provided evidence of, and discuss, organizations' learning styles in terms of the source and orientation of knowledge. Their argument supports the view that organizations might follow two paths. On the one hand, organizations learn by using their own knowledge to develop incremental capabilities; the authors define this style as a correction to an existing system. Organizations can use their own knowledge to create new capabilities to develop new processes and products (i.e. innovations). On the other hand, organizations can use external knowledge to make adaptations (i.e. to effect incremental changes) and/or transformations (i.e. by changing their paths).

DiBella et al's evidence shows that normally organizations tend to favour one learning style over the others. However they argue that organizations that are able to balance internal- external sources of knowledge and the exploitation-exploration of that knowledge are perceived as outstanding learning organizations. According to these authors, organizations that are able to develop multiple learning styles create the opportunities to perform in different market circumstances or competences.

Even though this interaction – i.e. between sources and types orientation – has not been traditionally taken to be at the forefront of research in relation to absorptive capacity, scholars have also looked at the independent phenomenon of how the learning dynamics are engaged with one of the sources or orientations'. Huber (1991), in an

attempt to offer an interpretation of the importance of the relationship between building up a learning capacity and the firm's long-term survival suggested "organizations...should maintain themselves in a state of frequent, nearly-continuous change in structures, processes, domains, goals, etc., even in the face of apparently optimal adaptation" (Huber, 1991: p. 93). Under this interpretation, organizations develop their learning capacity throughout a variety of learning dynamics.

One of the first types of learning dynamic developed by an organization can be recognized and integrated in what Huber identified as 'congenital learning' and 'experimental learning'. The former refers to the inherited knowledge that is embedded in the organization's creators. According to Huber, this initial approach to learning in organizations defines the routines and early operational conditions and could be accompanied by vicarious learning – i.e. imitation of competitors' products, technology and markets. Congenital learning is therefore used as the basis of how organizations mix what their creators know with how their knowledge can be used in practice.

The knowledge that comes after congenital learning is acquired through the deployment of the routines and it starts to give the required experience to the organization's members. As long as the routines are frequently repeated, learning dynamics are associated with performance – i.e. experience-based learning curves can be constructed (ibid.). Nevertheless, of greater interest is the learning that occurs from feedback on how the system operates, and the technical changes that enable understanding of what cause-and-effect relationships take place to enhance the routines. But, for this learning to happen, what Huber has implied is that organizations should have high levels of trust along with a culture of tolerance for mistakes. Antecedents of experimental learning are also considered to be instances of problem solving. Thus, according to this approach the firm's absorptive capacity during the early stages of its life is related to the learning dynamics that are prompted by the knowledge that is embedded in the creators and the first group of staff members.

Learning dynamics also come from adaptive processes. The concept of adaptation has been traditionally understood as a process of technology mutation and adaptation (Leonard-Barton, 1988; Tyre and Orlikowski, 1994). Although the adaptive learning

process might take the form of handing on technology, empirical research has found that alterations happen either in the way that technology is used or even in some aspects of a device itself once it enters into the operational routines.

However, the power of the technological receivers to influence the technology depends on the embedded engineering skills and understanding the routines and characteristics of the production system (i.e. those that have previously been developed through experimental learning). On the other hand, it also depends on the searching capabilities of the organization that enabled it to find the appropriate technology in the market to which it has access.³³

Leonard-Barton (1987) posited a concept she termed 'integrative innovation'. It can be seen as learning capacity, and it describes a particular way to absorb technology. She characterized this form of learning as an interactive process between developers and users that tends to modify capabilities and routines.

She exemplified this form of learning using the case of software development that is more likely to be closely related to users' needs. But even in this situation the author also acknowledged that engaging with users is not really a straightforward process. Based on the collected evidence from the software industry it is suggested that for this interaction to work users should be completely acquainted with the technology in order to understand the full potential of the process. Moreover, when users are involved in an integrative innovation, as the study suggests, the interactive conditions of the process require planning, and the developments should be clear and transparent to both parties.

The technological integration process in this type of learning capacity tends to treat users as co-developers; however, to take full advantage of the technology being implemented, the process should be accompanied by managerial support and should involve the development of operationally skilled users who will be able to recognize technical problems and propose solutions. For this type of learning to work effectively,

³³ Huber (1991) proposed the following: first, he argued that a focused search is not really needed until (a) a problem is recognized (this is a reactive rather than a proactive search), and (b) the value of the search is justified; second, he also acknowledged there is a distinction between a focused search for solutions and a focused search for information about already-identified solutions.

Leonard-Barton referred to the alignment of the two organizations involved working together in what she defined as an “integrative and continuously innovative effort” (ibid.: p. 12).

The underlying argument is that there is not a single path towards the firm’s absorptive capacity. Dodgson (1993), in one of earliest discussions, criticized the sense of uniformity in which learning in organizations was treated, arguing that a variety of learning dynamics can run at the same time, in different directions and at different speeds (although he reduced the analysis to what he called “complex organizations” (ibid.: p. 384); he also recalled from Marengo (1992) the argument that the learning system can take different patterns and shapes.

2.5 Theoretical motivations and main and supportive research questions

Hislop (2003) has suggested that the literature that emphasizes knowledge integration and change could be better understood if it also covered knowledge-related issues such as the type of knowledge (i.e. tacit or explicit), the distinction of component knowledge and learning mechanisms (Ellis, Margalit and Segev, 2012). Although the discussion of tacit and explicit knowledge itself is beyond the scope of the empirical analysis, by placing the emphasis on FLMs, the research discusses the interdependency between tacit and explicit knowledge as Shiravata (1983) once suggested.

Rather than just looking at MLMs as previous research has done, the intention behind this research has been to look closely at the FLMs that directly affect component knowledge, expanding in this the concept of dynamic capabilities by looking more closely the process of change in component knowledge (e.g. Katkalo, Pitelis and Teece, 2010; Gebauer, 2011; Weerawardena and Mavondo, 2011; Ellonen, Jantunen and Kuivalainen, 2011). This does not mean that the MLMs have been neglected (Schmidt, 2010); on the contrary, those mechanisms affecting the knowledge architecture of the firm are rather illuminating (Foss et al, 2010, Kay, 2010).

The relative significance of external knowledge has also been at the forefront of the research agenda. To some extent, the benefits of inter-organizational learning in

improving firms' innovative capabilities and addressing better their paths of learning have been proven. Nevertheless, it is essential to go further in the understanding of the dynamics through which inter-organizational learning takes place and how the knowledge integration process effectively happens.

So far the empirical evidence and theoretical claims have explicitly suggested the need to consider both inter- and intra-organizational learning as a combined process so to as have a more comprehensive view of knowledge integration. This issue matters once the real implications of inter-organizational learning for organizations are recognized (Tskouras et al, 2006; Harryson et al, 2008, Easterby et al, 2008). Further developments and contributions will have to focus on the interrelation between these two levels at which the learning process occurs (Holmqvist, 2003; 2004; Nooteboom, 2004; Robertson; Casali and Jacobson, 2012).

Although the concept of absorptive capacity has contributed to the understanding of the influence of external knowledge (e.g. Chen, Chen and Vanhaverbeke, 2011), further research is still badly needed. For example, empirical evidence has focused on R&D activities without considering, as was argued by Easterby-Smith et al (2008), the process-oriented view of knowledge, how previous experience is taken into account (Argote et al, 2003) and the influence of other possible learning events that organizations develop so as to benefit from external knowledge (Volberda at al, 2010; Newey and Verreynney, 2011; Lewin et al, 2011).

Based on previous considerations from the combined literature on knowledge management, organizational learning and capabilities, this research has focused on the link between knowledge integration, learning, building capacities and capabilities.

Attention has been focused on the interaction between the sources and orientation of knowledge (Alia, Peters and Lettice, 2010; Alia, Peters and Lettice, 2012). To enable a better understanding of the link under investigation and to provide a picture of the balance between exploitation and exploration, the locus of the research has been on firms that have experienced a transition process from mature single technologies to emerging complex technologies (De Boer et al, 1999, Chen, Williams, and Agarwal, 2012,

Peltoniemi, 2014). To promote a more comprehensive perspective of the organization as a whole, the empirical evidence has been collected from SMEs. Furthermore, in recognition of the dynamism of the context as an important feature of learning (Romme, Zollo and Berends, 2010; Salazar and Pelaez, 2011), the firms were selected from one type of setting that has been described as moderately dynamic and delimited by a low level of technological opportunities. As a result, the research has addressed the following question:

To what extent does the integration of external and internal knowledge for either exploitation or exploration explain the organization's learning-capacity building and its functional relationship with its technological trajectory?

Based on the foregone analysis, some supportive questions are asked that aim to offer a more focused explanation:

To what extent does the combination of different FLMs enable the organization's learning dynamics?

To what extent do different learning capacities (sources and their orientation) trigger the organization's technological transformation process?

To what extent do the efficiency, coherence and flexibility of the learning trajectory influence the scope and outcome of the knowledge-integration process?

How do the decision-making processes and patterns of growth explain the scope and outcome of the technological learning dynamics?

How do the MLMs explain the scope and outcome of the technological learning dynamics?

How do industrial differences (e.g. agro and food processing) affect the pattern of the organization's learning and technological trajectory?

In order to address these questions, an analytical and conceptual framework is suggested based on the previous discussion of the theory and bearing in mind the fundamental assumptions proposed by the literature discussed above.

The next chapter addresses the conceptual and ontological links that form the basis of the analysis of the empirical evidence.

3 A LEARNING-CAPACITY FRAMEWORK: KNOWLEDGE RECONFIGURATION AND KNOWLEDGE ORIENTATION

3.1 Introduction

Chapter 2 posited the discussions that researchers in related literature on organizational learning (Argyris, 1976; Fiol and Lyles, 1985; Levitt and March, 1988), knowledge management (Nonaka, 1994; Pisano, 1994; Grant, 1996), absorptive capacity (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van den Bosh et al, 1999) and, dynamic capabilities (Teece and Pisano, 1994; Teece et al, 1997) have conducted with regards to knowledge integration and learning. This chapter proposes then the conceptual and analytical features that frame the research for this thesis drawing upon the previous discussion.

The conceptual and analytical framework from the previous discussion centres the debate in three main aspects. First, the framework centres the analysis on the micro-components of learning (i.e. component knowledge, operational routines, FLMS and learning process). Second, the process of capacity building combines the knowledge integration (Tsoukas, 1996) and the learning system as part of the same structure for the evolution of firm's capabilities. Third, the framework proposes that the firm's capacity building occurs as a result of a sequence of events in which internal and external knowledge interact with the intentions of the firm to either exploit or explore new knowledge. The last part of the framework discusses the main macro components of learning that influence learning at the level of the micro components. These four main elements of the framework relate to the concepts of the literature analysed in the previous chapter. The table 3.1 links the discussion of the framework with those concepts from literature integrating the knowledge system, the learning system, the learning and the technological trajectory and the organization specific features.

Table 3.1. The relation between the concepts from literature with the key elements of the KILS

Themes from literature	Concepts	Key elements of the KILS framework			
		Learning schemes	Learning capacities	Technological transformation	Macro-components
Knowledge system	• Knowledge integration	*	*	*	
	• Knowledge transfer <ul style="list-style-type: none"> ○ Knowledge forms and knowledge conversion (embrained, encoded, embodied, embedded) 	*	*		
	• Knowledge reconfiguration (internalization, market contracts, relational contracts)	*	*		
	• Knowledge orientation (Exploitation and exploration)				
	• Component knowledge				
Learning system	• Learning mechanisms	*			
	• Learning processes <ul style="list-style-type: none"> ○ Cognitive learning ○ Behavioral learning 	*			
	• Learning methods <ul style="list-style-type: none"> ○ Participative and expert learning system ○ Socially based methods and formal communication based methods 		*	*	
	• Misalignments (value, technical, delivery)		*	*	
	• Causal ambiguity, unprovenness		*	*	
	• Uncertainty				
Learning trajectory	• Absorptive capacity <ul style="list-style-type: none"> ○ State of knowledge ○ Learning experience <ul style="list-style-type: none"> ▪ Ambiguity of success ▪ Superstitious learning 		*		
	• Congenital learning		*	*	
			*	*	

Technological trajectory	<ul style="list-style-type: none"> • Experimental learning • Path dependent changes/ path breaking changes 		*	*		
	<ul style="list-style-type: none"> • Appropriability • Operational routines (core routines- peripheral routines) • Effective transformation (Efficiency, scope and flexibility) 			*	*	
Organization Specific features	<ul style="list-style-type: none"> • Architectural knowledge • Knowledge governance • Organization's lifecycle • Combinative capabilities • Decision making system 		*	*	*	*
	<ul style="list-style-type: none"> • Organizations forms 	The framework specifies that organizations forms should be defined as an intrinsic characteristic because of its importance for knowledge composition of the firm.				

Source: the author

The remainder of the chapter comprises five sections (3.2–3.6). Section 3.2 explains the construct of technological learning and Section 3.3 describes the capacity taxonomy. Section 3.4 deals with the dimensions of an effective technological transformation linking learning and technological trajectories. A group of explanatory features associated with the organizational conditions of the environment are then described in section 3.5. The discussion leads to the proposed concept of the knowledge-integration and learning system (KILS) that aggregates the micro- and macro-components of the learning and technological trajectories. A set of propositions in the final section (3.6) are put forward to offer further explanations of practice in the light of theory.

3.2 The learning schemes: functional learning mechanisms (FLMs) and the learning process

The literature on organizational learning has paid close attention to higher order learning mechanisms (Kogut and Zander, 1992). Although these mechanisms are important for the strategic learning intent of the organization (Eisenhardt and Martin, 2000; Popper and Lipshitz, 2000; Zollo and Winter, 2002), they represent just one part of the story, as was argued in the previous chapter. The other part (micro-components) rests on the component knowledge (Boisot, 1998; De Boer, 1999), the operational

routines (Gersick and Hackman, 1990; Gilbert, 2005; Loch et al, 2013) and the FLMs, which focus on the cognitive and social practices from which knowledge is integrated.

In this sense knowledge integration is understood as the coordination process (Grant, 1996) in which firms by mobilizing a variety of component knowledge of different sources and types – i.e. automatic, conscious, collective and objective (Spender, 1996; Lam, 2000) – intend to solve the problems of transferability and appropriability through learning. As a result operational routines as the representation of behaviours are redefined either partially (exploitation) or totally (exploration).

In line with Popper and Lipshitz (2000), learning in organizations occurs through actions in which the interpretative processes of individuals and their social interactions are challenged to meet specific technological targets with regards to production and market conditions. As the framework proposes, knowledge integration and learning are parts of the same systematic process of knowledge creation and application.

On one hand, the micro-components become the actions through which knowledge integration and learning takes form and works, and from which the current component knowledge is exposed to change. On the other hand, the incentives, means of communications, culture – i.e. the meta-learning mechanisms (MLMs) – and the decision-making process create the organizational conditions (macro-components of learning) that enable the selection of certain knowledge directions and learning dynamics. The interaction of these two organizational learning components that should be analytically recognized as one integrated structure (Brown and Duguid, 2001; Ali et al, 2012) represent what is defined here as the knowledge-integration and learning system (KILS).

The framework nevertheless proposes that organizations are not completely conscious of the alignment and dialectic communication between the organizational setting and the actual actions of learning. The latter emerge more likely from either individual cognition or collective interpretation of problems, and the former – although it can be more strategically designed – can change the base of new interpretative systems. In short the KILS develops and evolves depending on how the organization gives meaning

to the technological and market context. Moreover, depending on how the firm records its previous experiences, both micro- and macro-components of learning take shape.

The KILS in organizations is therefore a complex matter. History, experience, individual and collective cognition, technological asymmetries, uncertainties and performance are some of the aspects that organizations should take into account. Because of this complexity, when FLMs are observed, researchers have sought to understand their singularities and specificities. But what happens with their plurality and consistency when multiple interactions among a variety of mechanisms occur?

Moreover, is the KILS just cognitive or behavioural or both? It happens either in the heads of individuals (Simon, 1991) or through interaction and practice (Teece et al, 1997). The literature on knowledge integration (e.g. Winter, 1987; Von Hippel, 1999; Brown and Duguid, 2001) has already offered some indications that the FLMs, the process and the methods might provide some important hints of the process behind the KILS; therefore, in the research for this thesis there is an emphasis on micro-components.

Different cognitive responses and social interactions occur to modify (or not) the performance of the routines (behaviour). The association between the FLM, the process and the methods, which occurs with all these interactions, is referred to as a learning scheme. Thus, depending on the type of scheme, learning events can bring together cognitive and behavioural processes as well as individual and collective actions. So, learning schemes individually or combined refer to how an organizational member (or team members) interpret(s) the system but more importantly firms through the learning schemes are able to push forward a process to redefine the meaning of the capabilities and routines.

By looking at the learning schemes (each scheme covering many learning events) the framework proposes that learning occurs as an interpretative process in which meanings at the individual as well as the collective level are challenged and then cognitive and behavioural processes are finally combined to react to, or anticipate to the changing conditions of the environment.

Therefore, learning schemes are to be considered the means through which organizations seize new knowledge and which enable them to modify their current component knowledge by undertaking a process of internalizing the new information or know-how into their routines. The learning schemes are the analytical representation of events in which knowledge integration and learning can be observed in organizations. So, by positing the observation on the learning schemes rather than questioning the outcome of knowledge integration and learning, the focus of the framework for this thesis is on what finally enables the firm's technological transformation.

The analytical construct of the learning schemes covers three components: FLMs, the learning process and the methods. The FLMs are the first component of the learning schemes; as discussed above they represent the learning intentions, can take different forms and are performed in a variety of ways.

In terms of the forms of the FLMs, the literature on technological learning has paid attention to certain types of mechanism such as new product development (NPD) (e.g. Henderson and Clark, 1990; Newey and Verreyne, 2011; Pavlou and Sawy, 2011), equipment acquisition (e.g. Flowers, 2007), hiring of skilled people (e.g. Song et al, 2003), the contracting of consultants (e.g. Bessant and Rush, 1995), introduction of management systems (e.g. Oliver, 2009) and experimentation or R&D (e.g. Cohen and Levinthal, 1989; Hage et al, 2008; Knott and Posen, 2009; Müller-Seitz, 2011). These mechanisms represent the intentions of learning schemes and the forms they can take. They could be described by their degree of explicitness, formality, scope, and sophistication (Shrivastava, 1983).

One of the arguments, however, is that through experience and retrieval of events organizations learn to learn. As a result, organizations tend to understand whether to use certain FLMs to accomplish their technological and market targets. Also, the way each mechanism is performed through time might change to fit the requirements.

The learning process, which is the second component of the learning schemes, deals with asymmetries in individual and collective interpretations (See also Sensing, Seizing

and reconfiguring from dynamic capabilities literature –e.g. Castiaux, 2012; Jantunen, Ellonen and Johansson, 2012). Indeed, approaches to dealing with the problem of the learning process have come to capture the transition from cognitive interpretation to routines (behaviours). Crossan and Berdrow (1999) developed a framework in which they defined this transition in a four-stage sequence – intuiting, interpreting, integrating and institutionalizing. In this thesis, the sequence has been reduced to a three-stage process – i.e. stages of reflection, assimilation and implementation. The sequence is simplified because the framework at this level of analysis is focused on component knowledge only. Drawing upon Crossan and Berdrow (ibid.), the definition of each stage of the learning process is further explained as follows.

Those events associated with **reflection** refer to the intentions to understand new technological approaches from a variety of alternatives, based on an understanding of technological status quo. Reflection is a stage of the learning process that might come from rational logic rather than relying on intuition (based on experience). Thus, searching through related activities such as technical experimentation, for instance, is a formal mechanism by which organizations, using the knowledge they have of their own routines, look to find alternative routes for them to take so they can perform in new markets and go in new technological directions.

Reflective-related events aim to respond to a perceived stage (by managers) of technological dissatisfaction regarding how the current conditions can fulfil productive opportunities. Indications of problems of this kind might generate a reflective response but also anticipation, based on the interpretation of signs related to problems in production, for instance. Knowledge integration from reflective events can be the most difficult of all as it tends to be related to a complete redefinition of the interpretative system; thus it might require a combination of methods like use of power, expertise and persuasion to go through an assimilation and implementation process. The more proven and collectively shared this knowledge becomes the greater its effectiveness.

Other events are related to **assimilation**. This stage combines what Crossan and Berdrow (ibid.) defined as ‘interpreting and integrating’. It is expected that events related to assimilation processes, if they are not systematic, rely on individuals’

intuition in terms of how they interpret the production system – i.e. the events rely on their state of knowledge. This stage of the learning process consists of the coordination of different configurations of knowledge so to as generate mutual and collective understanding regarding how adjustments of certain technology must be done to ensure optimization of the routines. It is a stage that prepares the organization for the diffusion of knowledge in either tacit or explicit forms. Some mechanisms like training or the support of consultants are also referred to as methods that help to elaborate collective conventions for the understanding of technologies. Trial and error, for instance, is deployed to collectively understand whether a technology should be implemented or not under controlled risks.

The third, **implementation**, stage involves the methods through which a firm internalizes new knowledge in combination with the established routines to redefine the course of action of the firm's trajectory. The implementation processes imply therefore the incorporation of information and know-how into the routines that constitute the newly accepted operational principles through which the production system will run. From this point onwards learning-by-doing is the most suitable process to gain experience and enhance the system. In Crossan and Berdrow's (ibid.) framework this stage is known as 'institutionalizing'. Once routines are modified they will be performed until a problem arises; then, new intuitions are perceived or rational processes are pursued.

This third component of the learning schemes links the process with the methods of diffusion and internalization. Following the framework of Karsnlüoglu and Easterby-Smith (2011), FLMs could be performed as part of either participative learning systems or expert learning systems. Either way, learning schemes must take place under certain conditions to ensure that knowledge is mobilized from individuals' cognition to routines.

The FLMs relate then to how tacit or explicit the information and know-how embodied in each mechanism could be (Kogut and Zander, 1992). It is assumed that market-governed mechanisms such as equipment acquisition and the introduction of management systems are more explicit and less ambiguous than even the hiring of skilled people and consultants where knowledge integration might require more

interaction. Other mechanisms like product development or experimentation are more likely to be tacit; coordination in these cases might then require an expert as a reference point as well as formal participative systems.

However, a single event related to a single mechanism and method might not be enough to pass through the interpretation of that knowledge to the creation of shared conventions and routines. As previously discussed, depending on the complexity of the knowledge and the routine involved, several mechanisms and methods should be used in order to generate behavioural changes. While some related events should be pursued through a systematic pattern along the learning process, others might be discretionary. This perspective defines the learning process as a sequence of stages through which new knowledge enters the organization.

An interpretation of this systematic or discretionary pattern of events led to propose in the research for this thesis that integration of new knowledge might require a sequence of steps before that knowledge is considered ready for exploitation. Organizations might then have a moment of understanding of all possible alternatives (i.e. learning-before-doing); this part of the learning process is also related to searching. They might face moments in which knowledge is processed and implemented as a response to a problem (i.e. learning-by-reacting). It might also happen that the integration of new knowledge is just part of the cumulative experiences of the performance of a certain routine (i.e. learning-by-doing).

While systematic patterns occur when a chain of learning events are engaged with the three-stage sequence of the learning process, discretionary patterns on the other hand represent isolated events along the learning process. Examples of the latter are events which are prompted by reactions and require a contingent and immediate solution for implementation, or research processes that are not aligned with the current direction of the production system. Some discretionary events might relate to what Leonard-Barton (1988) distinguished as 'misalignment' in the knowledge integration process.

All in all, the learning schemes are defined through the FLMs which explain the intention and form that a single learning event takes, the scope in the transition from

cognitive to behavioural indicating an association with the learning process and methods through which knowledge integration happens. Understanding knowledge integration and learning from this perspective serves to illustrate somehow the singularities that each learning mechanism might offer in terms of experience. However, as is discussed in the empirical analysis, the framework proposes an analysis of the complementary, rather than individual, effects of the FLMs throughout the organization's technological development. Some examples of FLMs derived from the literature are set out in Table 3.2.

Table 3.2. The learning schemes

Learning schemes (examples)	Intention of the related events	Degree of explicitness	Learning process methods
Technical and engineering experimentation	Anticipating information and know-how for possible technical problems in production	Tacit	Reflection through new rational logics and structured social interactions
Scientifically oriented experimentation	Exploring technological and market divergence in product or production systems	Tacit	Reflection through new rational logics and structured social interactions
Product development	Searching for market renewal and niches	Tacit	Non-structured social interactions with random procedures for assimilation and implementation
Implementation of information management systems	Improving coordination, storage of information and communication	Explicit	Implementation through a combination of formal documented procedures with structured social interactions
Recruiting of new workers	Improving or modifying the knowledge base	Tacit and explicit	Implementation through social practices by the performance of the routines
Technical training	Improving the quality and performance of techniques in production and market system	Explicit	Assimilation through structured social interactions
Management system practices	Certifying the technical conditions of production under regulated frameworks	Explicit and tacit	Assimilation and implementation through a combination of formal documented procedures with structured social interactions
Acquisition of technical devices and equipment	Improving the technological conditions of the production system	Explicit and codified	Implementation through formal documented procedures and one-to-one assistance

Source: the author

Each of these learning schemes can be represented by several events across the firm's lifetime. One of the main discussions related to the firm's absorptive capacity concerns the question of how organizations develop and evolve as they accumulate experience in doing something (i.e. as they build up learning experience). In the case of retrieval, which relies on the frequency with which a particular event is done, researchers (Levitt and March, 1988; Weick, 1991; Dodgson, 1993; Schilling et al 2003) have assumed that learning capacity improves as long as the organization continues to understand not just what, but also how, it has learned. This claim has led to the inference made in this thesis that the way in which any of these learning schemes is deployed might change over time in terms of the degree of explicitness and methods for reflection, assimilation and implementation.

The association of the learning schemes with each stage of the learning process as shown in Table 3.1 can be quite specific. Not all learning schemes depart from reflection and not all are meant to mobilize knowledge towards implementation. Another aspect of the learning capacity of the organization should indicate therefore to what extent different types of learning scheme need to be interrelated to achieve a specific strategic intention. This subject reveals the importance of identifying the patterns in the learning sequence – i.e. are they systematic or discretionary – but also of linking learning to the strategic orientations of the organization.

The key point is not to see learning as a final result but as continuous process. In this way it is possible to properly understand the real implications of learning in terms of the resulting capabilities and routines. In other words, each observed type of learning scheme in isolation presents an incomplete picture that will only explain successes and failures under certain contexts. What matters more than individual learning events is if their interdependency is consistent with the technological and market context that the firm decides to be engaged with.

The framework for this thesis proposes that (1) the learning schemes are the foundations from which an organization's learning capacity can be observed and understood, and (2) it should be possible to depict the organization's learning system

by focusing on the micro-components of learning. The following section focuses on how the organization's learning capacity is understood through the lens of the learning schemes, but more importantly, it also considers the way in which knowledge reconfiguration is related to knowledge orientation.

3.3A taxonomy of learning capacity: knowledge reconfiguration and knowledge orientation

This section highlights the importance of the reconfiguration and orientation of knowledge for the KILS. While the first section centred on the analysis of the link between knowledge and learning, here the discussion refers to a second level of analysis: that is, linking learning with capacity building.

'Knowledge reconfiguration' as was described above, refers more specifically to the interplay between internal and external knowledge by recognizing different ways to use the current capabilities 'to seek out new knowledge that can be used to anticipate and solve problems'. The KILS, then, is the result of two complementary processes. First, it develops through the process of reconfiguring the state of knowledge through sourcing internal and external information and know-how. Second, the KILS is defined through the orientation knowledge takes. The orientation refers to the implications that new knowledge has for current routines (i.e. exploitation) and for the creation of productive opportunities ('slack knowledge') (i.e. exploration).

It is expected that the problems of transferability might have different implications depending on whether knowledge is integrated within the same or different interpretative systems. Although characteristics such as the state of knowledge and the degree of explicitness of the information play a role in defining how to face the learning process by using either source of knowledge (i.e. internal or external), they could differ depending on the source. It is assumed also that those events in which firms try to develop new capabilities are expected to follow a different pattern in the learning process from those learning events where the organization is searching for the creation of new opportunities. Whether the integration involves a particular source and

orientation might lead to distinctive dynamics and so, learning capacities. The learning schemes just described embody these two features of knowledge.

While the literature referring to knowledge reconfiguration has traditionally distinguished the interaction of the firm with external and internal knowledge, the framework suggests that when organizations integrate knowledge, they are always open to external sources of information and know-how; but organizations differ from one another in how they approach those sources. Moreover, in line with work by Czarniawaska (2001), it is proposed that knowledge externally sourced for the purpose of creating an appropriate interpretative system must interact along the learning process with internal knowledge through staff members and/or by connecting with learning events. What matters the most for knowledge reconfiguration is how the evolving operational routines fit with the strategic intentions behind the integrated knowledge. So, in contrast to the internal–external traditional view, Grant (1996b) and later Lane and Lubatkin (1998) have both suggested three different approaches to how knowledge is distinctively integrated, these being from internal staff members, through markets, or via collaboration.

Although the perspectives for knowledge configuration of Grant (1996b) and Lane and Lubatkin (1998) share common ground, they slightly differ from one another: the latter authors' description of these three approaches to external knowledge has mainly focused on searching while the former author has been keener to offer a broader explanation of the learning dynamics and governance mechanisms.

Building upon these two approaches, the framework in the thesis defines knowledge reconfiguration as the attitude that organizations have towards the use of external knowledge to align their own experience with other organizations' experiences with the intention of adding value to the routines. As both views seem to complement each other, a broader description is used, although Lane and Lubatkin's (1998) terminology is more appropriate. Hence, three attitudes to source knowledge – termed passive, active and interactive – will be used instead.

Knowledge reconfiguration considered as **passive** refers to sources that relate mainly to staff members' experiences. Learning events and related learning schemes denoted as passive mobilize knowledge across functions within the firm's boundaries. These events occur when technical problems can be solved by trial and error and by experimentation using the information and know-how already embedded in the interpretative (cognitive) system of the staff members. Internal mobilization of personnel from one area of the firm to another, for instance, could be indicated as passive. This knowledge is mainly tacit and it is normally used to reaffirm current operational principles.

Knowledge referred as **active**, on the other hand, is sourced from the market. Lei et al (1996) defined knowledge sourced from market transactions as universal as it is considered generic, relatively easy to get and normally takes the form of already-made technology. Organizations that look for active knowledge, if they act systematically, tend to reflect on the most suitable option from the best combination between technology and transaction arrangements with the technological suppliers available. Information and know-how can take the form of equipment acquisition, the hiring of new engineering skills or the implementation of a new information system.

According to Lane and Lubatkin (1998), although passive and active sources are important for the organization's knowledge reconfiguration, they offer only a limited capacity for the addition of valuable capabilities to the routines. Knowledge indicated as **interactive** takes the form of alliances, joint ventures and projects or any other inter-firm network. In these types of learning event, knowledge is sourced through collaborations, and the interpretative system in these cases should be collectively constructed through practice as long as the interaction lasts. Therefore, interactive knowledge seems to be more appropriate when more tacit components of knowledge (how and why) are required (ibid.) and also when the operational principles are expected to be shifted towards the use of valuable productive opportunities.

Besides the sources of knowledge, the literature highlights the relevance of knowledge orientation for the knowledge-integration and learning system. Orientation is considered in two ways: it can be either exploitative or explorative (March, 1991).

These two types of orientation of knowledge explain whether the knowledge is used to improve current capabilities for existing market conditions or foreseen new technological trajectories to pursue future productive and commercial opportunities.

According to some authors (e.g. Nooteboom et al, 2005; Vanhaverbeke, 2009), knowledge integration and learning that happen either for exploitation or exploration follow singularities in the learning patterns in terms of the nature of knowledge, transferability, mechanism and methods deployed. Depending on the orientation, the influence on the interpretative system might affect the operational routines in a different way. Also, the transition from cognitive to behavioural changes might differ along the learning process from one orientation to another.

Another difference between the exploitative and explorative orientation refers to the location of the learning events. While the exploitative events occur within the current production system and organizational principles, the explorative events tend to be perceived as more distant, not just in terms of time, but also regarding the production structure of the firm.

Experimental and research events normally take place within the firm regardless of how they are sourced. Three approaches of doing research can be distinguished. **In-house research**, for instance, could be located in laboratories or small research groups with relatively little interference with production, as its aim is to build expertise for the understanding of the nature and dynamics of knowledge created under certain scientific procedures. Although in-house experimentation is assumed to occur under the same operational principles, its aim is to search for divergent technological solutions. **Contract research**, however, tends to be more specific and explicit according to the firm's needs; it is also used to gain research expertise but with the intention of developing certain productive opportunities. **Joint research** could be considered more distant as it might serve two different interpretative systems and the research may be aimed at foreseeing different technological directions in which the firm and its partner may not yet possess the required skills (e.g. transition from chemicals to biotechnology).

Although these two orientations of knowledge are considered analytically distinct, the suggested argument (e.g. Easterby-Smith and Prieto, 2008) refers to how organizations enable an iterative balance between the two of them. As described above learning dynamics might follow systematic or discretionary patterns. However, in order to create a balance, firms should move towards a systematic approach across the learning trajectory and not just use a discretionary approach, because exploitative-related events might also serve as a bridge that integrates the outcomes of explorative types of event. In explorative learning events a combination of social interactive and expert methods may be needed in order to avoid losing track of possible implementations of alternative technological and market opportunities.

Once the learning schemes are categorized with regards to the source of knowledge and orientation, they form the firm's learning capacities. Learning capacities are defined as the abilities and expertise that a firm gains by reconfiguring its attitude towards external knowledge through the use of a variety of mechanisms; in turn these mechanisms trigger capabilities for either improving the efficiency of the production system or creating the opportunity to use divergent and more advanced technologies. Indeed, the firm develops learning capacity through related learning experiences in which different learning schemes are used to fit existing capabilities with current and future strategic intentions. So, the learning capacities are the building blocks of the learning schemes.

The framework depicts learning capacity based on a taxonomy that takes account of the knowledge reconfiguration – i.e. passive, active, and interactive – and the orientation – i.e. exploitation, exploration. The matrix defines six types or groups of capacity; the first group corresponds to exploitative learning capacities, these being formative, adaptive and transformative. The second group comprises the explorative learning capacities identified as inventive, creative and renewed. This taxonomy of learning capacities could be seen as a decomposition of the absorptive capacity of the firm.

These capacities redefine the learning-related experiences of the firm, each of them, although, specific can be considered iterative and cumulative. Thus, firms with higher learning capacities are those who have not only developed continuous experiences in

each of the categories but also been able to understand the interrelated sequences between them (see Table 3.3).

Table 3.3. The firm’s learning capacities

Knowledge Orientation	Knowledge reconfiguration		
	Passive	Active	Interactive
Exploitation	Formative	Adaptive	Transformative
Exploration	Inventive	Created	Renewed

Source: The author

The distinction of all these types of learning capacity has already been supported by Dodgson (1993) who stated that a sense of uniformity in the learning trajectory and experience assumed from a single conceptual approach (e.g. that of absorptive capacity) tends to neglect the dynamics, directions and speeds that different learning events firms might assume. Furthermore, different learning dynamics might be needed to fit different strategic intentions at different points in the firm’s life cycle.

During their lifetimes, organizations develop different learning dynamics that allow them to build up their knowledge of the production system in certain directions by relying on a variety of learning experiences. Through this process the learning trajectory, in which all learning capacities became iterative and interactive, is outlined.

Formative capacity is initially developed by accumulating sufficient knowledge of the production and market system. It therefore might be related to the first learning experiences that firms face over their initial years. Once developed it forms the basis of a firm’s learning system. Learning events associated with adaptive capacity are required from the previous understanding of the routines and technological opportunities available. In contrast, transformative-related events might be needed when those technological opportunities are less certain.

A similar argument could be used for the three explorative-related capacities (i.e. inventive, created and renewed). The important aspect to understand is how those capacities are developed, and to what extent they are interrelated, or independent from each other, and which capacities should be pursued the most for having appropriate KILS.

3.4 Effective technological transformation

The third level of analysis searches for the implications of the learning capacities for the capabilities and routines. In other words the framework questions the extent to which there is an alignment between the firm's learning trajectory and the technological transformation that takes place along the technological trajectory.

The construct of 'technological transformation' is considered in terms of change in capabilities and routines – i.e. behavioural changes. In contrast to organizational routines, here the focus on change is on the operational routines, in which the sequences, practices and techniques of the whole production system of the firm are described. The operational routines are the recipients of the technology and the so-called component knowledge of the organization.

The operational routines are largely based upon tacit knowledge; however, they are observable by the interpretative system that the firm's members share. In other words, the routines are represented by the firm's members' perspectives, which define the state of knowledge at a certain point in time within the firm.

Operational routines are traceable through the identification of tasks that are repeatedly performed to ensure a market position. The type of technology and extent of market diversification define the complexity of the firm's operational routines. These routines are therefore associated with the firm's commercial activity. Routines that directly respond to the main market value of the firm are considered 'core routines'. The other routines support the organization's technological development: these groups of routines are considered 'peripheral' and they can be changeable once the organization realizes that the market offers a more efficient way of performing them.

The framework focuses on the core routines. Consequently, the technological transformation of the firm is understood in relation to the distinctive sequences, practices and methods of production that respond to the firm's market value – i.e. based on the interpretative system – at a certain point of time and over its lifetime. In this way the ecology of the firm's routines in terms of birth, substitutions and death is described.

One of the main arguments behind the framework for this thesis is about the extent to which the deployment of FLMS can be linked directly to modification and implementation of routines at a certain point in time; but more important is the question of how an effective transformation process can be described.

As the framework focuses on the process, linking learning to performance is not the main concern nor is it just about the modification of routines. In this sense Grant (1996b) questioned the effectiveness of technological transformation, offering a three-dimensional analysis to link knowledge integration, capabilities and routines.³⁴ Drawing upon Grant's proposition, this framework defines the alignment between the learning trajectory and technological trajectory according to the efficiency, coherence, and the flexibility of the knowledge integration.

Efficiency according to Grant's definition refers to the extent to which the firm's routines improve as a result of the knowledge integration and learning dynamics. Expanding his explanation from a process perspective, the efficiency will be understood as the degree of interdependency of a variety of learning schemes along the learning process from reflection to implementation. In this sense, this interdependency could follow either a systematic or discretionary pattern. In other words, description of efficiency relates to the sequence that a single group of events needs to follow to enable the modification of behaviours.

Coherence, on the other hand, links knowledge integration and learning with the firm's strategic intentions. While efficiency looks at the change itself, knowledge integration is

³⁴ De Boer (1999), Kenney and Gudergan (2006) and others have followed Grant's framework in assessing the effectiveness of knowledge integration.

coherent if the component knowledge embodied in the learning events is sufficient to enable the firm to accomplish its goals. Grant's definition refers to the scope of the knowledge integration; however, it just refers to the breadth of the specialist knowledge required (see Coen and Maritan, 2011). Coherence in this framework refers to the breadth of learning schemes to match the firm's strategic intentions.

The firm's strategic intentions can be first identified through the alternatives to growth that the firm has at its disposal to define its motivations for modifying its state of knowledge. These strategic intentions are complementarily defined by the extent of technological heterogeneity and market diversity required.

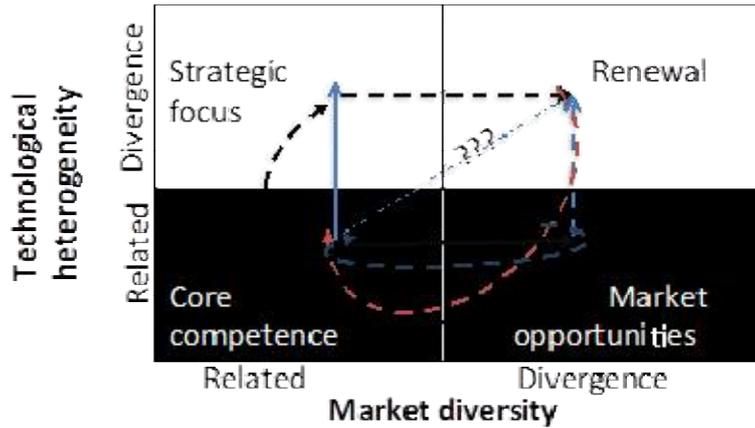
Based on the assessment of current information and know-how, the firm has four possible routes it can take in order to meet its strategic orientations. If the strategic intentions match the operational principles, learning events are exploitative and closely related to the current technology and market. So, the firm's strategic intentions aim to enhance its 'core competence'.³⁵ If technological divergences are required to improve the needs of the current market, then the direction is defined as that of 'strategic focus'. If the firm looks for market diversity to fulfil the potential use of the technology in place, learning events search to develop 'market-opportunities'. If both market diversity and technological divergence are needed, then, learning events tend to be explorative and the firm will search for the 'renewal' of its operational principles.

If it is assumed that the learning and technological trajectories are path-dependent, then path-breaking changes are not possible unless the firm has had the other strategic intentions beforehand. Moreover, strategic intentions are not considered exclusive; firms might pursue different directions, as the improvements of core competence are the foundation for understanding the direction that routines take over time. Moreover, according to the argument proposed by the framework, whatever direction the firm takes, once the routines become core an iterative loop is sketched (see Figure 3.1). So,

³⁵ This framework moves beyond traditional approaches that are in the literature on strategic management and that focus just on the development of (dynamic) core competence to secure competitive advantage (e.g. as proposed by Lei et al (1996)). The framework introduces the concept of core competence as one of the key purposes of knowledge integration and learning. Additionally it is proposed that firms should somehow develop a dialectic move in their search for market diversity and technological heterogeneity to constantly rebuild their core competences.

the strategic intentions are defined through the learning system and the firm's intentions.

Figure 3.1. Direction of the technological transformation



*Dashed lines represent possible trajectories

Source: the author

According to this framework, an effective technological transformation is also explained by the **flexibility** of the knowledge integration. In the sense of this framework it refers to the variety of learning schemes that firms have at their disposal to add new knowledge. It is defined through the learning experiences that firms are exposed to at certain points through using certain learning schemes, assessed through retrieval and how recently they were in place. So, the more flexibility the firm possess the more effective the technological transformation could be. It is expected that flexibility will increase over time, as the firm's routines become more complex and the strategic intentions more challenging.³⁶

This framework implicitly states that the firm's innovative performance is fundamentally based on a consistent process of development of its learning system over time, which focuses on the alignment with the technological trajectory. The technological transformation is effective when the KILS tends to enhance the levels of efficiency, coherence and flexibility.

³⁶ For instance when firms decide to enter into new international markets with more dynamic competence and higher-level technological opportunities.

3.5 The knowledge-integration and learning system (KILS) and the organizational environment

The link between knowledge integration, learning and technological transformation by means of the learning schemes it is not necessarily straightforward. So, although the framework emphasises the micro-components of learning, it proposes that firms develop a KILS that is systematic in principle in relation to the conditions of the organizational environment.

Thus, a dialectic interaction of how learning events occur and how the organization conditions its environment should be developed in the evolutionary process of the KILS. In this sense as the learning schemes arise as part of the organizational environment, changes at the organizational level also emerge as a result of the firm's exposure to learning at the level of the learning schemes.³⁷

As noted by Kogut and Zander (1992) the way knowledge functions within the firm – i.e. through creation, integration and application – cannot be separated from how the organization is structured. Drawing upon De Boer et al's (1999) suggestion, there are aspects of the knowledge-integration process³⁸ that are determined by distinctive organizational features. Their analysis includes the organizational form and the so-called MLMs – i.e. combinative capabilities. The framework in this thesis proposes that the decision-making process is another systemic feature that alters the way firms integrate knowledge.

This framework therefore suggests that an alignment and co-evolution between the learning schemes and the characteristics of the organizational environment should be pursued to assure a complete coordination of the KILS across time. As a result the organizational environment can restrict and/or enable the interpretative system of

³⁷ In a similar line of argument Barley (1990) previously stated: “When introduced into a work setting, new technologies initially modify tasks, skills, and other non-relational aspects of roles. These modifications, in turn, shape role relations” (p. 70).

³⁸ However, instead of using knowledge integration, these authors refer to the firm's absorptive capacity. De Boer et al define the term as the ability to integrate external knowledge, highlighting the importance of the organizational characteristics besides what Cohen and Levinthal (1989) called the ‘stock of prior knowledge’.

individuals, groups and the organization as a whole to push this complex process either forwards or backwards.

Although the organizational environment, which is also related to the organizational routines, tends to be stable over time, it is expected that firms tend to search for the most suitable organizational conditions that fit with the required learning dynamics to respond to the industrial competition. Thus the way firms are able to modify their organizational environments could explain further why and how they move along all learning capacities.

The most stable of all these organizational features are the organizational forms. Taken from the literature on knowledge management, an organizational form is referred to as the platform on which the structure, modes of hierarchies, interaction processes, incentives and means of communication are set. These forms represent the architectural knowledge of the firm and some authors state they are relevant in the determination of the type of knowledge firms create and mobilize. The way firms are shaped influences their knowledge configuration and learning patterns (e.g. De Boer et al, 1999; Lam, 2000; Kenney and Gudergan, 2006).

Literature on this stream of research has identified a variety of forms firms might take (Mintzberg, 1979; Aoki, 1986). Although this discussion is not at the forefront of this thesis, the framework proposes that the firms chosen as case studies should be categorised in terms of their form to analyse if an accurate explanation can be given of how firms reconfigure their knowledge through their learning systems.

Nevertheless, it is also acknowledged that changes in leadership (management) and knowledge structure might force firms to shift their form to fit with new conditions (Augier, and Teece, 2009). Also, it is argued that different characteristics from different forms might coexist within the same organization.

The decision-making process and level of uncertainty also explain how the firm's learning capacities are sketched across the firm's learning trajectory. According to Kogut and Zander (1992) the level of uncertainty that firms face at certain points can

motivate or restrict the opportunity to invest in knowledge and learning. As a result firms tend to rely on the experience of individuals or of a group as well as designed and structured decision-making processes for knowledge integration and learning (Shrivastava, 1983).

The framework proposes that decision-making processes be observed at different moments in time of the firm's evolution by using Shrivastava's taxonomy as a point of reference (the taxonomy comprises: one-man institution, mythological learning system, seeking culture system, participative learning system, formal management systems and bureaucratic learning system) in relation to the perceived degree of uncertainty due to, for example, the rate of change and ambiguity of the knowledge to be integrated. Therefore, how the firm's learning capacity is outlined across time is also related to the decision-making process and level of uncertainty.

A more dynamic feature of the firm's organizational environment relates to the MLMs. These mechanisms refer to how the organization frames its social establishment to create common ground through practices of communication between individuals and among groups. According to Grant (1996b) knowledge integration is influenced by how firms develop similar cognitive understandings of their routines.

Drawing upon De Boer et al (1999) the framework proposes that the way firms set up each of the so-called MLMs that are defined as system capabilities, coordination capabilities and socialization capabilities, has implications for the effectiveness of firms' knowledge integration and learning dynamics. And so, in line with Popper and Lipshitz (2000), the framework suggests that effective technological transformation at different strategic orientations is achieved when there is interdependency and alignment between the learning schemes and the MLMs.

All in all, although the framework focuses on how the firm's learning capacity is outlined through the learning experience – i.e. through the learning schemes – there is a recognition that organizations are conditioned by the organizational principles they set up. Consequently, these principles should be recognized in one way or another to avoid misleading explanations. Also, learning capacity should not be considered the same

throughout the firm's evolution, as knowledge reconfiguration and orientation might respond differently, and still lead to effective knowledge integration, under different organizational conditions.

3.6 Concluding remarks

The framework proposes several points of discussion at different levels of analysis to link knowledge integration, technological learning, capacity building and capabilities. The first level of analysis is directed at the dialectic movement that knowledge has in between it being tacit and explicit, highlighting the transition in the learning process from cognition to behaviours. The second level comprises a search for the interaction between knowledge reconfiguration and orientation to identify the different degrees of learning capacity that organizations face. This discussion allows the learning trajectory to be superimposed on the technological trajectory, which then permits the two trajectories to be compared. The third level of analysis searches for explanations by looking at some organizational characteristics of the firm, specifically for the purposes of understanding whether there is a correspondence between the learning schemes and the MLMs for the learning system. How an organization sets out and evolves to make the interaction between all these levels work is defined as the KILS of the firm.

The framework proposes a construct of 'technological learning' based on what is collectively called here the 'learning schemes' – which are represented through (learning) events – taking into account the learning process and methods for mobilization and internalization. Nevertheless, instead of focusing on their singularities, the emphasis of the framework is on their complementarities along the learning process. The framework proposes that these learning events might follow a systematic or discretionary pattern. Firms learn to learn when they understand the sequence of events that are required to modify the interpretative system under specific strategic intentions.

In addition, the framework unfolds the concept of 'learning capacity' at six different levels. It defines the extent of the interaction of external and internal knowledge – i.e. knowledge configuration – based on the firm's attitude towards external knowledge

being classified as passive, active and interactive alongside the knowledge orientation process – i.e. exploitation and exploration. It proposes that knowledge transfer means something different depending on whether the knowledge is integrated within the same (passive, exploitative) or different (active, interactive, explorative) interpretative system. Consequently, the learning capacity of the firm is not singular and homogenous along its lifecycle – it changes according to how the firm approaches knowledge.

The question is, however, how firms create an iterative balance between different learning capacities, because these capacities serve different purposes within the KILS. The framework suggests that firms with higher learning capacity are those who not only have developed sufficient and continuous learning experiences in each of the categories but also have been able to understand the interrelated sequences between them. Moreover, this understanding comes at a time when organizations tend to rely on the potential of their own knowledge of their markets before searching for and acquiring external knowledge. In doing so they search for codified knowledge before moving towards tacit knowledge. Consequently, once firms develop sufficient experience in each capacity, they are then able to learn to what extent there is interaction between the different capacities. If firms have a reasonable understanding of their routines it will be likely that they will choose the right direction, as has been suggested by Cohen and Levinthal (1991).

At this point the framework argues over the extent to which each of the learning capacities, and the interactions between them, can be linked to an effective technological transformation, and to address this issue, the operational routines are examined. Building upon Grant's (1996b) suggestion the framework proposes that more effective technological transformations occur when there is a high degree of interdependency between a variety of learning schemes along the learning process that serve to modify behaviours with regards to the firm's strategic intentions. In a complementary manner, it proposes that the greater the variety of learning schemes that firms have at their disposal, the more certain their technological transformation will be.

Accordingly, firms experience higher levels of learning capacity if they have effective technological transformations in correspondence to their strategic intentions. As just described, effective technological transformation is achieved through time as firms gain more learning experience of different kinds.

Finally, the framework proposes to match the learning and technological trajectories with the organizational conditions of the firm. It is stated that an alignment between the learning capacities and the organizational conditions should be pursued to assure a better effectiveness of the KILS. Thus, it is suggested that the macro-components of the firm be observed through the lens of the organizational forms, the MLMs and the decision-making processes, which are supposed to be the features that condition the interpretative system of the organization.

The proposed framework, therefore, differs from previous approaches that have acknowledged knowledge integration, learning and capabilities in several respects:

1. The framework focuses the analysis on the learning schemes as a broader way to understand how firms capture and mobilise knowledge and capabilities from different sources. Instead of focusing on a single specific learning context (e.g. R&D) the learning schemes refers to the contribution of a variety of learning events to the overall learning capacity. The framework, therefore, highlights the importance of connecting these learning events as part of a consistent process of capability building
2. The framework makes a distinction of different types of learning capacities acknowledging that a sense of uniformity in the learning trajectory from a single conceptual approach (e.g. that of absorptive capacity) tends to neglect the dynamics, directions and speeds that different learning events firms might assume.
3. Research on knowledge management has traditionally focused on architectural knowledge; however, these approaches tend to neglect the relevance of individual and group actions, which brings about the cognitive and behavioural

condition of knowledge integration. So, this framework emphasizes that knowledge integration is an inductive process that emerge from the dynamics of individuals in running the operational routines.

4. The framework also highlights that knowledge integration should happen continuously through different periods of time and across functions, and therefore firms should consider different approaches to knowledge integration at different moments of the learning trajectory. So, the framework states that the reconfiguration and orientation of knowledge change at different moments and strategic intentions of the firm.
5. Finally the framework differs from previous approaches by explicitly recognising that the knowledge of a firm is made up of a combination of tacit, explicit and codified knowledge that resides in the individual or collective memory of the firm, and in turn, this combination affects their function in integrating new knowledge.

The previous and present chapters have set out the theoretical discussion of the research. The framework explains the concepts and analytical links that will serve as a window of observation to look at the case studies. Although the framework builds upon previous discussions in the literature, it proposes an integrative and broader view of the complex phenomena of knowledge integration, learning, capacity building and capabilities. The next chapter describes the methodological approach used to fulfil the conditions required in the framework.

4 RESEARCH STRATEGY: A HISTORICAL COMPARATIVE IN-DEPTH 'TWO-CASE-STUDY' METHOD

4.1 Introduction

The chapter aims to explain and describe the research strategy and methodological foundations that guided the decisions in the research for this thesis. A historical comparative in-depth two-case-study method was chosen to answer the main research question.

The case-study strategy has therefore been used to conduct a rich and detailed analysis of how the micro-components of knowledge integration and learning – i.e. the learning schemes – interacted over a long period of time; the analysis in turn has then enabled a better understanding of the causes and consequence of the process of capacity building and capabilities.

Regarding the organizational settings, the study focuses on SMEs characterised as atypical within an emerging economy. So, the SMEs selected for the research have the following conditions: i) they show high level of growth, ii) intent to learn, iii) are are pioneers within their specific market focusing on local demands and, iv) are engineering based. As a result, the outcomes of the analysis are context specific and refer to high growth engineering-based SMEs within emerging economies.

The chapter is divided into two sections: the first (section 4.2) explains the logic and foundations of the research design and the second (section 4.3) describes the research process.

4.2 Research design foundations

The research design describes the logic behind the link between, on the one hand, the initial question of study, the data to be collected and the analysis and results, and on the other hand, the theory (Yin, 1994; Grunow, 1995). This section sets out the main features through which this research for this thesis has positioned the method of inquiry in order to search for validity and coherence throughout the analysis and resulted argument.

A case-study method was used as a research strategy. More precisely, the adopted approach for this research is called a historical-comparative, in-depth, two-case-study method. Although some of the aspects of this methodological approach were initially adopted (such as the retrospective perspective), over time the research was also shaped by the conditions of the context, the type of cases available and their accessibility. Nevertheless, the main research question and the chosen analytical framework provided enough support to justify the final approach and to maintain consistency throughout the research process in line with the phenomena that are being studied and the corresponding literature.

Given the discussions that qualitative research and particularly case studies have generated in social science over the years (e.g. Yin, 1981; Platt, 1988; Eisenhardt, 1989a; See, 1989; Leonard-Barton, 1990), scholars have suggested (e.g. Eisenhardt, 1991) that a clear specification of the design in support of the research process is essential to ensure a rigorous approach.

In this thesis, a line of argument is offered that is consistent with what it is expected and which avoids misinterpretations with regards to the scientific results of the study. Features such as the purpose, the typology of the case design, the sequence logic (deductive-inductive), and the replication logic (i.e. having more than one setting), as well as the distinction of context-setting, subject, unit of observation and timescale, are stated. Accordingly, the declaration of these characteristics defines the adopted epistemological position.

4.2.1 Paradigmatic approach

Based on the discussions offered by Raveswood (2011), Beverland and Lindgreen (2010) and Eisenhardt and Graebner (2007) related to the philosophical ideas with which the case studies are associated, this research is biased towards a postpositive paradigm (Guba and Lincoln, 1994). However, the declaration of this position requires further specification to ensure an understanding of first, the ontological problems presented here – i.e. the way of observing knowledge integration, learning, capacities and capabilities are explained – and second, the choices of methods.

The first point refers to the relative importance of prior theoretical developments. According to some social scientists (e.g. Corbin and Strauss, 1990; Eisenhardt, 1989a; Marshall and Rossman, 1999; Sudaby, 2006), one of the main issues that define the position of the scientific argument relates to the extent to which prior theoretical knowledge refers to and leads the research endeavour. In this sense the research question was posted by recognizing previous theoretical debates. In addition although the analytical framework further elaborates the constructs in a different vein from the established literature, it takes into account prior theoretical traditions and assumptions upon which are based the proposed analytical links.

Second, this research deals with the idea that beyond intentions and interpretations the reality is shaped by situations that are proved to have happened. The reality is observed based on proven descriptions of previous situations and interpreted through the lens of theoretical and analytical constructs. What is finally recalled is the existence of those analytical constructs through the evidence.

It should be pointed out, however, that by observing any reality retrospectively, total accuracy is not necessarily achieved. In other words, the meanings and interpretations of certain events could be different at the time they were experienced from when they were recalled (Mitchell and James, 2001) at the moment of carry on the data gathering (these interpretations are shaped by personal interest, experiences and qualification). The data collected from individuals was gathered based on the identification of what they recalled about past events and their understanding of significances of those events

(Lewis and Grimes, 1999). The incidents in the case studies for this thesis were described mainly through the recollection that interviewees had of the relevant episodes within the firms and they are based on the orientation given by the constructs; the descriptions were later associated with the categories previously stated (see chapter 3) as part of the analytical framework.

However, the research differs from this postpositive view in one main aspect. The definition offered by Burell and Morgan (1979) highlights the importance of predictions and regularities, but the results presented in this thesis do not intend to be predictive whatsoever, and changes in atypical settings under inconsistent circumstances were sought rather than regularities.

Incidentally, following the well-established conception of paradigm taxonomy proposed by Burell and Morgan (*ibid.*), the approach adopted for this study towards the research of inquiry has used what is referred to as 'radical structuralism'.³⁹ Apart from the already noted factors that have been used, the context and the chosen organizational settings were also selected with the intention of showing changes in the status quo. First, the selected context does not fix the reality of order, homogeneity, similarities and continuity. Second, based on the distinctive population and case selection criteria, the firms were expected to have moved in different directions from those that could have been defined by the deterministic conditions of the context. These atypical characteristics have been used to try to infer how it was possible for the firms to change their paths.

4.2.2 Purpose of the research

This section sets out the purpose of the research. This study aims to elaborate on

³⁹ According to the definition offered by Burell and Morgan this is an approach in which the researcher tends to search for objectivity but under changing conditions. Nevertheless, by assuming a postpositivist's position, objective reality can be observed and understood only imperfectly (Guba and Lincoln, 1994). The descriptions of events as historical 'facts' are mediated by how individuals are able to give meaning to the events and remember them. Moreover, events are reinterpreted through the lens of pre-existing theoretical knowledge about the nature of the phenomena in question. The reality is finally transformed into meanings. But these meanings can only be objectively understood if they are socially accepted.

theories⁴⁰ (Lee, 1999) – i.e. to expand theories rather than being just descriptive and exploratory. However, to describe in which way and to what extent this piece of research accomplishes this goal, a clarification of what ‘theory’ means is needed.

According to Sutton and Staw (1995) theoretical statements should be related to the creation of a logical argument that proposes (1) a group of concepts, (2) the links between them and (3) causal components that together enable a comprehensive understanding of the phenomena under investigation. If a study outlines just one of the three aspects it could possibly contribute towards knowledge but not essentially towards the developing of a theory. Accordingly, it could be interpreted that a single research study could offer one of the three following options: (1) a complete explanation of a phenomenon that has been partially explained, (2) a completely different analytical observation, or, if a theory-building statement was the goal, (3) the development of variations of a theory.

Following these authors’ suggestion of what a theory signifies in organizational management, this research includes to a certain degree the three characteristics just described but considers more closely the two first options. The research for this thesis aims to offer a complete explanation of the process of knowledge integration, learning and capability building by combining various streams of the literature (see Chapter 2). The research for this thesis uses an analytical framework (see Chapter 3) that is different from those employed by other researchers who have considered similar research questions.

Furthermore, in line with previous studies on knowledge integration, learning and capabilities, which have also focused on dynamic conditions (e.g. Van de Ven and Huber, 1990; Brown and Eisenhardt, 1997; Bingham and Davis, 2012), the study has searched for a theory by developing a narrative based on the historical progression of events (Pentland, 1999). These events have taken place at specific moments in time, under

⁴⁰ According to Lee (1999), theory elaboration in contrast to theory building (Eisenhardt, 1989) aims to observe empirical data based on the construct categories so to as understand the emerging patterns.

certain circumstances, and thus have become the representation of knowledge integration and learning; in this sense actions have been at the centre of the analysis.

This search for a theory depends very much on the substance of the research question, the answer to which is related to the understanding of the way things have evolved over time (Van de Ven and Huber, 1990; Langley, 1999).⁴¹ In the case of this study, the substance of the research question has been bound up with learning, capacity building and technological trajectories, all of which are concepts concerned with processes and the dynamics of change.

Langley (1999) has offered four characteristics of this type of research: (1) sequence of events, (2) temporal embeddedness, (3) multiplicity of levels and unit of analysis and (4) eclecticism. In terms of these characteristics this research has dealt with well-defined and chronologically organized events – i.e. learning events and learning schemes. It has involved a precise temporal setting for each case (a period of observation of longer than 20 years). The study has also included different units of analysis (learning events, learning capacities and learning trajectories). But factual events only were collected, thereby avoiding perceptions, for instance, which is why eclecticism in the data-gathering process was avoided.

Consequently, the research has followed the sequence suggested by Eisenhardt (1989) for carrying out case studies. According to this author case studies that are primarily carried out to develop theory should depart from theory-driven research questions, should recognize previous literature and should develop analytical constructs ahead of the research, but most importantly, they should rely on theoretical sampling. However, in the research for this thesis there have been two divergences from her approach: one is that it has focused on two, rather than multiple, cases, and the second is that instead of following an inductive logic, it has followed an iterative logic – i.e. a deductive–inductive approach was adopted.

⁴¹ Although the form of the research question is also important and was highlighted by these two authors as well, it is more appropriate to a discussion over the definition of the explanatory character of the research.

4.2.3 Logic sequence: deductive–inductive

In terms of the deductive–inductive sequence of inquiry, Eisenhardt and Graebner (2007) stated “the central notion is to use cases as the basis from which to develop theory inductively” (p. 25). However, rather than just taken and adapted from different theoretical traditions (e.g. knowledge management, organizational learning, dynamic capabilities and absorptive capacity) (see Chapter 2) a dialectic argument has been grounded on the empirical evidence to validate new theoretical constructs (see Chapter 3) and establish new propositions. In other words, the research has examined the data through the lens of the previously defined construct categories and propositions but has also searched for unexpected learning dynamics and interaction patterns between capacities.

This iterative sequence was probably appropriate for assuring a greater degree of theoretical generalizability and replicability. But, it has also been criticized for limiting the opportunity to find new explanations 'for certain phenomena that are being studied using a research strategy, which traditionally has offered the advantage of explaining the richness of the empirical evidence.

4.2.4 Typology

Three factors define the type of case study that was followed. First, the answer to the research question was sought by taking a retrospective–historical perspective. Second, data was captured from both case studies by using the same analytical framework and research protocols, so as to enable a comparative analysis between slightly similar settings – i.e. firms with related characteristics. Third, both cases were used to search for arguments that might explain the causes and consequence of firms' knowledge integration, learning and technological transformation.

Of these three factors, the last best defines the type of analysis chosen for the data. Case studies have traditionally been linked to descriptive narratives of large amounts of data with low or insufficient explanatory arguments. Nonetheless, a research-process

approach offers a narrative based on a chronological sequence of events, which essentially might raise explanations to as how those events occur. Also, a comparative analysis searches for explanations by controlling specific factors that the literature might have identified as important to distinguish.

The characteristics of the research design described so far were more likely to offer 'how' types of answers, however, it is often difficult to offer answers that explain 'why' events occurred. It then becomes relevant to declare in which way this research was intended to respond not just to 'how' but also to 'why' types of explanation. In this sense, as also argued by Sutton and Staw (1995) and Lawrence (1997), if the purpose of the research is to elaborate and expand on theory, the patterns that link all the events should be fully explained by giving the 'why' type of explanations.

To provide further clarification, Yin (1994) and Pentland (1999) have suggested some conditions that define better under which characteristics explanatory case studies could be pursued – four of these conditions are discussed below.

The **first condition** leads to a revision of the characteristics of the research question. According to Yin (1994), an explanatory type of question “deals with operational links needing to be traced over time” (p. 6). The research question in the case of this study links 'how' the firm's learning dynamics have led to capacity building influencing the technological trajectory. However, the question also serves to answer 'why' the capacity building has taken a certain sequence and 'why' the technological trajectory was routed towards a specific trajectory. The historical chain of events has been described from the inception of both firms, showing a sequence throughout their life cycles – i.e. the antecedents of events and their consequences are described.

The **second condition** relates to the narrative, which is not limited to the description of (learning) events but to the firm-embedded context, description of circumstances and routines. Under the **third condition**, the events are categorized and described under a stylized argument based on an existing analytical framework (see Doty and Glick, 1994). And finally, under the **fourth condition**, there are some fixed firm- and context-related features that allow for the finding of similarities and differences between distinctive

organizational settings – i.e. these are controlled observations. On the whole the case-study design has had behind it the intention of a search for both ‘how’ and ‘why’ explanations for the phenomena under study.

4.2.5 Replication logic

Another feature of case-study research is that of ‘replication logic’. Scholars discussing this aspect (e.g. Yin, 1994; Eisenhardt, 1991) have argued over the importance of using more than one case in order to have better development of a theory. In line with Yin’s (1994) distinction between theoretical and literal replications, Eisenhardt (1991) is keen on having a design that includes multiple cases – from two to ten – to ensure better, more robust and complete theoretical arguments, as already explained.

The research for this thesis was designed to go in line with this argument, in other words, to include more than one case; in fact, it was intended to collect evidence from multiple case studies to find explanations from different and similar evolving patterns of knowledge integration and learning interaction. Furthermore, following Eisenhardt’s (1989a) suggested procedures the research process followed what she termed ‘theoretical sampling’, which is consistent with what has been discussed up to this point.

Due to the limitations of the context and decisions regarding the population and sampling, two cases were finally identified and included for the empirical purposes. But because of the complexity of the analytical framework that combined different levels of analysis with a detailed historical sequence of events, having just two cases allowed for a more accurate description of the interaction and dynamics of the knowledge-integration and learning system than having multiple cases.

In order to have comparative settings, the cases were selected from the same population. In principle the required firms should have shown what is defined as ‘learning intent’, typified in this research through the identification of collaborative R&D experience.⁴² Thus, given the characteristics of the context, the selected cases could be

⁴² If a firm had developed a collaborative R&D project with one university or research centre it was presumed that it had a learning intent throughout its life cycle.

considered as atypical. The population of firms was taken from a database purposely built from the R&D projects presented for grants to the governmental organization in charge of the promotion of Colombian's science and technology, COLCIENCIAS⁴³ (Administrative Department of Science, Technology and Innovation) in what can be defined as biotechnology. This decision was consistent with the use of theoretical sampling.⁴⁴

A counter argument on replication logic in social science, however, has been related to the question of to what extent it is possible to find identical conditions in the social world compared with the natural world. Clearly, as Kaplan (1964) has suggested, social situations are not expected to be identical. Therefore, there should be an argument from the epistemics of the research that makes a clear rationale for replication, knowing that generalizability of the results is not the goal.

In line with the previous argument this research is more biased towards reflecting on previous theoretical traditions by framing the phenomena being studied of study under the same conceptual and analytical parameters. Accordingly, it is the analytical framework that is replicated by using the same research protocols. Based on Tsang and Kwan (1999) this type of replication could be considered as exact replication because the same construct and analysis were used to describe the phenomena that were observed in the firms within the same context.

Besides following a theoretical sampling for replication, it was expected that the research design would follow that proposed by Yin (1994) who distinguished between two types of replication: theoretical and literal. While theoretical replications search for contrasting results by having cases with at least one difference, literal replications search for similar results by maintaining the same features. As suggested by Yin a case

⁴³ COLCIENCIAS is a national and governmental organization, which is in charge of developing and promoting the policies, norms and standards of scientific and innovative development in Columbia.

⁴⁴ This decision was taken because of a normative criterion. According to the Colombian governmental setting COLCIENCIAS is the only organization in charge of the support and development of science and technology. By going down a different path it would have been difficult first to have clarity of type of project and second to identify its technological characteristics, especially if the objective was to find the intention to introduce biotechnological techniques.

design that follows theoretical replications is prompted to also have literal replications in each of the contrasting groups.

With this in mind, some common firm-related features in terms of size, age, industrial position and knowledge base were explicitly bounded in order to have some control over the results. The study focused on SMEs with more than 20, but less than 30, years in the market and with the characteristics of being specialized suppliers – see Pavitt’s taxonomy (1990) – with a related knowledge base in chemical engineering, microbiology, agriculture engineering and food engineering.⁴⁵

While similar firm-related factors were used to select the cases, different industrial applications were defined to contrast the findings. From the three possible related industrial applications, two firms were identified and found to be available as case studies in the agriculture and food-processing related industries. By defining the industrial applications, the results were restricted and differentiated to the nature of the operational routines required for the development of the two selected economic activities (these being the supply of ingredients to the food industry and the supply of seedlings to commercial fruit growers).

The study design was expected to generate similar and contrasting results from each of the two selected industrial applications. The reason for selecting industrial applications as a contrasting feature rests upon one of the relevant theoretical discussion points of the research; this point relates to the tension between exploitation and exploration and it is focused on finding differences in the learning dynamics and trajectories. As a result it was important to have cases in which path-breaking changes were evident. In other words, the study would potentially consider chemical, agricultural and food-related engineering firms that had intended to modify their technological trajectories by introducing biotechnological techniques through collaborative R&D projects – i.e. they would have expected to make the transition from single mature technologies to complex emerging technologies. Within each of the two selected industrial applications (i.e.

⁴⁵ All these knowledge bases have the potential to develop and apply biotechnological techniques to a variety of industrial applications.

agriculture and food-related engineering) it was possible to find one case in each which allowed for the exercise of theoretical replications.

4.2.6 Context settings: extrinsic and intrinsic conditions

An additional feature of the research design was defined by the deterministic conditions of the context settings. Tsang and Kwan (1999) make reference to two types of contingencies that affect the causalities of the phenomena under inquiry. They point out that causal power is activated by extrinsic and intrinsic conditions: the former correspond to those characteristics external to the object of study and the latter are related to the conditions defining the nature of the object. These two contingencies relate to the context and the characteristics of the subject in which the study takes place and its corresponding unit of analysis.

Regarding extrinsic conditions, determination of the characteristics of the context is an attempt to close up and limit a system that is believed to be precluded in open systems (Tsang and Kwan, 1999) where multiple conditions affect social structures and are probably changed through learning. This research defines two extrinsic contingencies that are expected to affect firms' learning evolution within the selected industrial context, these being market dynamics (Eisenhardt and Martin, 2000) and technological opportunities (Lam, 2000).⁴⁶

To some extent the delimitation of these two contextual characteristics create deterministic conditions in which the results have been placed. On the one hand, indications of the technological opportunities within the selected context are described as emerging as well as dispersed and discontinuous in relation to knowledge and technological availability.⁴⁷ On the other hand, the type of market dynamism considered is characterized by poorly regulated conditions and non-technically educated users or

⁴⁶ Discussions of how these two contingencies affect a firm's learning trajectory are well developed in Chapter 2 in which the theoretical arguments that support the research inquiry and methodological decisions are stated.

⁴⁷ Along with the analysis of the R&D projects, patent data on biotechnology-related techniques were studied to enable an analysis of the level of continuity and dispersion of technological opportunities. Although the thesis does not offer a description of these aspects because this was not intended (nor was there space), the databases can be seen if required.

buyers of the technological solutions, which make market dynamics highly moderated or slow (Karsnlüoglu and Easterby-Smith, 2011).

Although these two characteristics could be found anywhere else in the world, the decision to choose the Colombian context was closely related to the accessibility of data. Despite the recognition of the limitation of the findings to this specific geographic and political system, clearly defining the above characteristics will allow further comparative studies, either with similar or contrasting extrinsic conditions, for the development of stronger theoretical contributions towards what is being defined here as the knowledge-integration and learning system (KILS).

In terms of the intrinsic conditions, some aspects have already been explained with regards to the object of investigation, which has been characterized as well-established specialized supplier SMEs. So, the clarification of the object as well as the definition of the unit of analysis have offered a more accurate description of what the study has been about.

4.2.7 Unit of analysis

The case study for this thesis is clearly concerned with the learning dynamics of the firm; specifically this means the study has focused on those events – cf. which equate to the unit of observation – that defined the group of actions carried out by the firm to address changes in its operational routines over the years. The analytical framework thus offers a stylized perspective on how to understand these learning dynamics, distinguishing three levels of analysis; these are the so-called learning schemes, learning capacities and learning trajectory of the firm.

The **learning schemes** are the basic level of analysis represented by the collected events. Once the content of each event was captured it was possible to find repeated patterns, some of them more easily recognized than others,⁴⁸ that could be categorized into a typology of schemes (e.g. from one of the cases the 409 reported events were

⁴⁸ Some events such as technical training or machinery acquisition were clearly identified, but others were more firm-/industry-specific like technical implementations or supplier representations.

grouped into 17 types of learning scheme). The aim was to collect all types of event that had resulted in any effect on the operational routines. The events were selected through a combination of the codified (reports and databases) and tacit (individuals) memory of the firm. In both cases, the events were the representation of the selected memory of the firms regarding what they considered relevant for their technological trajectories.⁴⁹

The other two levels of analysis correspond to further aggregation of the learning schemes by finding similarities among them (sources and orientation) and having them distributed chronologically over the firm's life cycle. Consequently, the second analytical perspective corresponds to the type of **learning capacity** and the third to the **trajectory** traced over the years by these learning capacities; the trajectory gave a perspective at the level of the firm of the relationship between learning and technological change. Based on Yin's (1984) typology this research is in line with what he termed an 'embedded case study' – i.e. a multiple unit of analysis.

4.2.8 Timescale: longitudinal study

A final important factor to be considered in the research, as pointed out by Zaheer et al (1999) is that of the timescale. They have described three types of interval (existence, validity and observation) relevant to the foundations of this research and that are connected to the level of analysis.

As just explained, the learning dynamics were represented through those events experienced by the firms year by year, which was the selected time frequency. However, each of these events happened in an ad hoc manner, and each of them covered a different time span. Consequently, although the information was collected yearly, an event-driven strategy was followed (Gersick, 1991). This type of interval refers to what Zaheer et al (1999) defined as 'existence intervals' – i.e. events within a year.

⁴⁹ The researcher (i.e. the author of this thesis) offered a clear conceptual setting of what a learning scheme represented for the study, and through the interviews the key managers of each organization recalled possible events they considered to fit with this definition. In certain situations during the dialogue, the researcher picked up on specific events that the interviewee had recalled as such. When reports were reviewed the events were identified by the researcher and later confirmed by the key managers of the organization.

The learning trajectory was described by grouping the learning schemes according to their respective capacities in relation to the firm's life cycle. The interaction patterns between different learning capacities for theory building were sought over intervals of the firm's life cycle. While learning dynamics were described from year to year, the learning capacities were distinguished from inception through four well-defined stages of the life cycle – i.e. initial conditions, formalization, establishment and expansion – each covering periods ranging between four and ten years. These intervals have been defined as 'validity intervals' (ibid.).

The last distinction regarding timescale has been referred to as 'observation intervals' (ibid.). In the case of this research the decision was to look at firms with survival rates larger than 20 years. An observation period of less than 20 years would have limited the probability that a firm would have experienced the whole range of learning capacities and gained an understanding of their sequence over the firm's life cycle – i.e. along the learning trajectory – and the interaction patterns between the capacities. As a result an observation interval was chosen within the period starting in the 1980s and going up to 2010.

Nevertheless, the underlying question is how these choices have affected the results and why it has been important to make them explicit. As noted by Weick (1979), any effort to provide accurate explanations of the bounded conditions in which theoretical arguments are placed goes against generalizability of the results.

The importance of specifying timescales in the case of process research is twofold. First, theoretical arguments might raise different conclusions if the starting point for the firm's learning trajectory and capacity building is described at different stages of the life cycle (for instance, after the firm has reached an established position).

Second, contextual time is assumed to have implications for the type of conditions under which knowledge and technology are integrated; the fact that the time range covered a period, which started in the 1980s possibly, has consequences for the way that these firms evolved. In both cases the industries were emerging at that time. On one hand there were clear market opportunities and low or non-existent competence;

on the other hand technological opportunities were limited (from the managers' perspective there was no available locally embedded technological development or even proper engineering skills), and so it could be argued that market, technology and firms advanced hand-in-hand over this period. Even though the concepts and analytical linkages among them could have been demonstrated at different time settings, it seems unlikely that empirical results would have been similar if there had been higher market saturation and technological availability.

Table 4.1 summarizes the foundations of the research design in all the categories just explained, giving a complete framework from which the meanings and interpretations of the phenomena under investigation were derived.

Table 4.1 Foundations of the research design

Criteria	Foundations connecting to the research question	Foundations connecting data availability	Foundations connecting to theory
Purpose	Constructs, an analytical framework and initial propositions grounded on empirical evidence	Historical progression of events	Build-expand and generate theory
Sequence logic	Deductive (from theory)	Deductive-inductive	Inductive-deductive
Typology	Retrospective (historical)	Comparative cases	Explanatory
Replication logic	Atypical cases/subgroups' case design*	Theoretical replication	Literal* and theoretical replications (Yin, 1993)
Context setting	Deterministic consideration of context	Geographically bounded in Colombia / industrial applications	Emerging technological opportunities/moderated market/SMEs
Unit of analysis	Learning capacities	Learning dynamics: schemes and process	Organization's learning and technological trajectory
Unit of observation	Learning events	Description of learning-related facts recovered retrospectively	Learning schemes
Timescale	Observation interval:	Existence interval:	Validity interval:

	more than 20 but less than 30 years. From 1980s to 2010	events collected and grouped by year	from inception through the firm's life cycle
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* Because of the limited number of cases it was not possible to have more than one case within groups.

Source: the author

By specifying these criteria the intention behind the research has been to improve the accuracy of the results (at the expense of generalizability) and enable a better understanding of the theoretical contributions. All the criteria together, but most importantly the replication logic, the context, the level of analysis, unit of observation and timescale, set the boundary conditions within which the theory behind the research was developed. These delimitations imply that, given the epistemological approach and the corresponding method of inquiry, the results cannot be considered conclusive.

In summary, the factors discussed in sections 4.1 and 4.2 provide the rationale behind the selected method of study. The explanations point out that the case study, as a research strategy, was the most appropriate option among other possible strategies. The next section describes the research process that was followed and how it relates to the features of the research design that have just been explained.

4.3 Research process

The research process is defined as the steps followed throughout the study to search for an answer to the research question and make sense of the scientific argument that emerged from the results. Based on the criteria stated above, the process is likely to be consistent with both the paradigmatic approach and purpose of the case-study research despite the constraints and obstacles that this research strategy normally faces along the way. This section describes the course of action taken during the research, as well as the phases, the methodological decisions and the activities. An effort has also been made to identify the problems that affected the reliability of the results.

Throughout the process a constant dialogue was maintained between the theoretical justifications and the conditions and limitations of the context. As a result the sequence

was iterative rather than linear. Once the research had progressed towards examining the empirical evidence the empirical evidence, further adjustments to the research question, the analytical framework and the theoretical arguments behind the research were required.

Therefore, although a theory-oriented type of research was pursued, the way the evidence appeared during the process defined many of the methodological decisions. Decisions such as the way the population was framed, how the cases were finally selected and the reasons for focusing the research on specific types of firm were the results of a combination of theoretical justification and contextual conditions. It should be pointed out that the reason for adopting this way of proceeding was also because of the limitations of the available evidence. The limitations of the context for studies like this are clear from the theory on learning dynamics, which is process-oriented; therefore a more precise exploration was required to fully comprehend the type and amount of settings (cases) available from which to get the information in order to capture the expected outcomes from the theoretical framework.

The research was completed in eight phases. The research process started with the definition of the research question (phase 1); the question was defined in response to selected theoretical problems regarding the relationship between learning, knowledge integration and capabilities. It acted as a guide throughout all the phases, and enabled the research inquiry to be positioned within a body of literature (phase 2). Subsequently, the concepts and linkages were defined to frame the research (phase 3). These initial phases covered the first approach to the theory.

The next three phases (4–6) involved all the activities related to the fieldwork. One important aspect of this group of sequences was the definition of the empirical evidence, including the identification of the most accurate source for identifying the population of firms and characteristics of the cases according to the related aspects of the analytical framework (phase 4). The outcome of this part of the process was the selection of cases. The fieldwork then continued with data gathering (phase 5) and finished with the organization and evaluation of data (phase 6).

Both the analytical framework and research question were revised and adjusted once again during this part of the research process to check consistency and reliability. However, regardless of the modifications that had been made up to this point, the sense and substance were maintained. Changes were more related to the form in the case of the research question i.e. order and some specification of concepts-, and in relation to the framework they were more about the way the concepts were posted.

The research process concluded with the analysis and writing up of the reports (phase 7) and contrasting the findings with theory (phase 8). The writing up of the cases followed Eisenhardt's (1981) suggestion of writing each individual case separately followed by the cross-case analysis. An important point to highlight was that both cases were written by a single researcher (i.e. the author), and so bias in the analyses was likely to occur. However, to avoid this type of partiality and to ensure full engagement with – and therefore a certain amount of objectivity over – each dataset and its analysis, it was decided to do the writing up of each case immediately after the organization and evaluation of the corresponding data and then to allow some time to elapse between the two sets of analyses.

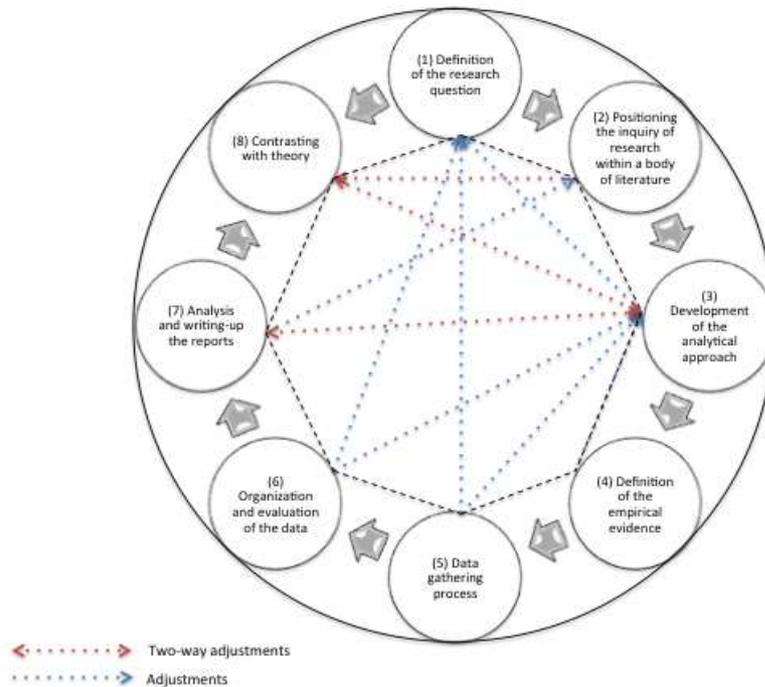
It was important at this point in the research to revisit theory and complete the discussions supported by the literature on learning, knowledge integration and capabilities. Of relevance also for the final discussions was to consider to what extent the emerging data could be treated by the analytical framework while the cross-case analysis was in the process of being developed.

As explained above, despite there being a strong analytical framework to guide the data gathering –i.e. a deductive process – some additional information came to light during the analysis that required explanation using further theoretical arguments – i.e. this was an inductive process.

Hence the research process could be described as cyclical in the manner described by Marshall and Rossman (1999) and Chatman and Flynn (2005). Although they wanted to show the possibility of using qualitative and quantitative methods simultaneously, the idea behind their work was to have an iterative sequence between theory and evidence.

This is a discussion that leads to arguments favouring systematic circular approaches against the traditional linear process to research. Figure 4.1 shows graphically the iterative sequence of the research for this thesis through the eight phases.

Figure 4.1 Phases of the research process



Source: the author

A more detailed explanation of how the phases related to the fieldwork process and analysis is given in table 4.2. The result of the previous phases of the research process related to the positioning of the inquiry and the development of the analytical framework were described in Chapters 3 and 4.

Table 4.2 Phases, methodological decisions and activities

Phases	Methodological decisions	Activities
(1) Definition of the research question	Research question responding to theoretical gaps	NA
(2) Positioning the inquiry of research within a body of literature	Focus on: <ul style="list-style-type: none"> Organizational learning and process research Knowledge integration Dynamic capabilities Absorptive capacity 	<ul style="list-style-type: none"> Identify initial works according to the primary literature selection Define some key words Identify through references a list of articles Identify through the journals the community where the inquiry of research takes place Identify common claims related to the inquiry of research
(3) Development of the analytical approach	Propose a new observation framework based on prior assumptions from the literature	<ul style="list-style-type: none"> Conceptual and analytical framework Initial propositions
(4) Definition of the empirical evidence	Strategic and theoretical sampling	<ul style="list-style-type: none"> Define the population framework Select case studies
(5) Data gathering process	<ul style="list-style-type: none"> Multiple sources Triangulation Collect factual events 	<ul style="list-style-type: none"> Define the research protocol Operationalize the analytical framework Contact the firms Present the research to the firms to ask for accessibility Organize the agenda Collect the information from the selected reports Collect data from the interviews
(6) Organization and evaluation of the data	<ul style="list-style-type: none"> Chronologic tabulation of events in a database Organize the narratives to support the description of the events 	<ul style="list-style-type: none"> Transcribe the recorded interviews by using the free software 'F5' Organize the physical files according to the topics Organize the interviews in a document by topic, interviewer and year Elaborate a database to organize the learning events according to the categories previously defined in the framework by using the information from the interviews and files Apply coding process to the data Assemble and integrate data Check the consistency and validity of the data by contrasting different sources Validate the information with the firms
(7) Analysis and writing up the reports	Write each case based on the analytical framework Single researcher	<ul style="list-style-type: none"> Write up the single case reports Review each case analysis with the firms Write up the cross-case analysis
(8) Contrasting with theory	Consider alongside similar and contrasting literature	NA

Source: the author

The sections below (4.3.1 to 4.3.4) describe the following in more detail: how the population was framed; the procedure to select the cases; and the way in which data was collected, organized, evaluated and analysed.

4.3.1 Definition of the empirical evidence

As stated above, the research question searches for the balance between exploitation and exploration and the interaction of internal and external knowledge and learning. The question therefore implies that the selected firms from which the evidence was gathered should have demonstrated to some extent a learning intent, but more importantly they should have undertaken an explorative learning mechanism – i.e. a collaborative R&D project.

Given the difficulty of finding such organizations within a Colombian context, the researcher decided to go through a search process that was as objective and systematic as possible. Even though this option was time consuming, it was chosen to avoid bias in the selection process and to enhance the rigour of the research.

The section below explains how the population and sample framework were selected and defined with the aim of selecting the cases for the empirical study.

4.3.1.1 Source of the population framework

In order to have a more accurate and systematic case-selection process to meet the required conditions of this research, the population framework was bounded by two conditions. First, the firm's learning intent was defined based on the events that the selected firm had performed as collaborative R&D projects across its learning and technological trajectories. Second, for the sake of the analysis – i.e. for looking at the relation between exploitation and exploration – the specific project (or projects) had to have been completed within a technological setting defined as an emerging complex system –e.g. in biotechnology, nanotechnology or the semiconductor industry.

Defining firms that showed these two characteristics was through the identification of scientifically oriented research projects carried out in Colombia over the period 1990 to 2010. COLCIENCIAS has promoted scientific and technological development since its creation in the early 1960s, and one of its main supportive mechanisms has been the funding or co-funding of R&D projects, initially with universities and more recently with other types of organization such as research centres and firms. Knowing that COLCIENCIAS is institutionally recognized for the development of these types of project was the most reliable way to identify potential cases for the purpose of this research.⁵⁰

⁵⁰ In Colombia other governmental organizations are able to provide financial resources for technological purposes. However, these resources are for technical improvements rather than R&D. These organizations are SENA (National Learning Service: acronym is in Spanish) and the Ministry of Agriculture. Even though they have funded firms, they are not scientifically oriented, and therefore they were rather unlikely sources of funding for the types of project or the firms required for this research. For this reason the databases of projects belonged to these organizations were not consulted. There were two other possible databases: one belongs to the Chamber of Commerce and the other to DANE (National Institute of Statistics: acronym is in

Moreover, because COLCIENCAS is a governmental organization it has a duty to register all the research projects presented for grants.

Among the alternatives, biotechnology⁵¹ was selected as the complex technology from which the projects were chosen. To understand whether there was a transition from a mature single technology to an emerging complex technology, three industrial applications were identified. Due to the long agricultural tradition of the country, one set of selected projects had been undertaken for the development of plants using biotechnology (e.g. micro-grafting). Another industrial application for this technology was found in the food industry, in particular in the substitution of chemical synthesis for naturally occurring compounds.

Firms that meet these conditions in a country like Colombia are difficult to find, especially because there is no reliable database containing information about them; in addition, most of the databases that already exist tend to be financially rather than scientifically oriented in terms of information, and are categorized by economic sectors, none of which allows for the clear identification of a firm's technological focus.

COLCIENCIAS at least holds a repository of information where all R&D projects presented for funding by different organizations, including firms, are registered.⁵² Even though this information is collected through site visits made by public officials, it is not openly available. To get access to this information system, permission had to be obtained from COLCIENCIAS.⁵³ The system is called SIGP (Integrated Project

Spanish) – which also has run the National Innovation Survey – but these databases do not distinguish between firms once they have been grouped by industrial classification.

⁵¹ Among all the alternatives regarding the so-called complex technologies, COLCIENCIAS has systematically allocated resources since 1990 to promote technological developments in this field. In 1995 it created the Programme of Biotechnology to pursue and develop a political agenda to strengthen the scientific endeavours in biotechnology but also in industrial development. Ever since, approximately 16 centres have been installed, 7 of them being dedicated to biotechnology research. In 2011 a governmental plan (CONPES 3697) was approved to give more institutional instruments and resources to the promotion and development of biotechnology. As well as this centralized process, there are also several regional initiatives dedicated to developing the biotechnology-based industry. All these considerations were crucial to the decision to focus the analysis on this complex technology.

⁵² These grants are mainly given to universities and research centres, but firms have also participated by themselves or through these two types of organization.

⁵³ Access to the information system was formally requested through a letter initially sent to the director of the biotechnology programme. The intentions of the research and the purpose behind the

Management System: acronym is in Spanish) – and it contains information on all programmes run by the organization to promote science and technology. There is no record that this information had been used for research purposes in the past; however, it has been used for policy purposes and decision-making. Thus, from this information system the R&D projects related to biotechnology from 1990 to 2010 were taken.

The identification of projects undertaken in biotechnology required the examination of three programmes.⁵⁴ As a result of this scrutiny a database containing all the selected projects was constructed in EXCEL (for more details, see the project database). First, the programme in biotechnology (the information system), that had been running since 1990, was initially reviewed, and 518 projects were finally registered on the database. The Programme of Science and Technology in Agriculture was also revised. From this programme a total of 365 projects presented for grants to COLCIENCIAS were registered. Finally, the Programme of Industrial, Technological Development and Quality was also revised. From this programme the last group of projects, accounting for 230, were registered. In total 1113 projects from a period between 1990 and 2010 were identified as biotechnologically related.

To register the projects from which the potential cases for this thesis were selected, the research proposals (and in some cases the progress reports) were carefully read to ensure they were understood in terms of their scientific content, industrial application and the type of organizations involved. Not all the projects registered in the system had supporting documents: these projects were excluded from the database. Five types of biotechnological application were identified in the selected projects, these being defined as agro-bio, food processing, bio-health, bio-processing and others.

It was clear that the majority of the projects (81%) were undertaken within the three first biotechnological applications. Three types of organizations led these projects, with

use of the information on those projects presented for grants were explained. Access was only possible within COLCIENCIAS facilities.

⁵⁴ The National Programme of Biotechnology was constituted in 1995. COLCIENCIAS was the only organization that defined boundaries to as what was identified as biotechnology within the system. Despite these boundaries other projects were also found in other national programmes, such as the National Programme of Science in Agriculture and the National Programme of Technological and Industrial Development.

research centres at the forefront of this technological development, following by universities and firms (43 firms appear as project leaders among the 128 that have been linked to one of these projects). Nonetheless, among all the projects only those that had both received the grants and been completed at the time that the database was constructed (27%) were included for the development of the population framework. Table 4.3 describes the categorization of the selected projects. It should be acknowledged that just 11% of the selected projects were collaborative.

Table 4.3 Distribution of selected projects

Biotype	Number of projects	Percentage	Distribution of projects according to the leading organization		
			Research		
			Universities	centres	Firms
Agro-bio	151	50%	57	84	10
Food processing	47	15%	18	9	20
BioHealth	48	16%	19	25	4
Bio-processing	41	13%	21	13	7
Bioremediation	15	5%	12	3	0
Bioinformatics	2	1%	1	0	1
Total	304	100%	128	134	42

Source: author's table based on the project database.

4.3.1.2 Population frame

The selected population of firms was taken from the project database that had been constructed according to the criteria just explained: from the 1113 reported projects presented for funding to COLCIENCIAS during the period 1990 to 2010, only 304 were included. The database of the population framework was therefore organized using those firms engaged in the projects described in table 4.3.

The population included all the firms that had developed an R&D project funded by COLCIENCIAS between 1990 and 2010 in any of the three biotechnological applications, and they were either leading the project or participating as a third party. The selected population accounted for 30 firms in total (12 more firms were included in the population to acknowledge other industrial applications. The characteristics of the

selected population therefore provide another reason for the use of the case study as a research strategy⁵⁵.

The population made up of these firms was characterized by size (ranging from small to large firms), lifetime and industrial application, and they fell into three groups. Most of the selected firms were medium-sized with less than 20 years in the market; next came large firms with more than 30 years in the market. The third group of firms were categorized as small with less than 20 years in the market. The distinction of size, time in the market as well as the industrial applications, as has been empirically acknowledged, made a difference in terms of the knowledge integration and learning dynamics (see table 4.4).

Table 4.4 Distribution of the population of firms

Industrial applications	Total	Large			Medium			Small		
		More than 30 years	Between 20 and 30	Less than 20	More than 30 years	Between 20 and 30	Less than 20	More than 30 years	Between 20 and 30	Less than 20
Agriculture	9				2	1	4			2
Food processing	15	7		1		2	3			2
Health	5						1	2		2
Others	12	3			1	2	3		1	2
Total	41	10	0	1	3	5	11	2	1	8

Sources: author's table constructed from the population framework database.

The population of firms was sufficiently diverse to have enough firms for control purposes. As can be interpreted from table 4.3 the possibilities for literal replications as suggested by Yin (1984) did not look feasible. This was quite problematic for the research design as it would have been preferable to be able to compare at least two firms within the same industrial application and time context but of different size. (Further research could consider expanding the population to overcome this shortcoming in the empirical analysis.)

Even though this population of firms was selected because they had undertaken a biotechnology-related R&D project, it did not mean that they were biotechnology based. The firms included were not representative of the standard classification of the biotechnology-based firm. A number of firms made use of biological resources for their production systems. Others pursued biotechnological techniques for experimentation

⁵⁵ The project database was developed in an EXCEL file and it is available for validation if needed.

and quality purposes. In general, these firms used, or were looking forward to using, biotechnological techniques for any part of their production system for either their core or peripheral routines. This is more the case in the food-processing industry; other firms related to the health sector tend to use chemical procedures. In the situation of nursery seedlings being raised for agricultural purposes, the use of very traditional biotechnological techniques was more likely to be the case.

Moreover, the selected population of firms did not necessarily represent all the firms in Columbia within the selected industrial applications. In agriculture, for instance, firms producing bio-inputs and seed-related firms were identified. But more importantly, according to ICA (Colombian Institute of Agriculture: acronym is in Spanish),⁵⁶ 105 nursery seedling firms and 112 ingredient supplier firms were registered in 2008 across the whole country. These firms were not included in the population because there was no feasible way of finding out their learning intent in terms of whether they had taken part in R&D collaborative projects, a criterion which was a vital feature of this research.

4.3.1.3 Case selection process

Based on the theoretical discussion on how knowledge integration, learning dynamics and change in capabilities are shaped by organizational and environmental circumstances, it was considered that a careful selection of cases should enable such distinctions to be seen which, in turn, would enable a coherent empirical argument to be developed and contrasted with theory. Also, the procedure to define the population as just described was driven by the foregone intention to observe the possible link between exploitation and exploration as well as the learning dynamics in the events in which organizations sourced knowledge either internally or from the environment.

Hence, it was highly important to select firms that had the intention of making the transition from mature single technological settings, which is the case for agriculture and food processing, to complex emerging technological settings (implied by the use of

⁵⁶ This is a governmental organization that is part of the Ministry of Agriculture and is in charge of promoting and assisting policies in the agricultural sector.

biotechnological techniques). In order to make this transition the selected firms should have undertaken learning events that had made them integrate knowledge in a different manner from simply having, respectively, an agriculture engineer and a chemical engineer.

Consequently, to understand whether differences in industrial applications have an influence on the way in which knowledge integration and learning dynamics happen in organizations, it was anticipated that at least one firm from each of the agriculture, food processing and health industries would be needed. Compared to industries like bioremediation where biotechnology is already a core technology, these other three industries have developed from more mature technologies and engineering foundations. Although these other firms were of interest they did not fit with the transition defined for investigation (i.e. single mature technology moving to complex emerging technology). By focusing on these three industrial applications only, the sample framework considered from the population was reduced to 31 firms.

This investigation revealed that one of the selected firms was actually an equipment supplier for firms that either offered environmental services (bioremediation) or that used these devices to solve environmental problems in production. These two reasons were sufficient motives to remove this firm from the analysis.

Following Eisenhardt and Graebner's (2007) suggestion, a strategic process of selection to identify the cases from the defined population was determined. In order to avoid bias in the selection three other criteria were used to select the firms from the population (which was now down to 30 firms), these being: collaborative R&D experience; using only SMEs and stipulating a minimum and maximum age of the firms.

Collaborative R&D experience: With the aim of providing evidence on interactive-explorative types of event (see chapter 3), the selected firms should have undertaken collaborative R&D projects. These events should have been developed after the year 2000. From the theoretical discussion and analytical framework this type of event seems to be one of the more complex for the knowledge-integration process, because of the nature of the activity in terms of the tacit character of knowledge, possible

asymmetries between the parties involved and technological divergences with respect to the current production system and knowledge.

One of the aspects to be addressed was related to the way in which the firms were able to build up what it is called the 'absorptive capacity' defined as the ability to explore new technological areas with a scientific partner that in the case of Colombia could be either universities or research centres. This aspect was determined through the learning scheme defined as collaborative R&D projects. By using this criterion the number of potential cases to be included in the sample framework was 12 (out of the 30 firms). And so, only those firms that had taken part in an interactive R&D project funded by COLCIENCIAS were selected as part of the sample framework.

Small and medium-sized enterprises (SMEs): Dealing with SMEs for the purposes of understanding knowledge integration and learning means approaching a firm which traditionally will have been seen as being limited in resources and capabilities. Its conditions for change are constrained by its ability to expand its knowledge base, use alternative technological solutions and identify a market niche that makes it push forward to a new position and diversification strategy.

SME managers also prefer more certain and immediate returns over less certain and long-term returns (Lewin et al, 2011). In terms of the interplay between exploration and exploitation as also noted by Lewin et al, this type of firm favours exploitation as it finds it difficult to search for new routines while improving old ones (Nelson and Winter, 1982). As result, according to this theoretical approach, SMEs' long-term survival is normally at risk, assuming, as indicated by March (1991), that it depends on how the firm is able to balance knowledge for exploitation and exploration.

The claims normally attached to SMEs become highly important in cases where atypical firms of this kind might be found. Choosing a firm that has undergone an explorative learning process and survived would make an interesting case to look at in order to make contributions to the understanding of knowledge integration and learning in firms of this kind.

However, SMEs were also selected for other practical reasons related to how well data could be managed that had been obtained from the memory of the organization about its learning mechanisms. Normally, when large firms are studied for empirical purposes, instead of observing the firm as a whole, for practical purposes an area of specific interest is defined, limiting generalisations to the firm as a whole. But because the interest for this research is not just about the functional aspects but also how the whole organization fits with the conditions, SMEs are more suitable subjects for the complexity of the analysis required. By filtering the number of firms to SMEs only, the sample framework was reduced from 12 to 10 firms for the empirical evidence.

Age of the firm: Survival has been one of the aspects in the learning literature that links knowledge and learning to performance. Most of this literature claims that firms that are able to cope with the environment through learning efforts have better survival rates than those where capabilities are rather stable over long periods of time.

In his study about process development projects, Pisano (1990) suggested that age influences their nature and performance. He compared projects in biotechnology with chemical projects, assuming that differences were related to the technological distance between a firm's production system and technological implementation. However, when he compared knowledge integration and learning in these two types of projects he stated that unexpected results were related to the fact that some of firms from which evidence had been collected showed entrepreneurial structures, which had limited their learning capacity.

Another facet of the research was to look for links between the functional learning mechanisms (FLMs) and the meta-learning mechanisms (MLMs): a process and historical perspective are more likely to reveal evidence of the organizational changes in these aspects beyond single events or strategic contexts. Moreover, one of the theoretical arguments linking the learning trajectory with the absorptive capacity of the firm states that organizations build up their capabilities throughout different but interrelated learning capacities, which are also affected by the way they started.

By taking into account all the requirements of the research design the most suitable timeframe to have, as a window of observation, was between the 20 and 30 years in which firms had already achieved an established position in the market. Thus, the selected firms were expected to have set up between 1980 and 1990. By filtering the timeframe to this period the number of cases available was reduced to two firms.

These cases were clearly selected because of their potential to allow the observation of the long-term learning and technological trajectories of stabilized firms that happened to be pioneers in their respective industries (within the Colombian context). Based on theoretical arguments from the literature on dynamic capabilities, it was expected that these firms had been exposed to different levels of knowledge interaction through their life cycles and had experienced different learning dynamics. By having undertaken collaborative R&D projects with a research centre, these firms also showed evidence of some level of absorptive capacity. The fact that the two firms had undertaken projects to develop biotechnological techniques, despite being part of mature industries – i.e. food processing and plant production – by using a single knowledge base – i.e. a chemical engineer and an agricultural engineer, respectively – was itself a sign of their path-breaking intentions.

These clues indicated that these firms would be potentially useful cases in which to observe the types of dynamics needed to explain the phenomena under study. The cases are considered interesting for being atypical (as judged by their learning intents and survival rates) for this context. So, a complex form of knowledge exposition and technological learning dynamics were expected from the two cases. Although the evidence these firms provided could not be considered conclusive, it had the potential to raise aspects of how the KILS evolve in which theoretical and practical contributions could be found.

Nonetheless, as a result of the limited number of cases available, three methodological constraints should be acknowledged. **First**, it would have been preferable to have had for each of the industrial applications at least one extra case to strengthen the arguments and findings. As acknowledged by Yin (1984), literal replication makes an argument more compelling for theory building. **Second**, contrasting sizes of firms

would have been useful to show how large firms behave compared to SMEs under the same industrial conditions and lifetime, and also to understand whether faster growth in size, under the same survival rates, has something to do with learning dynamics or whether there are other complementary aspects to an organization. **Third**, empirical evidence from surviving SMEs in which explorative events were not undertaken would have been useful in order to make an accurate contrast between other features, not learning related, that might explain an organization's existence. The two cases considered for this thesis favour the claim that learning and exploration are needed but questions do remain without proper contrasting data.

Additionally, following this systematic selection process – which led to the situation of having just two cases – was highly risky for the research because there were no guarantees of accessibility either to the firms or (more importantly) to the information required. This is why the contact strategy, as will be described below, was an important part of the process. Even though the context could have offered more options in terms of industrial applications, size and lifetime, a single researcher trying to achieve a larger sample would have been completely overwhelmed because of the scope of this research.⁵⁷

The two selected cases showed some similarities, which made their analysis comparable. Some of the similarities were defined from the selection process that has just been described; other similarities arose during detailed study of the cases. Apart

⁵⁷ Given the circumstances previously described regarding the likelihood of having other types of replication, the criteria were revised to analyse alternative options. The only feasible option was to include those firms that had not received grants even though they had presented projects to COLCIENCIAS; however, this option was not considered from the outset because a condition of the research was to have a guarantee that the chosen firms had developed collaborative R&D learning schemes.

By maintaining the other criteria, three other potential firms were identified. Those firms were contacted to verify whether they had undertaken R&D collaborative projects in order to have them as an option as case studies. By selecting two of the firms, one of the methodological constraints could have been solved (i.e. literal replication would have been possible). The third potential firm would have provided additional empirical evidence (from the health industry). But because of uncertainty over accessibility and due to the limitations of time and resources, the research continued with the two initially selected cases only. Nonetheless, it is important to acknowledge the fact that more options for case studies were possible and had been considered. Further extensions of this research that might include these additional cases could lead to more conclusive arguments.

from the size and length of time in their respective industries, the two firms shared characteristics such as their positions in the value chain, definitions of their business models, overall organizational forms and strategic responses to the market. Additionally, both firms pursued engineering-based knowledge (their core knowledge being focused on either chemical or agricultural engineering). The characteristics of the cases are described in table 4.5.

Table 4.5 Main characteristics of the cases

Characteristics	Nursery seedling firm (NSF)	Ingredient supplier firm (ISF)
Size (by number of employees)	Medium-sized firm (2010): 77 employees	Medium-sized firm (2008): 250 employees
Years established	27 years in the market	23 years in the market
Position in the value chain	Specialized supplier; at the bottom of the value chain	Specialized supplier; at the bottom of the value chain
Business model	Provide technological solutions for commercial farmers of perennials fruits	Provide technological solutions for food processing firms
Overall organizational form	In between operating adhocracy and machine bureaucracy (Spender, 1996); division form (De Boer et al, 1999)	In between operating adhocracy and machine bureaucracy (Spender, 1996); division form (De Boer et al, 1999)
Strategic response to market	Diversification (10 commercial lines)	Diversification (10 commercial lines); double segmentation
Engineering-based knowledge	Agricultural engineering (core); chemical engineering (complementary)	Chemical and food engineering (core); microbiology (complementary)

Source: the author.

The selection of the cases was also meant to be quite focused and narrow due to the complexity of the phenomena under investigation that included a historical analysis disaggregated into a number of levels, going from the micro-components of learning to the scrutiny of the dynamics of the organization as a whole (see Chapter 3).

4.3.2 Data gathering process

The data required revealed not only a considerable amount of detail of the organizations' learning and technological development, but also many of their strategic decisions. Sources were not publicly available; to get the data it was necessary to gain the collaboration of the firms, which meant they had to be willing to participate in the study in the first place.

Two main characteristics describe the data needed for the study. First, because historical events were indispensable, one feature was the tacit character of the data embedded in the memory of the firms' staff. Second, the data was related to facts rather than perceptions or qualifications of events; therefore the data collected corresponded to descriptions of historical realities. However, these descriptions were part of the retrospective interpretative system of individuals that could not necessarily be considered value-free; another problem was that perception of the past can be biased by the cognitive conditions of individuals and to what extent they are able to accurately recall events.

These characteristics of the data motivated some methodological decisions. First, to ensure the firms' collaboration, the support of the governmental institution in charge of the science and technology policy was required. Second, given the great detail of the information needed, the names of the participant firms were not disclosed in the research and confidentiality agreements were signed to guarantee ethical use of the information. And third, where possible, data gathering involved triangulation techniques: for example, in situations when facts were documented, data was also collected from reports, interviews with different staff members, and from other sources of figures that might have enabled dates and facts to be cross-checked.

Despite the conditions under which the firms were included as case studies, accessibility to the information and guarantees with regards to the quality and reliability of the data were required for the defined timeframe. Three aspects of the data gathering process were distinguished: the operationalization; the socialization and accessibility; and the data collection.

4.3.2.1 Operationalizing the analytical framework

The analytical framework was used to guide the data gathering process. Both the type of data and the sequence in which it was collected were defined based on the concepts and proposed analytical links.

Based on the theoretical arguments, three types of data were required. The first included the identification of the operational routines in which the component knowledge was embedded. The second type of data related to the FLMs defined as the learning schemes. The third type of data involved organizational features associated with the MLMs and the organizational routines. All these three theoretical constructs form the bases of the data needed for the empirical evidence.

As discussed, the expectation was that the data should reveal the interaction between knowledge, learning and capabilities. But more importantly, the data was expected to show how this interaction changed and evolved over time. The operational routines, the learning schemes and the MLMs were then captured from the historical memory of the organization. As a result, by putting together changes in routines and learning-related events, the technological and learning trajectories could be sketched.

Although the learning schemes were the main aspect of the empirical and analytical arguments, the starting point was the operational routines. Following Levitt and March (1988) routines are defined for empirical purposes as the formal procedures (of production) through which the organizations operate. So, rather than asking for knowledge or capabilities, the decision to capture changes in the firms' technological trajectories was through the understanding of their procedures.

At this point it was fundamental to gain an understanding of the firms' production systems. For instance, in one of the firms three main routines were recognized, one of which corresponded to the identification of chemical and natural components for industrial applications. Once this routine was clearly identified, the description of the procedures, sequence and links with other routines as well as the use of equipment and techniques were used to capture the nature of the routine. These routines described the

sequence of the production system by covering the methods of production, techniques (soft technology) and equipment and machinery (hard technology). In other words, the state of knowledge of the production system (Bohn and Jaikumar, 1992) was identified.

Also, both firms were asked about how the production system worked in relation to each commercial line. A value-chain perspective was used to understand all the links and sequences from the supply to the demand side including the firms' approach to their markets. The same technique was used to record the data from other processes like those related to quality, research and product development. The purpose was to link all the routines to the commercial lines.

Once the main processes were identified, the evolution of the technological trajectory was traced from its inception using retrospective techniques. Questions were asked such as: 'when did this routine start to operate?'; 'how and why did it start?'; 'how did it evolve in terms of equipment, human resources, use of techniques and sequence?'

Moreover, due to the complexity involved within production systems, distinctions between core and peripheral technologies were made. Although the peripheral technologies were identified, the data collection in terms of state of knowledge and evolution focused on the core technological routines.

In summary, four aspects that described the operational routines for the purpose of the data collection were distinguished: (1) soft and hard technologies related to the production systems; (2) commercial lines; (3) procedures, sequences and operational links, and (4) core technological routines from peripheral technological routines.

However, as these technological changes were expected to be associated with the way they occurred, when changes were described retrospectively, the means by which those implementations had happened were also recorded. The identification of the evolution and change of the routines – i.e. the use of soft and hard technology – then led to the inquiry about the learning schemes as well.

As already explained, the learning schemes correspond to those mechanisms through which knowledge was mobilized and integrated across the learning process. The

definition of FLMs stated above as the means by which component knowledge is acquired with the intention of having both a direct and an indirect impact on the technology and the production system – i.e. on the state of knowledge – serves well for empirical purposes; in other words, the KILS are used to modify the component knowledge.

In some of the events the learning schemes were intrinsically close to the description of how certain aspects of the routines were introduced; in others it was less clear. First of all, in order to capture and focus on the learning schemes, an association exercise was conducted with the interviewees. For each situation, they were asked to describe the events – i.e. learning events – that had then led to changes. The association consisted of first making a list of some recognized events, for example, the acquisition of equipment, training, the hiring of skilled engineers, the contracting of consultants. Second, analogies were used when it was necessary to make the concept of the schemes easier to understand from the perspective of the changes in the production systems. Thus, prior explanation of what a learning event meant and the use of analogies and follow-up questions like ‘how did those learning events happen?’ were used to capture the learning schemes.

Learning events were important to record for the study if they either existed in the memory of staff members or were explicitly codified in the form of reports. Also, if the degree of impact of an event on the routines was considered relevant for the firm’s members, that event was included in the list. The description of each event contained explanations about the source of the knowledge required for the event, its length, and the methods needed to implement it, along with its scope in terms of expected implications for the routines. In the case of the implications, the interviewees were asked to recall whether the purpose of an event was to influence current routines in some way or to assess knowledge for potential routines or non-existent technologies for current routines; this distinction helped to clarify the nature of the event (i.e. to what extent it was explorative or exploitative).

Regarding organizational features, five aspects were explored: (1) data about decision-making processes; (2) attitudes towards uncertainty and risks; (3) the system of

incentives; (4) alternatives to growth; (5) organizational forms. The three first characteristics correspond to the MLMs, as explained above, while the last two relate to aspects of a firm's organizational design that are acknowledged to be relevant for that firm's learning dynamics. The main managers of both firms were questioned directly about these aspects, but they were also deduced when descriptions of the learning events were gathered.

Overall, the sequence for data collection just described went from the micro aspects of routines and learning to the macro-related features. The research protocol was designed to collect data starting with the identification, emergence and evolution of routines, and from then onwards to examine the links between routines and learning dynamics, and therefore to describe how knowledge integration is mediated by learning. The focus on routines and learning schemes helped to clarify and distinguish the different levels at which knowledge, capabilities and their respective changes are embedded within organizations. It was anticipated that understanding the micro aspects across time might provide some clues on how an organization actually moves forward within its market and technological setting. However, distinctions of this kind still need further specification because, by being centred on the analysis on behaviour and practice-based learning, they enable an organization to be studied via its processes.

4.3.2.2 Accessibility of data

As described above, the strategy to gain access to the firms was highly important due to the limited number of cases, and to this end, two strategies were pursued. First, the support of an organization of reference, in this case COLCIENCIAS, was asked. Second, a combination of communication methods was used, starting with a formal letter but then also using an informal phone call. The initial communication was directly with the main managers of both firms.

Once the organizations had been selected by using the institutional support of COLCIENCIAS, a formal letter was sent to each of the firms by post and email which aimed to introduce the research and its intentions. It also contained an explanation of how and why the firms had been selected for this purpose, an important part of which

was to provide a brief description of the selection process so to as highlight the position of the firms within their industries, and the particular relevance of their experiences for the research needs. Also, the researcher was introduced and an appointment with the main managers was requested at which there would be a presentation. The director of the Programme of Biotechnology at COLCIENCIAS signed this presentation letter.

After the letters had been sent they were followed up with telephone calls to confirm that the organizations had received the letter and to coordinate appointments with the general managers and key individuals of the firms. It took one month to negotiate with the firms to get the first meetings with them. These meetings aimed to introduce the project to the organizations and confirm their interest in the study. The conceptual and analytical aspects of the research were presented. Contrary to arguments about how to approach firms, the thoroughness of the concepts and analysis were found to have been conclusive in ensuring the acceptance by each of the firms to take part in the study.⁵⁸

Before the data gathering started, decisions were made over the conditions under which the information would be managed, and agreement was reached over which reports and relevant documents were to be made available, with whom the interviews were to be undertaken as well as the interview programme. A confidentiality agreement was also signed to assure the firms that their names would only appear in cases allowed by them, and that the information would only be used for research purposes.

4.3.2.3 Collecting the data: sources and process

The data on both firms was collected over three different periods. Key individuals (the main manager and those responsible for each area) were assigned to help with the data gathering process from each of the firms. SME 1 (the nursery seedling supplier)

⁵⁸ Both firms organized a meeting after the presentation to decide to whether to carry on with the study and to discuss the implications for them. The study was accepted after each organization had assessed the value of the research in terms of how it would contribute towards an understanding of their routines and learning dynamics.

appointed the directors of the three areas of the firm.⁵⁹ SME 2 (the ingredient-supplier firm) appointed the directors of the seven main areas of the firm.⁶⁰

During the first stage, defined as the 'recognition' stage, each of these persons gave an overview of the firm and their area in particular; the researcher (the author of this thesis) was also given a tour to enable him to see how each area actually operated. The aim of this stage, apart from giving a first-hand perception of the firm, was to make a list of the archival data available and figures for each area and to define the scope of the interview for each of the persons engaged in the firm.

Due to the complexity of the data in terms of its level of detail, its links with different levels of the organization and its historical perspective, multiple sources of information were required for triangulation. This first stage of data gathering helped the researcher understand whether it was going to be possible to follow the planned methods.

Clearly both firms had different ways of collecting and storing their previous experiences. Despite one of the firms having a greater quantity and diversity of documents, the other had adopted a much more systematic, continuous and rigorous approach. However, both firms had sufficient personnel who understood the trajectories and backgrounds of their firms to enable events to be traced from multiple angles. Indeed, the low level of mobility and the long-term trajectory of some of the key people in the firms as well as their knowledge of the firms' histories and other areas of the organizations allowed for different perspectives on past events. The main characteristics of each source are described in table 4.6.

⁵⁹ The first two were the programme managers, one in charge of the main fruits and the second in charge of the programme of avocados and the project of soil substratum (growing bags). The second appointed person was the director of the biotechnology laboratory.

⁶⁰ R&D manager, logistic and production manager, laboratory and quality control manager, quality system coordinator, marketing and sales manager, administrative and the human resources manager.

Table 4.6 Sources of information

Source	Description	
	NSF	ISF
Documents	The firm developed an annual review report that included all the events per programme and an overall description of the firm's strategic intentions. The documents were continuous and covered the whole lifetime of the firm, under more or less the same parameters.	The firm did not have a single document that aggregated all its events. The documents were discontinuous in time or did not cover all the firm's lifetime.
	The documents were annual reports written by the firm's main manager using information collected from the programme directors. These documents recorded all the actions undertaken by the firm and the technical problems faced in production.	The documents included reports, project proposals, annual management revisions, manuals, lists of events (training events, equipment acquisition, employees, participation in international trade fairs) and general management documents. The documents were written by the key individuals of the firm.
	26 annual reports (1984 to 2010) were reviewed. All documents were delivered in physical form.	14 types of documents were reviewed. Most were delivered in digital form including EXCEL and WORD files. Some documents were delivered in physical form.
Figures	<ul style="list-style-type: none"> Quality of the production system in terms of efficiency (1993–2010). (Seed planted- plants sold)/seed planted Sales in number of plants (1984–2010) History of employees (1984–2010) 	<ul style="list-style-type: none"> Sales in Colombian pesos (1987–2010) Clients for year of creation and commercial lines (1994–2011) Commercial lines according to the date of products' market opening (1998–2011) Production and productivity (2007–2011) History of employees (1987–2010) Training (1994–2011), travel and assistance with expenditure to attend trade fairs (2004–2011) Demands of product development categorized by commercial line (1994–2011)
Interviews	One-to-one semi-structured open-ended interviews. All the interviews were recorded with the permission of the firm and interviewees. 5 interviews conducted. On average each interview took 1.14 hours. Interviews were held with 3 directors (1 of them was interviewed twice) and the main manager.	One-to-one and group semi-structured open-ended interviews. All the interviews were recorded with the permission of the firm and interviewees. 18 one-to-one and 2 group interviews conducted. On average each interview took 1.04 hours. Interviews were held with the 9 key managers (some of them were interviewed twice), 2 sales assistants, the 2 main managers and, additionally, an external consultant who had known the firm since it started.

Source: the author.

The second stage of data gathering included a review of all the documents to plan the best way to handle the data. The ISF was more open and trusting than the second regarding its documents, which it allowed to be taken out of the premises and copied.

The NSF only permitted the researcher to see and make notes on its annual reports in its facilities. Before the interviews started an initial interview guide was prepared which contained an outline of all possible themes that needed to be covered.⁶¹

During this second stage, the first round of interviews were also conducted with key individuals of the first firm. As described above, an aim of the first part of the interviews was to understand the firms' routines and their evolution over time.

The third stage of data gathering entailed conducting the interviews, which started with a presentation of the first impressions by the firms of their views of the research. The researcher then presented what he had understood about the routines up to this point and requested feedback from the firm. Once clarification was provided about the routines, the second round of interviews were more about clarification of the learning schemes and how they related to the changes in routines that had been previously acknowledged. During this third stage of work, interviews were conducted with the managers of both firms. In the case of the ISF, both the current manager and his predecessor participated in the interview. These interviews were particularly related to organizational features, although information about the routines and learning schemes was also sought.

One important aspect of the interviews was the assurance of anonymity for the informants; none of the internal staff nor the main manager would be able to deduce who had said what about the firm apart from the researcher.

By having documents, figures and interviews as data sources, confirmation of the existence, consistency and dates of some of the events was possible, avoiding vague descriptions and lack of precision. By having group feedback after the data was collected, bias as well as misinterpretation of how the events were recalled was reduced. Moreover, collecting the data across different periods helped improve accuracy and completeness (Jick, 1979); before the second and third stages, a careful scan of the data

⁶¹ Although semi-structured interviews were intended, protocols for conducting them were prepared to ensure a consistent and thorough approach (using guidelines) towards all the topics.

was conducted to highlight what was possibly missing, thus reducing the risk of having gaps in the information.

4.3.3. Organization and evaluation of the data

Due to the amount of data collected from each of the cases related to the operational routines, the learning schemes and the organizational features, a systematic procedure for the organization of the data was followed. The data was organized using the following rationale: (1) to ensure that no data had been missed, all the collected information from all sources was organized according to the categories previously defined in the analytical framework (see Chapter 3) and (2) to allow its historical continuity to be observed and traced, all the data was then ordered chronologically.

The information from all types of archival documents collected from both firms was then extracted into a WORD file called 'collective document'. The categories assigned to the data ranged from general issues of the firm, through descriptions of the technologies which distinguished each specific aspect of the production system and its corresponding routines, to the identification of all learning events grouped into the categories of the learning schemes – e.g. technical training, hiring of engineers, equipment acquisition. Some of the learning events were easily grouped but others were firm-specific and had not necessarily been previously recognized in the literature.

All the interviews were recorded with prior authorization from both the organization and interviewees. The interviews were transcribed in Spanish. For the transcription a free software called 'F5' was used. Once all the transcriptions had been completed, this data was also included in the 'collective document' using the same logic. This document then served as the basis and aggregated source of all information for the elaboration of the cases.

Once the data on the learning events had been organized, it was coded in a database set up in EXCEL. The learning events were identified from the data and assigned categories according to the given descriptions. The coding included categories such as type of

learning scheme, the description of the learning event, year, the knowledge provider and source (i.e. passive, active or interactive), the orientation (explorative or exploitative), the capacity according to the combination of source and orientation, the area within the organization, the stage of the process, the commercial line, technical problems, the knowledge learning process (i.e. reflection, assimilation or implementation), scale, scope, type of action (i.e. proactive or reactive), motivation and technological orientation (i.e. core competence, market-opportunity driven or strategic focus). All possible learning events were thus chronologically registered in the database.

The quantitative data corresponding to sales, production, employees and so on was organized in another EXCEL file. This data was used in the analysis to enable greater precision and accuracy in the identification of the events. The descriptions from the interviews were compared and contrasted with the quantitative data. Moreover this type of data was used to distinguish between the transition periods of the firms' life cycles.

Once the databases were constructed, the categorization was checked for consistency and validity. This evaluation was undertaken in three different ways: first, by comparing and contrasting all similar learning events based on the categories; second, the EXCEL files were sent to the firms for them to check for any mistakes in the interpretation of the data in terms of the dates, areas or commercial lines; third, a check for redundancy was run (to see if any events had been repeated in any way).

In summary, all the collected data was organized in the collective document,⁶² the learning scheme database⁶³ and the EXCEL file of the figures. From these three documents the cases were elaborated. The process was the same for both cases.

⁶² This document was written in Spanish and is available for validation if needed.

⁶³ The learning schemes database was developed in an EXCEL file and it is available for validation if needed.

4.3.4. Data analysis method

The analysis followed two criteria. First, all relevant events were described year by year in order to have a process and chronological perspective. Second, by following the analytical framework each of the categories was distinguished and their links acknowledged.

Thus, in order to recognize and better understand the complexity of the firms' technological development from their inception, some analytical distinctions were made. The analysis was conducted first by separating the events in terms of their respective commercial and managerial experiences, and second by following the technological and learning dynamics. In other words, the operational routines and technological trajectory as well as the learning schemes and learning trajectories were identified, described, traced and matched with the firms' life cycles and the organizational features.

These categories represented the building blocks from which the patterns were sought. The periods and transitions were defined according to the taxonomy of the learning capacities (sources of knowledge versus knowledge orientation) in order to identify the learning and technological dynamics and thus allow comparisons between the capacities within cases and among cases.

The data was organized and analysed by a single researcher (the author of this thesis), and, to avoid misinterpretation from one case to the other that might have occurred because the details of each might get confused with the other in the mind of the researcher, each case was written up immediately after its corresponding data was organized. The intention behind this procedure was to assure some independence of mind of the single researcher and that might otherwise have been questionable, mainly because both cases were replicated from the same conceptual and analytical framework.

Following Eisenhardt's (1989b) suggestion, the data analysis started with the writing up of individual case histories. The chronological description of the histories kept very tightly to the proposed window of observation. The within-case analysis focused on

comparing each firm with itself at different moments in time (learning schemes, learning capacities and MLMs); as a result four transitions periods were identified throughout each firm's life cycle. Thus, all the learning capacities were extracted from the analysis of the learning events, allowing a close look at how each of the firms had approached a variety of sources of learning and exploitation and exploration processes. The within-case analysis also looked at how the interaction between the learning and the technological trajectories had occurred. Observing the firms' routines over a 20-year period, and learning from a micro perspective, a macro and overall understanding of each firm was obtained.

Next, the theory behind the research was compared and contrasted with the findings of each of the cases. Although a deductive logic was used, other aspects came out from the histories that required a revision of the theory to ensure a more accurate interpretation supported by literature. An inductive logic was then deployed. Moreover, to strengthen the interpretation of the data, the managers of both firms were requested to review the research documents for instances of possible misunderstandings and mistreatment of the data.

After these internal reviews by both firms, the cross-case analysis was conducted; this started with a search for similarities and difference in the way the learning capacities had been built up across time and the relations between them. The cross-case analysis focused on the conceptual and analytical constructs as well as on the discussion of the initial propositions from the analytical framework. The analysis offered a refinement and from it emerged new tentative propositions in relation to the link between knowledge integration, learning capacities and capabilities.

As a result of the exploratory analysis of the evidence in relation to the proposed literature on knowledge and learning, and with the focus being on process research, it is possible to argue that the purpose of building–expanding and generating theory was achieved. Nevertheless, all the theoretical arguments cannot be considered conclusive whatsoever due to the methodological constraints that have been pointed out in this chapter.

The overall analysis involved an iterative dynamic between deductive and inductive logic in which interpretations were constructed from the analysis of the data based on the analytical framework and later contrasted further with theory.

Chapters 5 and 6 cover the case-study reports that have resulted from the research strategy just described.

5 LEARNING AND TECHNOLOGICAL TRAJECTORY OF A NURSERY SEEDLING FIRM (NSF) WITHIN THE FRUIT INDUSTRY, 1983–2010

5.1 Introduction

This chapter describes how a nursery seedling firm (NSF)⁶⁴ built up its learning capacity between 1983 and 2010 (a process henceforth referred to as 'learning-capacity building'. The analysis explores the dynamic interaction between the sources from which knowledge was taken (i.e. passive, active and interactive) and the orientation of that knowledge (i.e. exploitative and explorative), outlining the firm's learning-capacity building and its learning trajectory. This interaction was observed through 'learning schemes', defined as the vehicles through which the firm's capabilities changed over time. So, the case provides evidence for the process of learning-capacity building and its relationship with the technological trajectory throughout the firm's knowledge-integration and learning system.

The NSF's economic activity consists of raising nursery seedlings, specializing in the fruit industry, positioning the firm at the bottom of the fruit value chain. It sells certified plants of perennial fruit trees to farmers with commercial orientation. The firm was a pioneer in the industry, which is made up of SMEs.

However, what a certified plant means within this market is still not clearly defined. As a result a fuzzy situation of price regulation and quality specification has been created. In other words, the firm has commercially produced its certified fruit-producing plants within a non-commercially controlled market. Although the firm has made some efforts over the years regarding this market distortion, it has not necessarily responded with aggressive market strategies. But at the same time the firm has grown steadily over the years. Hence, the chapter first describes the conditions within the NSF's market and industry, defining the firm's position and delimiting its context.

⁶⁴ The name of the firm has been replaced by the term 'the nursery seedling firm' (NSF).

The technology to propagate plants and produce them was already available when the NSF was first established in the early 1980s. Although the market is not especially dynamic and neither is there a high demand for knowledge and technological development, the firm has been able to continually introduce technologies developed elsewhere through time for which it has been recognized in Colombia as the technological leader in this field over the years.

The firm first introduced technology by growing plants in bags of soil to ensure certain soil conditions. Although this first-generation method of production is still used within the firm, newer generations of technology were soon learned which resulted in incremental changes related to both an understanding of the varieties and their behaviours, and the development of propagation techniques. The firm adopted grafting (second generation) and micro-grafting (third generation) and is currently moving towards the use of inurement techniques⁶⁵ through etiolation (fourth generation) as the next step in its technological development towards production efficiency and quality. So, the technological trajectory is outlined to frame the technological settings in which the learning trajectory was developed.

Alongside its technological strategy the NSF has been developing a market strategy based on diversification. Thus, technical efficiency and market diversification have mainly driven the NSF's strategic choices along its learning and technological trajectories.

The learning trajectory relates the learning schemes required and the way in which they are linked to the learning process – i.e. whether learning is by reflection, assimilation or implementation. The NSF used 17 types of learning scheme throughout 409 reported learning events from 1983 to 2010. Therefore, the case explores the association of these learning schemes with any of the stages of the learning process.

As expected these learning schemes also embodied the characteristics and composition of knowledge. The commonalities displayed among these learning events with regards

⁶⁵ Techniques to harden or acclimatize plants to their growing conditions.

to the interaction between exploitation and exploration and the sources of knowledge – i.e. passive, active and interactive – defined how the firm developed its learning capacities – i.e. capacities that were formative, adaptive, transformative, inventive, created, renewed. Hence, the analysis of the case also: describes the process by which the NSF’s learning-capacity building from 1983 to 2010 occurred; provides evidence of the transitions that took place throughout the six learning capacities; and more importantly, considers the extent of the interdependence of the learning capacities.

Lastly, the case seeks to understand the functional relationship between the learning-capacity building and the technological trajectory. Development of all the learning capacities exhibited a sequence that was part of the firm’s knowledge integration over time: starting from the initial establishment of routines, developing new capabilities and identifying problems and alternative solutions, while passing through the assessment of new technologies. The evidence shows that through this knowledge-integration sequence, the efficiency (interdependency along the sequence), coherence (rationale and direction, i.e. core competence, market opportunity driven, strategic focus and renewal) and flexibility of the technological trajectory throughout all learning capacities are explained.

All in all, the evidence provided from the case aims to illustrate how the association of learning events (learning schemes) with passive, active and interactive sources of knowledge, and the orientation of that knowledge have shaped the firm’s learning-capacity building. The evidence also demonstrates the extent to which a functional relationship between the learning with the firm’s technological trajectory has been developed. Furthermore, the analysis of the case aims to illustrate how the firm has oscillated between changes that were ‘path-dependent’ and ‘path-breaking’.

The case’s description follows the analytical framework already explained in chapter 3. Section 5.2 describes the characteristics of the firm’s production system and the market. Section 5.3 defines transitions across the firm’s technological trajectory. Section 5.4 focuses on the definition of the learning schemes, exploring the links with the learning process. Section 5.5 describes the process of capacity building and transitions in the

learning trajectory as well as the technological trajectory. Finally, section 5.6 summarizes the preliminary findings.

5.2 Evolution of the firm's market and industry position⁶⁶

This section describes the evolution of the NSF's position within its market and industry in order to give a picture of the context in which its technological and learning trajectories were developed. The section portrays the circumstances in which the NSF started and how it entered the industry, its position over time, the market strategies used by the firm and its growth process in terms of size (employees) and sales.

Before the firm was founded there were only one or two producers of nursery seedlings in the country, both under governmental control. Public bodies controlled and supplied all the seeds and plants for agricultural purposes under certain regulations; they determined the quantity and type of plants available in the market. The output from these government producers did not match the real needs of the market, neither in terms of volume nor quality. Fruit agro-industrial production at that time was characterized by a lack of certificated plants with assured technological settings which could guarantee standardized production in terms of physical characteristics of the fruit, healthiness and efficiency of production. The NSF started in the early 1980s in response to these poor and critical conditions.

The NSF had its origins in December 1982 when an experienced agronomist decided to join forces with a chemical engineer to start up a commercial nursery that would fulfil all the technical requirements to supply high quality plants for the agricultural industry. To begin with they formed a joint venture to explore the conditions of the market with an initial investment and the knowledge and experience of the owners. It was not until 1986 that the firm was formed and constituted as a Limited society Ltd.

⁶⁶ As the two SMEs were pioneers and leaders in their corresponding markets, their managers had a great level of understanding of their market and technological contexts. So, the sections in each of the case reports related to the market were constructed based on information collected from the managers and key members of the SMEs.

The production of the NSF within the supply chain in the fruit industry sits at the bottom of the downstream activities but even so it has a very important technological role for the whole value added across all the stages of the fruit value chain system. The product is defined as 'certificated propagated plants of perennial fruits' and the market is oriented towards those farmers whose interests lie in industrial production for large-scale commercial purposes.

Over the last 25 years the firm has been considered a pioneer in the development of propagated plants in a market comprising 123 other SMEs that currently exist in Columbia and that are involved in this activity.

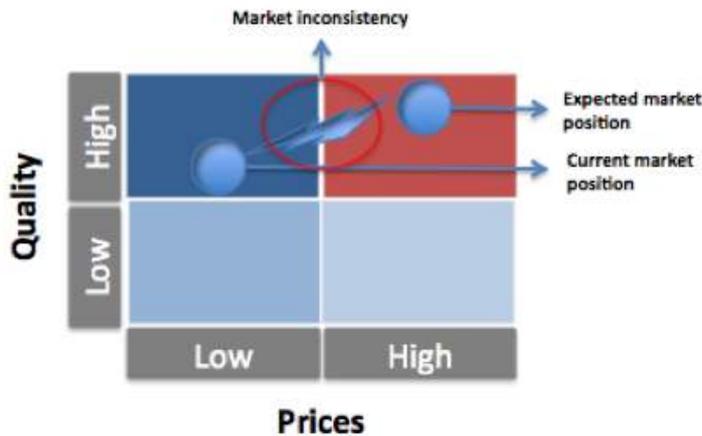
A public organization, ICA (Colombian Agricultural Institute: acronym is in Spanish)⁶⁷, is in charge of exerting control over the market; nevertheless the commercial regulations for this type of product have never been sufficiently clear regarding what can be defined as a certificated plant.

Therefore, the learning efforts made by the firm to increase the technological quality of its plants have not been fully recognized by the market in terms of value. As a result the commercialization process has been difficult. This specific situation has created incentives for this firm to develop a new understanding not only of fruit production but also of the concept of the market in an attempt to position itself within a specific category in the market.

As a result, during the commercial and production process, the firm has faced a market distortion over the years. This has been one of the main problems that the firm has encountered: it has produced high quality plants compared to its local competitors but the market price has been lower than it should have been because of a lack of understanding of the technology by its customers, and poor commercial regulation and controls (see Figure 5.1).

⁶⁷ The Colombian Agricultural Institute is a national public entity with the purpose of designing and executing strategies to prevent phytosanitary problems. It also undertakes applied research according to the needs of the agricultural sector in Columbia. Source: <http://www.ica.gov.co>. 09/10/2012

Figure 5.1 Expected market position vs current market position



Source: Based on data given by the NSF

Rather than following an aggressive market-expansion strategy to overcome this distortion in the market, and as a way of getting its product recognized by farmers, the NSF has adopted a market-reference system characterized by three types of mechanism.

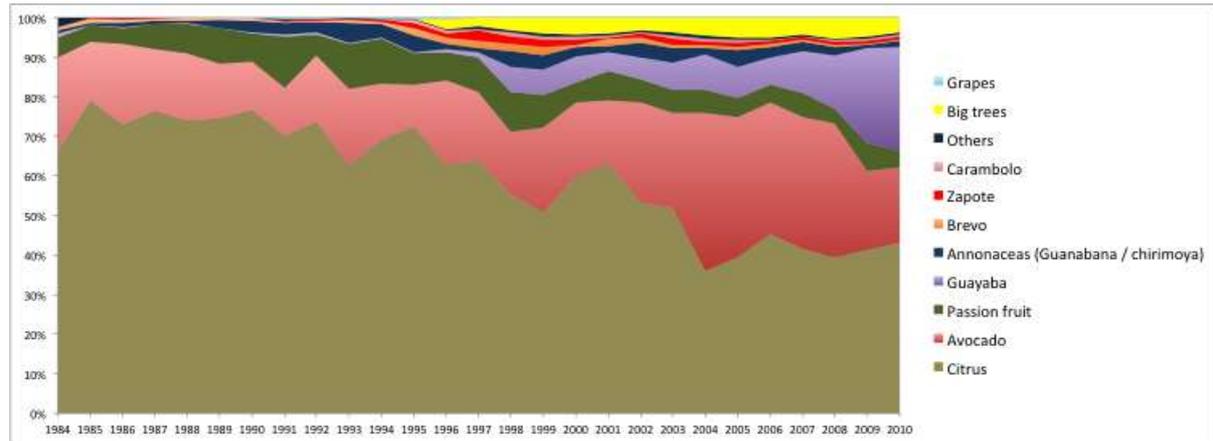
Firstly, public bodies and key individuals within them have been identified to endorse the quality of the plants. Secondly, farmers who have experienced improvements in their production by buying these plants have been asked to pass on this information to other farmers. But the main and the third market impulse, which has included commercial recognition, has been provided by one of the NSF's owners who is also a well-known technical specialist in the country, and who since the 1950s has given advice to the Columbian fruit production system and still remains influential in the industry.

Simultaneously the firm has followed a diversification strategy over the years. Despite the dominance of citrus fruit within fruit-agricultural production in Columbia, the NSF has looked to fulfil the market gap by offering different breeds and varieties of other fruit species.

This diversification strategy has been pursued progressively. Thus, other species such as avocado, passion fruit, guava and exotic fruit such as guanabana, brevo and zapote have gradually been introduced into production by the firm, based on its initial

experience with production of citrus (see Figure 5.2). However, citrus fruit still accounted, on average, for 60% of the total sales over the period 1984 to 2010.

Figure 5. 2 Level of diversification



*There was no data for 1983

Source: Based on data given by the NSF

In 1996 the NSF started to use a laboratory to develop micro-grafting techniques, implementation of which has enabled the firm to move towards the exploration of another market niche, and it has become a supplier to other nurseries of certified seeds and buds for grafting, using its collection of fruit that it had developed over the years. This move could be seen as somewhat risky as the firm was selling its expertise to its competitors.

It seems then that to avoid this market distortion the NSF has developed two commercial strategies over time: (1) a reference-system approach to the market, and 2) diversification. These two strategies have enabled the NSF to increase sales of propagated plants by an average of 15% per year.

The NSF's life cycle has gone through four main periods as shown in Table 5.1. The first period covered the start-up of the firm (from now on called the 'initial conditions' stage) with an increase in sales of 65%; the second period started in 1987 when the firm was in the 'formation' stage with an increase of 23.6% up to 1991; then came a third extended stage of 'establishment' when the growth in sales stagnated until 2001. From 2002 the firm experienced a moderate market expansion with a pick-up in 2007, showing on average an increase of 3.11% up to 2010.

Table 5.1 The NSF's life cycle 1983–2010

Period	Stage	Index sales growth (base 100,1984)	Average growth per year	Size	Employees	
					From	To
1983 - 1986	Initial conditions	236	65%	Micro	7	8
1987 - 1991	Formation	1225	23.6%	Small	11	30
1992 - 2001	Establishment	1277	0.27%	Medium	52	52
2002 - 2010	Expansion	1488	3.11%	Medium	53	77

!

Source: Based on data given by the NSF

As previously described, the process of the firm's growth through time has been mainly demand-driven rather than through an aggressive market strategy. The lack of recognition of the value of the technology involved in developing the plants, which has limited the opportunity for rapid market expansion, is mirrored by the firm's cautious approach to employment growth and is in line with its risk-averse strategic approach.

Although production does not require an intense level of human resources, it needs quite specific technical training of staff to carry out the routines required for it. As shown in Table 5.1, over its life cycle in terms of personnel, the firm has moved from being micro to small and lately has become medium sized. Given the evidence of the direct connection between production and demand, these transition periods from micro to small to medium sized match the periods of increases in sales.

During the period between 1983 and 1986 (initial conditions) while the firm explored the characteristics of the market, the level of production was limited by its fixed assets (land, equipment, personnel), and employment remained at a low level. During the next five years (formation), once the market expanded, the firm increased its resources (land and equipment) and almost quadrupled its personnel. A rapid rise in numbers was seen in 1992 as the firm became medium sized (establishment), but there was no further growth in employment until after 2004 (during the period of expansion) when the NSF had another major increase in employment, reaching the level of 77 people, 70% of whom were in production.

When the NSF first entered the market, there was a clear market opportunity in which two experienced engineers (an agricultural and a chemical engineer) took on the risk of offering to certify fruit plants to farmers. However it has not yet been fulfilled. The firm has maintained its position in the fruit industry, at the bottom of the value chain. Despite the challenge of getting the quality of its plants recognized within a non-regulated market, the firm's commercial strategies were not intensively aggressive; nevertheless, they were sufficient to keep up the pace of growth over the years, taking the firm towards an established position, and enabling expansion within its life cycle. So, from a commercial angle, the firm has played within a 'moderately dynamic market' but as will be explored in the next section the firm responded to this condition by taking the lead in the technological trajectory within the industry.

5.3. Technological trajectory 1983–2010

While the previous section focused on the NSF's growth in the market and its strategic position, this section describes its technological development strategy. The NSF devoted considerable effort into developing new techniques for propagation to the extent that it is also known as the pioneer and technological leader in Columbia. This was a deliberate strategy with the intention of providing a guarantee of the quality of the plants offered to the market in order to differentiate itself from its increasing and non-regulated competition. This section traces the evolution of the NSF's production system over the period 1983–2010, showing how the technological trajectory has developed to enable the firm to exploit opportunities in the market.

5.3.1 Core Technology

The operational routines in the NSF have been installed to produce certified propagated plants of perennial fruits. This means that the firm has the knowledge and skills to identify the appropriate varieties, propagate them under certain environmental conditions, and replicate their genetic characteristics so to as guarantee to farmers a specific level of efficiency of production, plant resistance and fruit quality.

5.3.1.1 Plant propagation technologies

Here, 'knowledge' refers to propagation technologies used to multiply plants of the same breed for commercial agricultural purposes in order to transfer their genetic characteristics to new plants. Currently a wide variety of techniques are available to suit a grower's requirements. However, the applicability of these techniques can vary from species to species, depending on a plant's characteristics and behaviour.

Although the complexity of the knowledge and the learning process required to accomplish a specific propagation technique may be greater than for another technique this does not imply that one technique is better than another because each might serve a different purpose. Each propagation technique is appropriate for each fruit with regards to the resistance of the plant to harsh environmental conditions and to diseases (e.g. to fungi), its degree of variability and the level of economic efficiency as measured in terms of scale of production.

Four generations of technological development can be distinguished in the trajectory of the firm for the production of propagated plants. The first generation for propagation technology (defined as plant production in bags by means of substratum⁶⁸) was established when the firm started to produce citrus fruit seedlings in 1982; this was also used later on for other fruit. The second generation, plant production by grafting, was introduced in 1986 initially on citrus fruit and mango and extended over the years to other fruit species. The third generation, plant production by micro-grafting, was implemented in 1996 when the services of a laboratory were hired to explore and introduce this technique to ensure that the mother plants were clear of potential viruses. The fourth generation was introduced in 2004 and is still being developed. It aims to use inurement techniques through etiolation; this alternative technique is being explored for those fruits that show a high level of genetic variability, e.g. avocado.

The development of each of these generations has required the firm to add new capabilities and routines to its production system and to solve the different technical problems that have appeared once production was increased.

⁶⁸ Substratum is the material in which the plants germinate and grow.

The analysis of the technological trajectory focuses on seven species out of the ten already mentioned in Figure 5.2 (see Figure 5.3). Yellow shading shows how the production in bags was the dominant technology during the first four years of production. Later on, in 1986, this condition started to change for the main fruit types when the grafting technique was established in citrus, mango, annonaceae and avocado, and by 2000 this technology was also implemented in guava and sapodilla (orange shading in the figure).

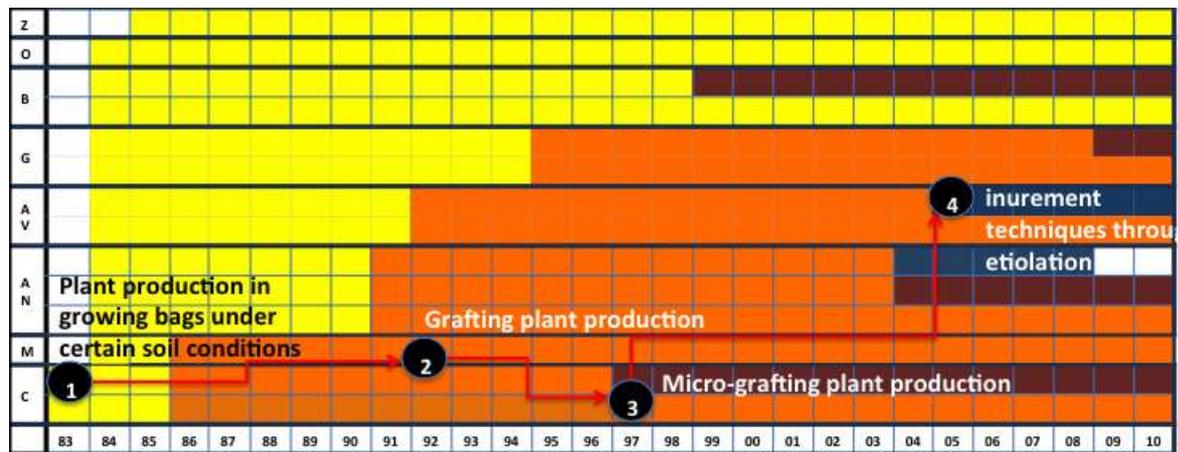
In 1996 the laboratory started work that enabled the introduction of micro-grafting technology that was initially applied to the production of citrus and later on to brevo, annonaceae and guava.

Finally, in order to reduce the degree of variability present in avocado, clone propagation technology was explored although without much success at the time of data gathering. This technology was also explored in guanabana, but no case has been made to adopt this process either technically or economically; grafting and micro-grafting techniques were and still are the predominant technologies for this fruit.

These two last technologies for production, in fact, have been used to improve the conditions and characteristics of the varieties by cleaning mother trees⁶⁹ so they would produce better quality buds and seeds for propagation purposes, rather than being used within the core production system to deliver the final product. Even if the firm were able to shift most of its production to the laboratory, the latter remains mainly as a supporting facility for quality analysis and research purposes.

⁶⁹ These technologies are used to take away all possible trace of virus that any plant could carry within its genetic characteristics. By cleaning the mother trees it is less probable to transfer virus to the propagated plants.

Figure 5.3 Chart of the NSF's technological trajectory by fruit 1983–2010



- C=citrus; M=mango; AN=annonaceae; AV=avocado; G=Guava; B=Brevo; O=others; Z=Zapodilla;
- The bars in blank refer to periods in which the related technology did not have any implication for the specific fruit

Source: Based on data given by the NSF

The NSF, as acknowledged by the main manager, has led the technological progress of this activity:

Since the beginning the NSF has pioneered the technological development of the seedling nursery production in Columbia, and across its trajectory it has drawn the technological path for others in this activity...

Main Manager, 2011.

5.3.1.2 Selection and collection of varieties

Apart from the ‘plant propagation technologies’, the NSF’s core technologies also consist of the ‘selection and collection of varieties’. This activity is normally done by external organizations, either public or private. However, according to the main manager these organizations have not carefully screened and developed varieties with the right (genetic) attributes to be distributed for propagation. As a result, all this work has been done mainly by the NSF, through the creation of its own collection based on previous knowledge and by trial and error according to the behaviour of the plants in the field. The NSF started with certain rootstocks that the owner thought were the best; however, over time some of them have been abandoned.

The information regarding appropriate rootstocks and varieties has been collected over the years in different regions through analysing a variety of combinations and behaviours. At this moment it can be said that the NSF is reasonably confident which rootstock and variety behaves better than others in each region.

However, this is an on-going and never-ending process, especially because the NSF has chosen a diversification strategy that implies discoveries of new breeds which may have different characteristics; this approach means the knowledge about the plants has to be constantly updated. But the process of identifying, characterizing and valuing the appropriate multiplication technique for a new variety is highly costly for an individual firm. According to the main manager and engineers, research centres or universities should at least do the first two activities (i.e. identifying and characterizing plants) with a germplasm⁷⁰ bank. A further barrier to this research is that often many of the technological developments regarding this experimental process are discontinuous and isolated.

From the chart in Figure 5.3, four transition periods can be distinguished delimited by each technological generation being explored and introduced into the firm's production system. The movement from one generation to another has been related to the features of each of the fruit species. During all this work, the firm's aim was to deliver better quality plants as well to as improve efficiency during the vegetative cycle in terms of death rates. In order to fulfil these two requirements additional technological efforts were required which were oriented towards having healthier plants and to guaranteeing the characteristics of the varieties. The rationale behind these efforts has been related to the fulfilment of the technical requirements and to solving the problems that appeared once production of the varieties started to increase.

⁷⁰ Germplasm is living tissue from which new plants can be grown. It can be a seed or another plant part – a leaf, a piece of stem, pollen or even just a few cells that can be turned into a whole plant. Germplasm contains the information for a species' genetic make-up, a valuable natural resource of plant diversity.

Source:

www.seedquest.com/keyword/seedbiotechnologies/primers/germplasmresources/introduction.htm.

10/10/2012

5.3.2 Peripheral technologies

The whole group of propagation technologies and selection and collection of varieties represent the core technological trajectory. However, in addition there is a peripheral trajectory that indicates other technologies associated with problems also related to the quality and efficiency of production. Three of these peripheral technologies are the use of substratum, the irrigation system and the technique of forecasting a production plan.

The substratum contains the nutrients and water needed to maintain the plant in the first stages of the vegetative cycle. A good substratum ensures the health and strength of the plant. The aim of the NSF has been to develop a standard substratum that can be used for all the fruit species. Although the substratum is one of the main components of the propagation process less formal attention has been paid to achieving this aim.

Over all these years the firm has struggled to find a substratum that allows a good level of efficiency. According to the main manager and engineers one of the factors that has influenced the death rates of plants is the use of inappropriate substratum:

It was not until 2008 when we came to fully understand that the efficiency of the production process is influenced in 50% [of cases] by the genetic quality but the other 50 % by the quality of the substratum...

Main engineer, 2011.

The irrigation system is another peripheral technology that a nursery faces over its trajectory. Adequate irrigation means having appropriate humidity levels to guarantee the absorption of the nutrients but at the same time reduce the risk of infections or pathogens. Up to now, progress in this respect has been poor and inefficient especially because it requires a high level of investment. The irrigation system the engineers and main manager would like to introduce is 'drip irrigation', which consists of having a hosepipe along the field from which water is regulated by drops being delivered to each tree.

Finally, the firm has faced a management-oriented problem regarding the technique of forecasting a production plan. Because the firm has a product with a biological cycle the production forecast needs to be as precise as possible to avoid production exceeding market needs, which would result in losses. Some plants need to be sold before they reach a size, which the market will not accept. Others can be transplanted to flowerpots, but this represents an extra cost for the nursery.

Over the first ten years the forecast had been done intuitively. In 1996 the firm implemented a strategy of offering plants in flowerpots, which since then has represented an average of 4% of total sales. After 2004 the firm started to forecast production based on the use of monthly averages by using figures from previous years. Although the accuracy of the prediction of production improved, the method did not allow the firm to identify trends. In 2008 two techniques, the 'simple moving average' and the 'exponential average double', were implemented.

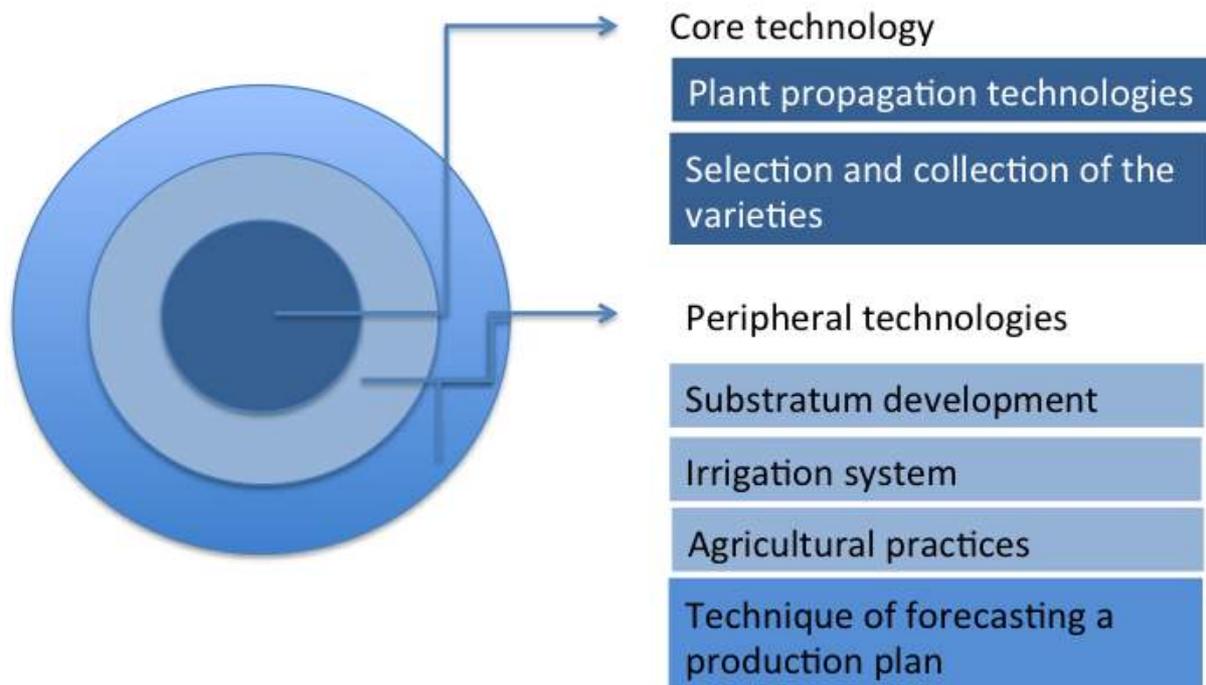
By changing its production forecast techniques, the firm has been solving its forecast problem and it has been able to establish more accurately the estimated programme for the following year's production. This improvement has been observed by comparing the forecast curve with the sales curve: the closer these two curves get to each other the better the efficiency of production.

Thus, the complexity of the production process goes beyond the core technological development, as has been acknowledged above. Even though propagation is the main focus of the technological development to change the genetic characteristics of the plants, an understanding of the peripheral technologies also has to be developed in order to achieve a certain level of efficiency within this activity. In the case of the NSF the so-called peripheral technologies have also played an important role in the firm's progress.

As already acknowledged all these technologies coexist within the production system due to differences in the technological requirements demanded by each of the specific fruit species. Therefore the firm has accumulated through experience the capability to develop each of the routines as part of its production system; these routines therefore

embody knowledge (technical skills), facilities and equipment acquired over the years (See figure 5.4).

Figure 5.4 Core and peripheral technologies



Source: Based on data given by the NSF

In a way the technically driven environment created within the firm has enabled the evolution of technology in the NSF. The manager and engineers have followed a problem-solving management approach that has allowed them to constantly identify inefficiencies within the production system and look for alternatives and solutions. All the technologies have been adopted in response to technical requirements that have emerged from production and market expansion.

However, even though these developments have improved the quality of the plants delivered to the market, all these efforts have also involved some risks that have limited the rate of change in the firm's technological trajectory. These risks are summarized in two main features: market recognition of the technological settings; and the level of technological opportunities. These two risks could be considered as characteristics of the business environment, which were not under the firm's domain but which shaped the conditions of its technological progress.

The first risk is related to how the incentives of the market create the conditions for users (customers) to recognize the technological value embodied in the range of products. In the NSF's case, although the market has slowly identified the differences between plants being due to differences in the application of technology to their breeding, this has not been happening as fast as the firm would have liked.

The second type of risk is related to the technical, engineering and scientific knowledge available locally. According to managers and engineers the level of technological opportunities⁷¹ is perceived as low given the discontinuities in, and dispersion of, local knowledge, and the lack of interest that technological suppliers (such as technological centres, consultants, specialised equipment providers) have in the development of fruit propagation methods. This situation has made the process of searching for appropriate technology from external sources more time-consuming and haphazard, especially because of the type and amount of resources made available by the NSF.

This section has shown how the firm has improved its techniques by building upon its previous technical knowledge, experience and requirements. It has also shown the technological breakthroughs that were generated over time through the need to solve problems faced in production. The evidence shows that the firm has fluctuated between 'path-dependent' changes that continually enhanced its core capabilities, and has started to move towards making 'path-breaking' changes by developing new capabilities to address new technologies. Hence, the section has described the complexities of the technological trajectory along four technological generations and across eight fruits. Moreover, the analysis recognizes the risks involved along the technological trajectory that have to some extent restricted the pace of the firm's technological progress.

⁷¹ The concept of technological opportunities was explained to the interviewees as the knowledge they have access to for their technical requirements when it is needed to either solve problems or undertake research to make progress in their current technological settings.

The next two sections explore the association between the learning schemes and the learning process and the course that the learning trajectory followed along the technological trajectory.

5.4 Technological learning schemes and the learning process

The analysis focuses on two aspects of learning. The first relates to the learning schemes used to mobilise new component knowledge into the firm. These learning schemes, which are observable events, are considered the vehicles through which the action of learning occurs. So, this section will identify the learning schemes that the NSF has used to move along the technological trajectory throughout a series of events.

The second aspect is related to what has been defined in the literature as the 'learning process'. This three-step process includes reflection, assimilation and implementation, and defines the scope that a certain learning scheme has for the KILS. It is expected that each learning scheme is associated with a certain stage of the learning process, creating a dependent relationship that defines each scheme's influence along the technological trajectory. So, this section aims to explore the link between the learning schemes and the learning process throughout the development of the NSF's technological trajectory.

Moreover, according to the evidence provided it could be interpreted that three features have driven the KILS. The first refers to the search for market recognition and access to knowledge. Although it would have been quite strategic for the NSF to have understood which learning scheme would have best suited the implementation of a certain technique or method, accessibility to the required information and the type of choices they made were limited by contingencies and their experience.

The second feature is related to the extent to which there were commonalities in the knowledge base across commercial lines or fruit species; in other words, this feature was about finding out the extent of the knowledge base. As has been mentioned, one technological generation is not necessarily better than another, because the best technology to adopt depends rather on the characteristics of each fruit species; however,

the technological generations share the same technical principles. The manager and engineers in the NSF have historically adopted an approach which favours experimentation – i.e. they assessed first and decided later which route to take. Therefore, the diffusion of any particular technology, as part of the process of knowledge integration, has in most cases been time-consuming; before the decision to follow a particular course has been taken, it has been preceded by a period in which events are mainly oriented to reflect and assimilate the implications of this new knowledge for the operational routines.

The third feature is related to the perceived level of unpredictability that learning events have on the efficiency of the production system. Since the firm is dealing with living organisms rather than an inorganic artefact, reactions are less foreseeable: the product could follow uneven patterns of production despite the recognized scientific knowledge that has been applied to it. This feature became more critical as production was expanded.

These three features have shaped the choices that the managers of the NSF have taken to give shape to the KILS. And so, these features along with the risks described in the previous section might explain the way in which the firm's managers decided to undertake the learning schemes. Indeed, some of these explanations are related to the fact that the firm's managers based their decisions on a search for technical recognition, but external sources to seize new knowledge were normally chosen randomly with no clear strategic orientation.

The NSF went through 409 learning events associated with 17 types of learning scheme over its learning trajectory from 1986 to 2010 (see Table 5.2, in which the learning schemes are numbered 1–17; in the following discussion, they are considered in groups of related schemes, and each scheme is referred to by its number in the table.) As expected, these events are linked to certain stages of the learning process – i.e. reflection, assimilation and implementation. Thus, they embody the content, the sources and the orientation of any knowledge.

The first group of learning schemes are technical adjustments (1), operational practices (2) and managerial practices (3). These three learning schemes are related either to the assimilation or implementation of information and know-how.

The events related to technical adjustments (1) refer to all the technical knowledge aimed at modifying techniques and methods of production within a specific operational routine. Technical adjustments were, in most of the cases, applied to respond to a particular problem that had arisen during the production of the previous year. So, the majority of these events were reactive rather than proactive.

Many of these implementations were introduced directly into the production system based on the knowledge that field workers and engineers had obtained through experience. Therefore, these events tend to be passive and the knowledge is intended to be exploitative.

Although most of the technical adjustments were acknowledged in the annual performance report,⁷² there was no clear evidence that a formal protocol to perform this learning scheme was developed. Consequently, this scheme was carried out informally and structured project-based learning did not precede these improvements.

Operational practices (2) refer to those technological efforts made by the firm to define the protocols and characteristics of the production system. The events associated with this learning scheme intend to provide the registration and evaluation of methods of production to determine the efficiency of the system; they also aim to analyse the quality and characteristics of the product. In short, the knowledge assimilated through this scheme gave the information that allowed for correcting and adjusting what had failed within the production system.

Due to the characteristics of the product and the lack of management-related training, these learning events were developed by trial and error and were not standardized, particularly regarding their correlation with the costs of the production. Nonetheless,

⁷² An annual performance report has been produced by the manager since 1986, and describes the state of production.

over the years the registration and evaluation of quality and efficiency have been improved. The firm has normally used the knowledge, experience and skills embedded in their engineers to run these types of event, and the orientation of this learning scheme is therefore exploitative.

Management practices (3) refer to those technological efforts made by the firm to introduce information technology systems to manage, and improve the planning of, the use of resources and production. Marketing efforts and campaigns were also events associated with this type of learning scheme; these events embody knowledge that is intended to reduce the uncertainty of the production system. These practices are associated with assimilation within the learning process and have had the tendency to be systematic and routinized.

The second group of learning schemes comprises product development (4) and service development (5); events within them were mainly carried out to assimilate and implement know-how related to the characteristics of the firm's existing products to give more added value and benefits to the farmers or to enable moves towards another market niche. The events associated with these schemes supported the firm's diversification strategy.

Product development (4) in the context of this firm aims to increase the range of varieties and rootstocks. It consists of identifying the physical, organoleptic⁷³ and genetic characteristics of new species and analysing whether or not the species are suitable for local environments.

The NSF has identified some of the new varieties within its portfolio by using information from foreign companies, by looking at the literature and by randomly identifying varieties produced elsewhere – e.g. Ecuador, and African and Asian countries. Despite the experience that the firm has in collecting varieties, it has not developed a systematic method of identifying them.

⁷³ Properties experienced by the senses.

The NSF has developed its services (5) through its experience of building up all the skills that allow it to offer technical advice to farmers (who are its main customers) about their crops' growth. Furthermore, the firm has transferred some of its knowledge to other seedling nurseries on how they can also provide a commercial advisory service to their customers; through these services, the NSF has helped them to catch up with the technology.

The third group of learning schemes includes infrastructure improvements (6) and the acquisition of equipment for production (7) and for specialized laboratory requirements (8). Although the facilities and conditions under which fruiting plants are produced represent important aspects of the technological support, changes in the production system tend to be related more to techniques and methods of production. So, the NSF could be categorized as a non-capital intensive firm.

Infrastructure improvements (6) were driven by a problem-solving approach, generally justified by a kind of investment project. These types of improvement have been found in the market, and so local suppliers were used for this purpose.

The small amount of equipment (7) and the few changes in infrastructure (6) that were introduced did not generate significant modifications to the methods of production. Only the implementation of a biotechnology laboratory (8) to support the production system demanded different skills within the firm (e.g. a chemical engineer), and the routines required to perform these capabilities took time and additional research efforts to be established.

The fourth group of learning schemes includes hiring engineers (9) and obtaining technical assistance (10). Given the characteristics of its production the firm has required agronomists to support its operational routines. The firm has on average maintained two engineers to manage the propagation process of the whole range of fruit varieties (9); in many cases the engineers have been considered the key individuals in the firm's technological development. They have also played an important role to shape the conditions in which the KILS works regarding the development of capabilities and the diffusion of propagation techniques across fruit species.

In addition, a set of networks, mainly developed by the owner, has allowed the NSF to have access to external technical assistance (10). These external advisors were especially hired to help solve technical problems (assimilation) related to: the selection and identification of varieties; techniques to respond to phytosanitary conditions; propagation methods; methods for the validation of the production routines; and market strategies. In other cases they were hired for research purposes.

The fifth group includes learning schemes such as specialized formal training (11), technical training (12), technical missions (13), and support to attend conferences (14). The assimilation processes arising from these schemes were in specific cases the origin of some research-related events and of technical implementations in others. However, the NSF did not necessarily rely on external training, either formal or informal, 'for its understanding of its need for technological development.

Research-associated schemes comprise the last group. Three types of scheme were identified: technical experimentation (15), experimental research (16) and engineering research (17). The NSF used these schemes to reflect on how to integrate new technologies and to understand the best solutions for problems arising within the production system.

The NSF has traditionally produced some technical and scientific evidence to support its claims about the characteristics of its fruit plants in terms of their resistance to illness, their productivity and their fruit type; the firm has also used this evidence to improve its techniques and methods of production. Nevertheless, these research activities have been more engineering and technologically oriented rather than scientific.

Through technical experimentation (15) the NSF has identified alternative solutions to technical problems in its operational routines. So these events can be categorized as explorative and primarily passive.

Experimental (16) and engineering (17) research is easily identified within the firm because the events related to this learning scheme have employed more scientifically

based methods than all the other events. These experiments have been conducted mainly by the firm’s engineers, but also by external contractors – e.g. universities and public research centres – and through collaboration. Experimental research can be defined as understanding problems through scientific observation, and then being able to identify more accurate solutions to solve those problems. However, the research conducted by the NSF has not completely fulfilled this definition, as the firm has not always had a full understanding to as what constitutes scientific research. Therefore, to improve its research capability the firm has participated in collaborative research projects with regional research centres and universities – i.e. through interactive means. By taking part in these projects the firm expected to integrate scientific expertise from these external organizations into its own experience to solve engineering problems related to the most advanced propagation technologies.

Table 5.2 summarizes the similarities and differences across all of the learning schemes through which the NSF has reflected, assimilated and implemented knowledge (see column labelled ‘Learning process’). The distinctions between all the groups of learning scheme can also be seen in terms of the orientation of the associated knowledge (exploitative or explorative), the source of the knowledge (passive, active or interactive), the type of action implied (proactive or reactive), the implications of the knowledge to be integrated, and the degree of formalization of the related events engineering.

Table 5.2 Learning schemes and the learning process

Learning scheme	Stages of the learning process			Orientation	Source	Type of action	Implications	Degree of formalization
	R	A	I					
Technical adjustments (1)		*	*	Exploitative	Passive	Mainly reactive	Introducing methods of production	Non-structured / tend to be routinized / systematic
Operational practices (2)		*			Mainly passive / few interactive	Mainly proactive	Registration, evaluation and quality	Non-structured / non-standard routines / systematic
Managerial practices (3)		*	*		Mainly active / some interactive / few passive	Proactive / reactive	Management, control and planning	Project-based/ non-standard routines / systematic

Product development (4)	Varieties		*	*	Exploitative	Mainly passive / few active	Mainly proactive	Market diversification and expansion	Non-structured / non-standard routines / non-systematic
	Characteristics							Characterize rootstocks and varieties	Project-based / non-standard routines / systematic
Service development (5)				*		Passive	Reactive	Market diversification and expansion	Non-structured / non-standard routines / systematic
Infrastructure improvements (6)				*	Exploitative	Active	Proactive	Protection of the production	Project-based / non-standard routines / systematic
Equipment acquisitions (7)				*				Intend to improve efficiency and quality	Non-structured / non-standard routines / systematic
Specialized laboratory (8)				*				Quality and research purposes	Non-structured / non-standard routines / systematic
Hiring engineers / technicians (9)		*	*	*	Mainly exploitative	Active	Proactive	Introducing methods of production and maintaining standards	Non-structured / non-standard routines / systematic
Technical assistance (10)		*	*						Non-structured / non-standard routines / non-systematic
Specialized formal training (11)				*	Exploitative	Active	Proactive	Identifying and understanding alternative methods of production	Non-structured / non-standard routines / non-systematic
Technical training (12)				*					Interactive
Technical missions (13)				*		Mainly exploitative			
Assistance to attend conferences (14)		*	*		Explorative	Mainly passive / few active	Proactive	Understanding problems and methods of production	Non-structured / non-standard routines / systematic
Technical experimentation (15)		*							

Experimental research (16)	*		Mainly passive / some active / few interactive	Proactive	Identifying new techniques or ways to solve technical problems	Few project-based cases / non-standard routines / systematic
Engineering research (17)	*		Interactive	Proactive	Identifying new technologies and methods of production	Project-based / non-standard routines / non-systematic

Reflection "R"; Assimilation "A"; Implementation "I"

Source: Based on data given by the NSF

The association of a particular learning scheme with a certain stage of the learning process defines the significance of that event in terms of the firm's knowledge integration. But, it is the complementary effect of a variety of learning schemes throughout the learning process that has an effect on the efficiency of production. However, neither the association nor the complementarity was necessarily comprehensive for the firm. As a result, although the relationship between the learning schemes and the learning process from reflection to integration was effective in some of the reported events, in others it was weak. Nevertheless, the knowledge-integration and learning system seems to have been coherent over the technological trajectory, as will be discussed in the next section.

This section has described the variety of learning schemes used by the NSF over its technological development. In addition it has provided evidence that each learning scheme tends to be associated with a specific stage of the learning process. The next section will explore the extent to which the interaction of these learning schemes, through the learning events, has accelerated knowledge integration along the technological trajectory, resulting in a steady improvement in learning capacity over time.

5.5 Learning-capacity building and the technological trajectory 1983–2010

The association between the learning schemes and the learning process through a series of events over the NSF's technological trajectory also relates to the sources from which the knowledge was taken and the knowledge orientation within the firm (i.e.

whether the orientation was explorative or exploitative). This section emphasizes the connection between knowledge sources and orientations, describing the process in which the NSF built up its learning capacity from 1983 to 2010.

Learning capacity is defined as the ability to integrate knowledge from sources that are passive, active and interactive for either exploitation or exploration. So, six categories of learning capacity – i.e. formative, adaptive, transformative, inventive, created, and renewed and – are distinguished. These learning capacities are developed through the performance of the learning schemes; therefore each category has its own dynamic. However, the relevance of these categories is highlighted by the extent to which they are interdependent along the trajectory. Throughout the 409 reported events associated with the 17 learning schemes these categories and their interdependence are explored in terms of their functional relationship with the technological trajectory – i.e. through the efficiency, coherence and flexibility of the trajectory.

Formative learning capacity uses knowledge already embedded in the staff, and is based on their previous experience in conducting operational routines. The learning events linked to this capacity are developed by experienced engineers (e.g. agricultural engineers) and field workers (e.g. technicians in agricultural practices), and so are considered as passive. The formative-related events are intended to improve the quality of the plants and the efficiency of the production system, and hence are oriented towards exploitation. Learning schemes such as technical adjustments, operational practices, service development and product development in some cases are associated with this learning capacity.

The firm began to develop formative capacity from when it started up in 1983; this capacity coincided with creating the initial conditions and enhancement of capabilities of the production. The first technological generation, which consisted of the use of growing bags under soil of substratum, was established under this capacity. Furthermore, after 1986, in the early development of grafting technology, these schemes served as vehicles for the implementation of related routines. Ever since then the schemes associated with formative capacity have been intensively used through a range of events for the assimilation and implementation of know-how to establish the

operational routines over the technological trajectory. Additionally, the diversification strategy was pursued using knowledge that the main manager had on searching for and identifying new species and varieties (i.e. product development).

On the whole, formative capacity could be considered as the foundation of the learning trajectory, supporting the knowledge-integration system of whatever learning event happens as a part of any other learning capacity. Moreover, through the development of formative capacity the firm has obtained a better understanding of its operational routines.

Adaptive learning capacity was developed simultaneously with formative capacity. The prime example of this second capacity was the sourcing of knowledge on techniques and devices produced elsewhere through market mechanisms such as prices and contracts, so adaptive learning events are featured as active. This capacity is better suited to the development of new capabilities once a firm wants to assimilate new information and know-how under the same operational principles: thus, it is oriented towards exploitation. The events associated with this capacity have mainly taken the form of equipment acquisition, infrastructure improvement, technical and formal training, the hiring of technicians and the assistance of experts over the learning trajectory. The implementation of specialized software (i.e. through managerial practices) was also adaptive.

This learning capacity was initiated in 1986 by hiring a new engineer who had the aim of developing grafting technology capabilities once there was a need to produce plants with better characteristics in terms of resistance to disease and quality of the fruit, starting with the production of citrus fruit. Afterwards, adaptive learning events also played an important role in the diffusion of this technology, as well as the micro-grafting technology, across the fruit species.

As illustrated, by developing these first two learning capacities the NSF assimilated and integrated knowledge first from passive sources and then, from 1986, from active sources through a combination of different learning schemes. During this period (1983–1986) and the following one (1987-1991) of the firm's lifetime the routines for the

production in growing bags under soil of substratum were established and the capabilities for grafting technology were in the process of being developed. So, both learning capacities interacted as part of the knowledge-integration strategy in the establishment of operational routines and the development of new capabilities for these two technologies.

In 1992 the first explorative learning events took place, through which the NSF began to build up its **inventive learning capacity**. These events were initially conducted because of some failed technical adjustments, which led the firm to decide to identify more carefully alternative solutions to its technical problems. Some of those problems were related to the establishment of grafting routines and their diffusion from citrus to other fruit plants. So, the staff (engineers and fieldworkers) conducted these technical experiments so to as better understand these failures in production – i.e. these events were passive sources of knowledge. Although these reflective events were not clearly articulated within the structure of KILS, they became common practice and were continuously used. Moreover, once the firm had more experience in doing these experiments, it eventually began to systematically link them with many of its technical implementations – i.e. it was linking inventive capacity with formative capacity.

The relevance of these research activities became more obvious in the NSF when in 1995 it sought the assistance of a public research institute – ICA. This technical assistance of engineers from ICA was contracted to investigate the benefits of the use of a nutrient for plants in the germination process (the trials were done initially in guava).⁷⁴

Furthermore, during 1995 the firm started to consider implementing the micro-grafting technique, which it finally did in 1996 by contracting the services of a local laboratory (El Cultivar). By using the services of this laboratory, the NSF performed its first experimental research aimed at characterizing the rootstocks and varieties of its fruit species. With these two events **created learning capacity** was initially developed.

⁷⁴ According to the relevant regulation, when a new substance (either chemical or organic) is used the approval of ICA is required to avoid any harm to the agricultural system. Therefore the firm hired ICA to conduct the experiments mainly to assess the accuracy of the methodology. Source: Resolution 1023 de 1997 (<http://www.ica.gov.co/getdoc/a5c149c5-8ec8-4fed-9c22-62f31a68ae49/Fertilizantes-y-Bio-inumos-Agricolas.aspx>). 20/10/2012

Later, in 1999, the NSF established a laboratory of its own so to as have control over the speed at which its micro-grafting capabilities were developed and gradually applied across the whole range of species. Highly specialized laboratory equipment was acquired and a chemical engineer with laboratory experience was hired. Over the following years the firm continued contracting external research from local universities such as the University of Valle and Nacional (both public universities), governmental organizations like Corpoica⁷⁵ (Colombian Agricultural Research Corporation: acronym is in Spanish), from CIAT (International Centre for Tropical Agriculture: acronym is in Spanish) which is a private research centre, and Brokaw, which is a very similar company located in California.

Although this type of experimental research was not an intensive practice over the learning trajectory, these research contracts contributed to the identification of better solutions for the use of nutrients in the germination process, during which the highest death rates throughout the production system occurred. Moreover, this type of research was complementary to the comprehension of the micro-grafting technique (for some species), the characterization methods and later in the technological trajectory for the assessment of the clone propagation system.

Thereafter, the **renewed capacity** was developed. The implementation of the micro-grafting technologies demanded a greater research capability, and so from 2002 the NSF began also to collaborate with local universities and research centres to perform experimental and scientific research. During this year an agreement was signed with the University of Valle to complete some experiments, initially to look for new techniques to solve phytosanitary problems. With this agreement, the NSF opened a window to further collaborative research projects. From 2003 onwards the firm started to

⁷⁵ Corpoica is a decentralized public entity that provides services to the private sector. It is responsible for generating scientific knowledge and technological solutions through research, innovation, technology transfer and training of researchers, for the benefit of Colombian agriculture. Source: <http://www.corpoica.org.co>. 20/10/2012.

participate in a variety of other projects with other organizations such as Biotec Corporation,⁷⁶ CIAT, Corpoica and the Nacional University.

These projects were intended to assess new technologies and identify how to develop the capabilities to introduce them into operational routines as well to as improve research capabilities. In 2004 the clone propagation system was initially evaluated by using some of these explorative events. Other research areas such as plant health, micro-grafting techniques and the characterization of varieties were tracked down through interactive research. However, the scope of these projects was overestimated within the knowledge-integration and learning system of the firm, and in some cases no further thought was given on how to develop these new capabilities and even less attention was paid to the establishment of the routines: this has been a particular problem in the case of the clone propagation system.

All in all, from 1992 the NSF decided to pursue these explorative learning events, first by using its own knowledge and experience – i.e. through passive sources of learning – and later (from 1995) by adding contracted research from local organizations – i.e. through active sources. Finally (from 2002 onwards), the firm complemented its research experience by collaborating with local universities and research centres – i.e. using interactive sources.

From this point onwards, the KILS of the firm included events that were part of learning schemes that had passive, active and interactive sources, and which were oriented towards both exploitation and exploration.

Lastly, **transformative capacity** started to be developed within the NSF's learning trajectory. As part of the reference system approach to the market (commercial strategy used by the NSF) in 2003 the firm decided to interact with the National and Regional Fruit Councils over fruits such as citrus, mango and avocado to develop a campaign with

⁷⁶ Biotec Corporation is a public organization created in 1995 with the aim of promoting applied research in biotechnology for agricultural and industrial development. Source: <http://biotec.univalle.edu.co/indexnew12.htm>. 20/10/2012

the aim of promoting the protection of the fruit, in other words, to have controlled environments (citrus was the selected case⁷⁷).

In 2005 the NSF went into partnership with Corpoica on a visit to see the model of production of EMBRAPA⁷⁸ in Brazil after having met this corporation at an international congress on citrus fruit production. After this technical mission the NSF evaluated EMBRAPA's model and techniques against its own model in which protection of production was the main component. Subsequently technical implementations were carried out to assimilate lessons from the mission that ended up with modification of the firm's infrastructure and implementation of various techniques.

Consequently in 2006, the NSF continued its collaboration with Corpoica and participated in a project with them for which the firm provided some of its plants that had been produced in a protected environment so they could be compared with non-protected ones regarding cropping performance in the field. Finally, in 2009, an indexation test⁷⁹ was run by the same organization – these events are classed as managerial and operational practices. All these events were developed with the aim of going one step further in certifying the quality and standards of production.

By observing the evidence it can be recognized that the firm has moved across the full list of learning capacities throughout its learning trajectory. During its first years the firm started to learn through the use of schemes associated with 'formative capacity'; later on, in 1986, 'adaptive capacity' was introduced. Both capacities were intended to be exploitative and started to be developed simultaneously through a variety of learning schemes. After 1992 the firm began to use explorative learning schemes, and so developed its 'inventive capacity'; this was followed by 'created capacity' in 1995 and

⁷⁷ According to the NSF's experience with citrus fruit, varieties will perform better and avoid phytosanitary problems if their production is protected from nursery seedlings right through to plantations. Source: Main engineer, 2011.

⁷⁸ EMBRAPA it is the Brazilian Agricultural Research Corporation. Its mission is to provide feasible solutions for the sustainable development of Brazilian agribusiness through knowledge and technology generation and transfer. Source: <http://www.embrapa.br/english>. 24/10/2012

⁷⁹ This indexation system allows certification of the standards of production of a greenhouse and it registers the percentage of plants free of virus within the production (the NSF was found to be clean of viruses across its entire production). This procedure was done as an activity within the project entitled 'New technologies for the massive production of clean plants of the variety "Lima acid Tahiti"'. Source: NSF's Annual Research Report, 2011.

‘renewed capacity’ in 2002. Finally, in 2003, ‘transformative capacity’ was developed, completing the course of the learning trajectory.

As illustrated through the evidence, each learning capacity contributed to the knowledge-integration and learning system but not independently of each other. The learning events were interrelated in practice and the experience of one learning capacity complemented the other. However, as has been acknowledged, the learning trajectory was not necessarily a comprehensive process for the firm. Exploitative and explorative learning schemes from different sources – i.e. passive, active and interactive – once started, were deployed simultaneously. Therefore, the importance of the evidence relates to the complementary and iterative dynamics between the six learning capacities throughout the learning trajectory (Table 5.3).

Table 5.3 NSF’s learning-capacity building 1983–2010

Learning capacities	Learning trajectory			
Renewed capacity				Experimental research Engineering research
Created Capacity			Technical experimentation Specialized laboratory equipment acquisition Experimental research Hiring key specialist Technical assistance	Technical experimentation
				Specialized laboratory equipment acquisition
				Experimental research
				Technical assistance
				Assistance to attend conferences
Inventive capacity			Technical experimentation Experimental research	Technical experimentation
				Experimental research
Transformative capacity				Management system implementation Technical mission Operational practices
Adaptive capacity	Hiring key specialist		Hiring key specialist	Hiring key specialist
			Equipment acquisition	Equipment acquisition
			Technical assistance	Technical assistance
			Infrastructure improvement	Infrastructure improvement
			Assistance to attend conferences	Assistance to attend conferences
			Product development	Product development
				Specialized formal training

				Technical training
				Managerial practices
Formative capacity	Technical adjustments Product development		Technical adjustments	Technical adjustments
		Product development	Product development	Product development
		Operational practices	Operational practices	Operational practices
			Service development	
				Managerial practices
Firm's life cycle	Initial conditions: 1983 - 1986	Formation: 1987 - 1991	Establishment: 1992 - 2001	Expansion: 2002 - 2010

* The parts of the table marked in red represent the period in the firm's life cycle in which each learning capacity started to be developed and shaped the learning trajectory of the firm

Source: Based on data given by the NSF

The pattern that the learning trajectory follows throughout these learning capacities defines the firm's knowledge-integration and learning system. In the case of the NSF the formation of the system across time followed a learning sequence: (1) operational routines were established (a focus on formative capacity); (2) new capabilities were developed (a focus on adaptive-transformative capacities); (3) problems and alternative solutions were identified (a focus on inventive capacity); (4) those capabilities were then applied across different fruit plants or commercial lines (a focus on adaptive-formative capacities); (5) new problems were identified again within the production system (a focus on creative capacity); (6) once new technologies with research requirements were assessed (a focus on created-renewed capacities) the firm started to find ways to assimilate and integrate the required capabilities. As a result of this process the intensity of the learning events and diversity in the use of learning schemes increased over time – i.e. there was flexibility within the technological transformation – making it clearer how this sequence across the learning capacities became iterative rather than linear.

To put it differently, the learning-capacity building was developed through a functional relationship between the iterative sequences in which the knowledge-integration system was developed and the firm's technological trajectory outlined changes in capabilities and operational routines. This relationship exhibits two other features: first, the coherence of the learning trajectory regarding the rationale behind the development of technological capabilities and the direction of the technological strategy, i.e. core

competence, market opportunities, strategic focus and renewal; and second, the efficiency of the technological transformation which is described by the degree of interdependency along the sequences of the knowledge-integration strategy over time.

The first movement from production in growing bags under soil of substratum to the grafting technology illustrates these features. The grafting technology was adopted because at that time the NSF understood the need to guarantee certain characteristics of the varieties in terms of resistance of the plants to disease and quality of the fruits, which in contrast was not possible with the use of growing bags under soil of substratum. The efficiency of the knowledge integration was due to the interaction between the adaptive and the formative learning schemes; as shown above, the knowledge to develop this technology was already available elsewhere in engineering skills, so a person was hired to develop the capabilities, and in turn this was followed by technical adjustments to establish the routines. By implementing the grafting technology the firm's strategic choice focused on the enhancement of its core competences.

The transition from grafting to micro-grafting and then to the clone propagation system can be explained in a similar way. Micro-grafting was implemented because of the need to have clean varieties; clone propagation was required to reduce the level of variability between plants in the propagation process for some fruit species – e.g. avocado. For the assessment of both technologies the deployment of experimental and scientific research was required, and so to achieve efficiency of knowledge integration, the interaction between explorative – i.e. created and renewed capacities – and exploitative – i.e. adaptive and formative capacities – was needed. At the time of data collection, micro-grafting was in the process of being applied across fruit species and clone propagation was a technology still under evaluation.

During these transitions the firm's technological strategy, as well as remaining focused on core competences, was also directed towards the identification of a new market niche – i.e. the strategy was being driven by market opportunities and by technologies (see Table 5.4).

Table 5.4 KILS: Learning-capacity building and the technological trajectory 1983-2010

Learning capacities	KILS			
Renewed capacity				<p>Technology: inurement techniques through etiolation</p>
				<p>Knowledge integration</p> <p>Assessment of new technologies >></p>
				<p>Assess new technologies:</p> <ul style="list-style-type: none"> - Evaluate alternative techniques to eliminate diseases caused by different types of virus and assure health and genetic quality of the plants <p>Assess new technologies:</p> <ul style="list-style-type: none"> - Evaluate methodology for the clone propagation system in avocado - Evaluate methodology for the micro-grafting technique in brevo - Alternative solutions to assure the health and genetic quality of the plants

Created capacity				Technology: micro-grafting plant production	Supportive technology
				Knowledge integration	Identification of problems and alternative solutions > Assessment of new technologies>>>>
				Assess new technologies: - Characterize rootstocks and varieties of the fruit species - Evaluate methodology for the micro-grafting technique in citrus	Assess new technologies: - Evaluate methodology for the clone propagation system in avocado - Evaluate genetic properties of the fruits e.g. mango and guava - Characterize rootstocks and varieties of the fruit species - Specialized laboratory facilities
Identifying alternative solutions on: - Use of a nutrient for plants in the germination process	Identifying alternative solutions on: - Use of a nutrient for plants in the germination process				

	<ul style="list-style-type: none"> - Seeding method was defined - Infrastructure for seed supply was settled - Combination of organic material was worked out to enable the germination of the plant - Routines in another 5 fruit species were established 		<ul style="list-style-type: none"> - Use of fertilizers and nutrients - Use of substratum - Phytosanitary solutions for pattern development - Propagation methods - Grafting technique 	<ul style="list-style-type: none"> - Irrigation system - Services on diagnosis in phytopathology - Assistance in the seedling nurseries establishment of seedling nurseries - Grafting technique 	<ul style="list-style-type: none"> The indexation test was established The quality analysis were established
Direction	A focus on core competences	A focus on core competences	A focus on core competences Complementary direction on: Market opportunities Strategic focus		A focus on core competences Complementary direction on: Market opportunities Strategic focus
Firm's life cycle	Initial conditions: 1983-1986	Formation: 1987-1991	Establishment: 1992-2001		Expansion: 2002-2010

*The parts of the table marked in red represent the technology and knowledge integration process encounter by the NSF at each period in the firm's life cycle in relation to each learning capacity.

Source: Based on data given by the NSF

This section has described the process by which the NSF progressed through the learning capacities over its learning trajectory, providing evidence of the interdependency and functional relationship of the learning capacities with the firm's knowledge-integration strategy and the technological trajectory.

5.6 Summary

This chapter has presented evidence on the development of the NSF's learning-capacity building and its functional relationship with the technological trajectory. The learning schemes, defined as the vehicles in which learning occurs and the capabilities change over time, were used as the observed events. So, these learning schemes formed the basis for an analysis which had the aim of enabling an understanding of the extent to which there was an interdependence between sources of knowledge and their orientations along the learning and technological trajectories.

This historical approach reveals a wider picture of the co-evolution of learning (as measured by the learning capacities) and technological capabilities (as measured by the technological trajectory) in the context of a 'moderately dynamic market' with dispersed and erratic 'technological opportunities' within established engineering-oriented SMEs, like those in the fruit agricultural industry in Columbia.

The NSF was a pioneer in the market of certified fruit plants and a technological leader in the use of propagation technologies. Throughout 27 years in the industry, the firm pushed its market and technological development forward through 409 learning events across 17 learning schemes – e.g. technical implementations, product development, technical assistance, experimental research.

The evidence shows that these learning schemes exhibited a dependent relationship with certain stages of the learning process, defining the scope and outcome of a particular event for the knowledge-integration strategy along the technological trajectory. As has been illustrated, some learning schemes were associated with reflection, and were mainly about understanding problems and evaluating new technological developments but had no direct influence on capabilities and routines;

others were associated mostly with assimilation in that they allowed new capabilities to develop; and yet other schemes were associated with integration, causing a direct effect on the established routines. So, through this relationship the evidence offers a first hint of the complementarity between learning schemes across the stages of the learning process.

Nevertheless, as indicated by the evidence, both the risks and the features of the knowledge-integration system limited the choices with regards to the way in which the learning schemes were decided upon and conducted (level of investment, resources and time) to accelerate change along the technological trajectory. In addition, the use of many of these learning schemes was random and non-systematic, basically because the managers were more preoccupied with the current situation rather than because they had a comprehensive picture of the implications of a particular choice for the knowledge-integration system. These conditions seem to be more determinant for SMEs in defining the course of action of their learning and technological trajectories.

In other words, is unlikely that a particular learning event acting through a learning scheme has an impact on the technological trajectory independently; once this is understood firms might make rather more systematic and strategic decisions.

Consequently, the commonalities displayed among those learning schemes with regards to the interaction between exploitation and exploration and the sources of knowledge – i.e. passive, active and interactive – define the link between the schemes and the firm's learning capacities – i.e. those that are formative, adaptive, transformative, inventive, created, renewed. The formative capacity acted as the foundation of the learning trajectory, outlining the path-dependent changes of the technological trajectory; the inventive capacity also led to path-dependent changes in which technical experimentation helped solve problems that had arisen within existing capabilities and routines. In contrast, the adaptive and transformative capacities were developed to prepare the firm for the creation of productive opportunities. Also the created and renewed capacities were developed to start moving the knowledge of the firm towards the use of divergent technologies in the search for path-breaking changes.

Nonetheless, this oscillation between path-dependent and path-breaking changes was not linear along the trajectory. The evidence reveals a rather complementary and iterative dynamic between the six learning capacities throughout the learning and technological trajectories.

This dynamic is explained by the sequence that the knowledge-integration strategy exhibited over the technological trajectory. In the NSF this sequence began with the establishment of operational routines (a focus on formative capacity), moved to the development of new capabilities (a focus on adaptive-transformative capacities), was followed by the identification of problems and alternative solutions (a focus on inventive capacity) and the application of those capabilities across different fruit plants or commercial lines (a focus on adaptive-formative capacities), when new problems were identified again (a focus on creative capacity) within the production system. Once new technologies with research requirements were assessed (a focus on created-renewed capacities) the firm started to find ways to assimilate and integrate the required capabilities. As a result of this sequence the functional relationship between the learning-capacity building and the technological trajectory is explained.

The evidence suggests the importance of technical arguments – along with market signals – in making decisions (coherence in the effectiveness of the KILS), understanding the scope of the learning schemes regarding the learning process, but more importantly acknowledging the level of interdependency required along the sequence, i.e. the complementarity between the learning capacities, to complete the knowledge integration (efficiency). Some of the perceived failures in the use of certain learning schemes – e.g. experimental and scientific collaborative research projects – occurred because of the lack of acknowledgement of the gap between the learning and the technological trajectories. Nonetheless, the evidence also implies that these types of failure seem to have been addressed over time. Flexibility of the KILS in the case of the NSF was gaining once the firm achieve an established position, and so, the learning events were developed more intensively and the firm started to use a wide variety of learning scheme to bring new knowledge into the routines.

The learning and the technological trajectories occurred under steady organizational conditions. This firm has been influenced by different sources, has moved almost simultaneously from exploitation to exploration and vice versa and has gone down different paths along the technological trajectory. These conditions certainly give an indication of a dynamic learning environment within the organization. So, the evidence seems to indicate that organizational routines do not need to have dynamic changes hand in hand with movements of the learning and technological trajectories; the case reveals that the way in which organizational conditions (such as the organizational form, the decision making process and the MLMs) fit with the FLMs and operational routines is an important aspect to develop effective technological transformations along the KILS. In the case of the NSF a high level of staff empowerment and an inclusive decision-making process appeared to encourage a learning environment.

In summary, the evidence provided by the case reveals that although having learning capacity is important for a firm's knowledge-integration and learning system, what really matters is how a firm achieves simultaneous interaction among learning capacities; it can do this by creating an understanding of the functional relationship of the learning capacities with the technological trajectory through a consistent technical and market rationale and by ensuring effective interdependence between the capacities along the knowledge-integration sequence.

Nevertheless, the findings of the case study are limited to a market defined as 'moderately dynamic' with dispersed and erratic 'technological opportunities', and firms categorized as established SMEs that are engineering-based and in which 'organizational routines' are featured by a matrix structure comprising high levels of empowerment and an inclusive decision-making process based on consensus.

The current case combined with that in Chapter 6 present the empirical evidence that provides the basis for cross-case analysis.

6 LEARNING AND TECHNOLOGICAL TRAJECTORY OF AN INGREDIENT SUPPLIER FIRM (ISF) WITHIN THE FOOD INDUSTRY 1987-2010

6.1 Introduction

This chapter presents the evidence from the second case for the analysis of the dynamic interaction between sources of knowledge – i.e. passive, active and interactive – and their orientation – i.e. exploitative and explorative. While the first case focuses on an SME within the fruit industry, in this second case the empirical analysis is centred on an SME within the food industry. So, the chapter describes the learning trajectory from 1987 to 2010 of an ingredient supplier firm (ISF)⁸⁰. As with the case in the previous chapter, this case provides evidence for the process of learning-capacity building and its relationship with the technological trajectory throughout the firm's knowledge-integration and learning system.

The economic activity of the ISF consists of supplying ingredients – e.g. improvers of flavour, colour and textures, additives and preservatives – to the food processing industry specializing in human consumption. In common with the NSF, this firm is also located at the bottom of the value chain, which means it has no direct interaction with the final customer. Rather than just focusing on the commercialization of its products the ISF has developed its market strength by offering a package of technical solutions to its clients that includes advice on the development of formulas, conditions of production, and quality of products.

Ingredient supplier firms are well-established businesses worldwide. In Columbia this activity kicked off during the 1960s when the first firms were created, since when there

⁸⁰ The name of the firm has been replaced by the term 'the ingredient supplier firm' (ISF).

has been a consolidation of the industry and market position. Nowadays this activity accounts for approximately 112 firms spread all over the country.

Regarding the size, capital structure, age and market diversification strategy, ingredient supplier firms are quite diverse in Columbia.⁸¹ The majority of these firms are medium sized; most of them started operations during the 1980s but there is also a high presence of large multinationals firms with either a sales representation office or a production facility within the country. Other smaller firms have entered the market more recently, most of them operating from the late 1990s. These small- and medium-sized locally established firms have mainly started and developed their business models by representing well-known, recognized products of large multinationals, this being a common pattern in their entry and positioning strategies.

Moreover, the products that these firms offer the market could cover a variety of needs and applications in a broad range of products from the food processing industry – e.g. raw meat products, dairy products, sauces, beverage, snacks. Therefore, some of these firms have decided to specialize in certain products and industrial applications but the majority of them have tended to develop a diversified portfolio of products.

Within this context, the ISF has grown (since 1987) from micro to medium sized and, in terms of number of workers, is now moving towards being a large firm. Regarding its response to the market, the ISF has aggressively undertaken a diversification strategy, competing with a range of products for different industrial applications and positioning itself as a strong option within its market (which comprises food processing firms), even against large multinationals.

The firm has focused its attention on small food processing firms albeit not exclusively. In order to reduce the market efforts demanding from these small firms, and increase the firm's economies of scale, the ISF has decided to compete also for the market of large food processing firms. Hence, the next section (6.2) provides more detail on the characteristics of the market and industry, focusing on how the ISF has reacted and defined its position over the years.

⁸¹ Database of firms was taken from <http://www.revistaalimentos.com.co>. 03/05/2013

The ISF's knowledge base for developing its technology – formulas and protocols for the mix of components (termed 'mixes' from now on) – is supported by a combination of chemical and food engineering along with the use of microbiological techniques. The firm's core technology has been developed through three key routines: (1) the identification of artificial and natural components for industrial applications; (2) the mechanics of production to make the mixes; and (3) the analysis of ingredients to ensure their characterization and standardization. Section 6.3 describes how the ISF's learning and technological trajectories took place across these three routines.

To carry on with its technological development the ISF also followed the pattern of using the experience of large multinational firms by representing them through the commercialization of their products to acquire knowledge and technical reputation. Nevertheless, while it was using other firms' products, the ISF also started to create its own ingredients, starting from using replication and imitation techniques to undertaking engineering design and research. Accordingly, the learning trajectory has been driven by the firm's approach of having a dual market strategy and technical specialization.

As was done with the previous case, the learning trajectory of the ISF was observed through the learning schemes and their association with stages in the learning process – i.e. reflection, assimilation, and implementation. The ISF reported 850 learning events from 1987 to 2010, all of them grouped into 23 types of learning scheme. Section 6.4 explores the similarities encountered among these learning events so to as firstly define these 23 learning schemes and explore their connection with the learning process, and then secondly provide a comprehensive picture of the depth of the firm's knowledge-integration and learning system (KILS).

Consequently, Section 6.5 focuses on the commonalities among these learning events regarding the sources and orientation of the knowledge that defines the learning capacities – i.e. formative, adaptive, transformative, inventive, created, renewed capacities – and the way the firm developed each capacity over time in relation to the observed lifecycle (1987–2010). This analysis provides evidence of the extent of the

interaction between, and interdependency of, internal and external knowledge across the firm's capacity building.

The complementary interface of all the six learning capacities defines how the firm went through a knowledge-integration and learning system. It started from the establishment of routines and the development of new capabilities within its existing routines, and moved to the implementation of alternative solutions to problems, the diffusion of existing capabilities across different commercial lines, and the assessment of new technological requirements and markets. In line with the previous case, the ISF's trajectory over the six learning capacities exhibited an iterative interaction along the technological trajectory.

All the evidence from these two cases reveals the continuous movements that these two firms exhibited through the learning events outlining both 'path-dependent' and 'path-breaking' changes. As with the previous case this evidence also exposes how this tension was balanced by the iterative use of internal and external knowledge in situations when the knowledge integration displayed some degree of efficiency, coherence and flexibility along the sequence.

In summary, to enable a comprehensive and comparative analysis, this case follows the same structure of the previous one. Section 6.2 describes the characteristics of the firm's production system and the market. Section 6.3 defines transitions across the firm's technological trajectory. Section 6.4 focuses on the definition of the learning schemes exploring the links with the learning process. Finally, section 6.5 describes the process of capacity building and the transitions in the learning and technological trajectories.

6.2 Evolution of the firm's market and industry position⁸²

This section describes the evolution of ISF's market and industry position in order to give a picture of the context in which the learning and technological trajectories

⁸² As noted earlier, the sections in each of the case reports related to the market were constructed from information collected from the managers and key members of the SMEs.

occurred. The section portrays the circumstances in which the firm started and describes how it entered the industry, the market strategies used by the firm and its growth in terms of size (employees) and sales. The section also defines the transition periods faced by the firm over the observed lifecycle (1987–2010) that are used in the following sections as the building blocks for the analysis of the learning and technological trajectories.

The food industry in Columbia has evolved towards the segregation of activities across the value chain, marking clear boundaries and positions for every firm. This situation created the opportunity for firms like ISF to become a specialized supplier of ingredients for food processing firms in the late 1980s when the industry was experiencing an expansion and there was a small number of large competitors within an unsaturated market.

The ISF originally started with the administrative and financial support of another already established firm called ALICO whose owner had observed the need to offer a combine service, including packing, machinery and ingredients, to the food industry. ALICO was mainly focused on packing and accessories but there was still a market need for ingredients, additives and specialized equipment; while ALICO had previously intended to form a group of firms to fulfil these markets, in 1985 a chemical engineer who was associated with a biochemical engineer invited ALICO's president to form a partnership in the creation of an ingredient supplier firm.⁸³

At this time the ingredients and additives market had been mainly developed by a multinational firm called Griffith Colombia S.A. that had production facilities in the country; it had a long tradition and a good technical reputation. So, there were already high standards to be met for a new entrant in this industry. Griffith was focused on the market of large food processing firms, although it also dealt with a few that were of medium size. Therefore there was a commercial opportunity within the segment of

⁸³ These three persons were already qualified and highly experienced in the food industry when they decided to create the ISF. The president of ALICO was the former vice-president of an important food processing firm in Columbia before he took the decision to become their provider instead. The two engineers were also experienced managers of two other well-established food processing firms. So, between them, the three partners had considerable technical knowledge of, and experience in, the industry.

micro-, small- and some medium-sized food processing firms, whose production needs were not matched with the current offer. Consequently, there were high transaction costs for these SMEs because their production requirements and stock capacity was significantly less than what this multinational firm was able to offer.

With this market opportunity already identified, the financial and administrative support of ALICO and the managerial, commercial but especially technical experience of these three partners, the project of the ISF started and was formally constituted in May 1987 as an Anonymous Society (A.S.).

The first group of products were designed through an engineering process called replication or what is commonly known as reverse engineering. These products were nitrite, garlic and onion salt and seasoning of salami, chorizo and ham and they also developed a functional ingredient based on ascorbate. The first group of products were initially oriented towards meat processing firms.

At the start of their commercial activity the ISF wanted more knowledge of its potential clients and decided to develop a database of all existing SMEs within the meat industry. Based on this information the firm put in place a strategy it termed 'operation mole'; as the name suggests, the strategy was kept under wraps so to as hide the ISF's initial commercial intentions from Griffith, because it considered that any actions that were freely exposed in the market would have generated an aggressive reaction from its larger competitor at a stage in its development in which it was still vulnerable.

As part of this strategy the ISF decided to conduct one-to-one visits to these SMEs to offer not just their products but also technical advice and training processes with the promise to help them improve the characteristics of their meat and efficiency of production. The sales force was then set up, starting with the hiring of engineers with previous knowledge of the food industry.

This market segment was attractive, albeit very fragmented, not really known and with low or non-existent engineering capabilities. Moreover, regulation of the food

processing industry was still weak.⁸⁴ The demand for technology-based ingredients coming from these SMEs was not clear and required considerable market effort, and the ISF soon discovered that it was not really a profitable market. Nevertheless, the firm continued to develop this market segment especially because the philosophy behind the business was to promote and improve competitive conditions of local firms in the food industry.⁸⁵

As a result, the ISF continued to supply the SME market, but in order to survive financially the firm's managers decided, five years later, to go for the segment of large food processing firms as well. By this time the firm had gained enough production experience, but more importantly had achieved a good technical and commercial reputation. The owners of the firm used their social networks to gain entry into the large firms market. In 1991 ISF started to supply ingredients to some large firms such as RICA RONDO, Comestibles DANN and Tiboli. The development of this market segment gave the ISF some initial profit margin and allowed it to move towards the administrative and financial independence from ALICO that was finally obtained in 1993.

In summary, during its early years the ISF established its market position by focusing on micro-, small- and some medium-sized clients, offering customized solutions and helping them in their production development. To do this the firm made the commercial effort to search for, and look after, its clients instead of waiting for them to come to it. Although the ISF maintained a consistent market entrance strategy, once it had gained some recognition it decided to pursue more high-profile clients with better production capacity and so from this moment started to develop a 'dual market strategy' involving these two segments (see Figure 6.1).

⁸⁴ INVIMA, which is the governmental organization in charge of regulating the quality and standards required for the food industry in Columbia, was formed in 1994. Prior to this, there were no clear standards regarding health issues, procedures and norms for food processing firms. Source: http://www.invima.gov.co/index.php?option=com_content&view=article&id=57&Itemid=68.
13/03/2013

⁸⁵ According to the interviewees most of the ISF's clients were micro-sized firms with capacity of production less than 5 kilos per batch of production and with the help of the ISF and the other firms of the group these micro-sized firms managed to increase their production to levels up to 30 kilos per batch of production and develop efficient production plants in a very short period of time.

Figure 6.1 Market position



Source: Based on data given by the ISF

The ISF's main focus was initially on the meat industry. But, at the beginning of the 1990s the managers anticipated that this market was heading towards a stagnation point. Moreover, despite the efforts to atomize the clients in the SMEs market segment, once the firm decided to look for the large food processing firms market, nearly 80% of its sales were oriented towards one firm of this segment. The ISF's survival was at risk due to its dependency on the meat processing market and one large firm.

In 1992 the ISF began to search for new market applications and opportunities, although some of them, as will be described, were initially developed as part of specific contingencies for the firm. The very first initiative to diversify the firm was pursued using a business that ALICO wanted to leave behind, consisting of the production of soy-based proteins. So, the ISF decided to learn how to produce textured proteins from this soy-based product and installed a production facility that started working in 1992. In this way the development of the protein line began.

After a while another business line was developed: this consisted of the import of breadcrumbs and the idea came from a competing firm at an international fair. However, the ISF did not initially progress the business because it was considered too costly. After further investigation, the ISF's management team realized that the only breadcrumb firm in the Columbian market was producing for self-consumption only. With no competitors for an external market for this product, the ISF saw an opportunity to develop this business itself, and it learned the basic operational routines from the firm

that it had met at the fair. Thereafter, the development of breadcrumb production started with a pilot plant in 1995 that later on became a proper production facility.

By 1997 the ISF had already developed some kind of market recognition regarding its capabilities to develop formulas. Then an opportunity arose – promoted by the firm’s president’s social networks – for the ISF to develop formulas for the production of sauces for a new big client. Although the business was unrelated to the firm’s previous production system, it was a clear path towards diversification. Thereafter, the commercial line based on the production of sauces was started in response to the needs of this specific client – with a small production plant and the hiring of a food engineer who specialized in formulas for sauces. From here, the ISF slowly started to open the market for sauces.

In line with previous commercial developments, the nutritional line was fostered by a combination of exogenous market conditions and the firm’s existing technical and operational experience. This commercial line had its origins in a business initially contracted by a governmental organization called ‘Columbia Solidarity’ that had hired the ISF in 1998 to produce a nutritional supplement for children. This commercial relationship did not last long (four years) but based on this production experience the firm created its first and only product oriented to the final customer with a brand known in the market as ‘Power Max’.⁸⁶ However, it was only in 2004 that the ISF started to properly develop ingredients to promote the nutritional line within the firm.

Another business line worthy of mention is that referred to as ‘cleaning and disinfection’, created in 1999. This line of business started because the clients started to experience problems with their production processes, initially blaming the ISF on the grounds of the quality of its ingredients and additives. Because the firm’s relationship

⁸⁶ This product was created in a very unusual way. The product did not arise from market demand; it was an idea that emerged internally to improve the nutrition of the firm’s operational staff by using production facilities already in place to produce ‘solidarina’. In time the management team saw that this mix presented an opportunity; the firm undertook market research, added flavours to the mix and decided to commercialize the brand, hence ‘Power Max’.

with its clients was focused on the provision of technical assistance⁸⁷ rather than just the commercialization of products, it was possible for the sales force to identify that the real problem in their clients' production processes was due to their lack of cleanliness.

Over the years of operating its own production plant, the ISF had already gained experience in developing a programme of cleaning and disinfection. As a result the ISF offered their clients the service of implementing a cleaning programme in their plant. However, the ISF did not have the required products for this service, and initially it had a supplier agreement with a firm from the United States called VIRCO.⁸⁸ Since then, this business line has evolved commercially within the firm, becoming one of the most important services for the support of the food industry.

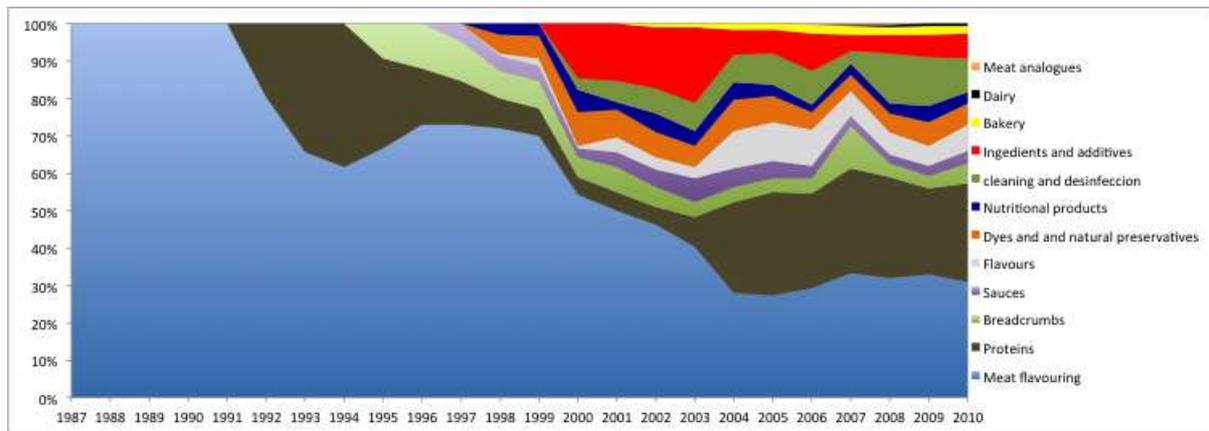
All in all the previous description outlines the diversification process followed by the ISF. However, it was only in 2003 that the firm conducted a strategic and more careful analysis of how its products could have application across a variety of industries. As result the firm drew clearer distinctions between lines of business corresponding to industrial uses in the food industry – e.g. dairy industry, fisheries, bakeries – and it specialized in some existing products in order to have a better commercial and promotional strategy.

Figure 6.2 summarizes the sales of each commercial line, as a percentage of total sales, representing the evolution of the firm's portfolio over time. From the figure it is possible to identify three phases in the firm's diversification strategy.

⁸⁷ Starting in 1999 the firm began to develop a seminar mainly aimed at the meat industry with the intention of creating a space where suppliers and clients could explore new developments in the production of food processing in areas such as ingredients, methods of production, equipment and packing. Since then, the seminar has been run every two years. The Columbian meat industry has recognized and institutionalized this event as a space for dialogue, interchange of ideas and acknowledgement of technological developments for the industry.

⁸⁸ Along with these situations, the government started to increase the controls on the food industry in terms of safety and sanitation and Ordinance 3075 was launched. This ordinance defined the parameters of quality in the production for food processing firms. Source: http://www.invima.gov.co/images/stories/aliementos/decreto_3075_1997.pdf 18/03/2013

Figure 6.2 Level of diversification



Source: Based on data given by the ISF

During the first phase the firm specialized in a group of products that responded to the needs of the meat processing industry – i.e. 100% of the sales were represented by meat flavouring products. In the second phase (after 1992) the firm took advantage of some contingencies and exogenous situations that, as previously described, had evolved into new business opportunities. The third phase in the diversification process started in 2003 when the ISF made a strategic decision to organize its line of businesses and, as will be further explained below, (from 2005) it reinforced each line by matching its sales force with its engineering and design (E&D), creating a clear distinction between groups of products. In this way the firm reduced the level of its market dependency over the years.

In addition to its commercial diversification, the firm decided to spread its influence to other parts of Columbia, as well to as other countries. Since the ISF had been created, ALICO (already an established firm) had been its business partner; the partnership presented an opportunity for ISF to take advantage of ALICO's commercial network and administrative support to expand its market to other major cities – e.g. Barranquilla, Bogota, Cali. From 2002 the same pattern was used to develop the international market, initially to neighbouring countries such as Ecuador, Peru and Venezuela.

Since then, the process of geographic diversification has moved forward. First the ISF has become independent of ALICO; then, to focus on international markets a manager was assigned, and later the firm started to move towards the design of its own

ingredients, intending to use its these original products as a way of dominating the market and taking over from international suppliers.

As described, given the conditions of the market and the industry, the ISF has responded to the evolving context by developing a strong technical recognition. Consequently, its market strategy has concentrated on five fronts: (1) customizing solutions; (2) building a strong engineering sales force; (3) aggressively searching for clients and paying one-to-one visits; (4) creating loyalty by helping its clients to develop their businesses; and (5) diversifying commercially and geographically.

Taking into account how the ISF has moved over the years in terms of the diversification phases previously described, along with its market position, growth process (i.e. sales and employees), level of acknowledgement of its resources, capabilities and strategic orientations, a series of transition periods can be identified. Table 6.1 describes the life cycle of the ISF since it was formed in 1987, up to 2010 (when the data was collected).

Table 6.1 The ISF's life cycle 1987–2010

Period	Stage	Index sales Growth (base 100, 1988)	Average growth per year	Size	Employees	
					From	To
1987 - 1991	Initial conditions	339	52%	Micro	4	9
1992 - 1996	Formation	5560	75%	Small	16	41
1997 - 2004	Establishment	49871	27%	Medium	71	172
2005 - 2010	Expansion	109777	17%	Medium	187	255

Source: Based on data given by the ISF

The first stage is defined by the development of the firm's initial conditions, a period in which the ISF had a small number of staff – the firm started with four employees and remained micro until 1999 – and began to understand the operational routines required to run a business, achieving an average growth rate of 52% per year.⁸⁹

⁸⁹ As explained before the first years were difficult financially, up until 1991, when the firm got its first clients within the large food processing firms segment.

A new transition period can be identified from 1992, when the firm started hiring more staff, becoming a small firm with increasing market recognition, represented by an average growth rate of 75% per year, and passing from a threshold of vulnerability to a phase of formation when its strategies and routines became clear for the market segment the firm wanted to participate.

After ten years of producing ingredients for the food industry, the ISF was considered an established firm, and it entered a transition stage with a new line of business requiring new capabilities and new staff – i.e. the firm became medium sized. Although the growth rate (on average 34% per year) was much less than in the previous stages, during this period both the diversification strategy and the areas⁹⁰ – e.g. production, engineering and design (E&D), research and development (R&D) – were more clearly defined.

This period was also marked by changes in the industry and market. Over the second half of the 1990s food processing firms started to develop engineering-based technology, mainly because of the creation of university programmes in food engineering. Along with the technical specialization of these firms, some of the micro- and small-sized firms started to increase their production capacity, demanding even more ingredients.⁹¹ Moreover, the regulations in terms of food security increased and the demand for a certification process and better control mechanisms became stronger.

From 2005 the firm's expansion was accompanied by significant events for its development. During the period 2005 to 2010, the management style changed: first, a new person was put in charge of the firm; second, the business lines were better coordinated in terms of the alignment between E&D and the sales force. Moreover research activities became more relevant and more common practice, with the aim to search for new ingredients; in doing so, during this stage, the ISF promoted further links with local universities to enable its use of their facilities, to raise its profile among

⁹⁰ 'An 'area' is the term used by the firm to refer to a group of people who respond to specific activities and responsibilities as part of the operational system.

⁹¹ According to the interviewees the ISF went from an average of 25kilos per client per sale to 100kilos during this period. This was clear evidence that these micro and small firms began to increase their production capacity. This increase can be considered to be the result of the strategic consistency in maintaining 'operation mole'.

students, and through seminars and research. Although the average rate growth during this period was just 18% per year, in absolute terms the firm more than doubled its market, something that had never happened before.

In summary, this section has described the conditions of the market and industry and the ISF's evolving position over the years 1987 to 2010. From the initial conditions, in which experienced engineers had found a niche in the food processing market, the firm has developed through the years by having a consistent strategic orientation – i.e. by identifying a clear market segment and diversification strategy – combined with good use of commercial opportunities. In this way the ISF has reduced its vulnerability against competitors in a highly diversified industry. Finally, the section has distinguished four transition periods over the firm's life cycle that will be helpful in the understanding of the technological and learning trajectories, which are the main focus of the following sections.

6.3 Technological trajectory 1987–2010

The ISF's technological development has been based on the use of chemical, biochemical and microbiological techniques focusing on the composition of artificial and natural components that together were expected to offer improvements in the production of processed food.

The ISF was one of the first firms within Columbia to be established in a market where large multinational firms have had the technological lead. Inevitably, therefore, over the firm's life cycle there have been technological imbalances between these large firms and the ISF in terms of production equipment, formula development and laboratories, but the firm also had other challenges to overcome. This section describes the process by which the ISF defied its technological disadvantages to take then seize market opportunities over the period 1987 to 2010.

6.3.1 Core technology

ISF's core technology consists of the development of formulas and protocols of production to provide a range of technical solutions for flavouring, consistency, durability and texture of a variety of products for the food processing industry. These formulas and protocols, translated into products, are defined by: the characteristics of the artificial and natural components to form a mix; the order and quantities in which those components should be added; the right equipment to guarantee a standardized mix; and the characteristics of quality to provide a reliable service to the market.

So, the operational routines to develop ingredients for the food processing market go beyond the mechanics of production. Although it is one of the important aspects of the technology, the E&D behind the development of the formulas is considered the nerve centre of the whole technological system. The third important group of routines of this core technology is related to the quality analysis procedures that take place in the physical chemistry lab and microbiological lab. In brief, the technological development has mainly focused on three routines: (1) the mechanics of production, (2) the development of formulas (artificial and natural components), and (3) the quality analysis system.

6.3.1.1 The mechanics of production

The firm began to recognize the technology needed for the processing of ingredients and their corresponding routines by focusing on the mechanisms of production for the mixtures. Once the first products were designed by using reverse engineering as previously described, the ISF instigated the following systems and procedures for its production facilities: (1) a system with a process that departed from the selection and weighing of ingredients according to a formula; (2) a mixing procedure with a predefined order and time; (3) sampling of the mixtures for analysis of quality in a laboratory; and finally (4) if the product was approved, movement of the production batch to the packing area, then to storage and delivery areas.

The sequence follows a similar pattern to other chemical-engineering-based production systems. Despite the apparent rigidity of the sequence, regarding the methods of production, the technological trajectory has mainly been influenced by the equipment used to prepare the mixtures, and for weighing.⁹²

Moreover the ISF has also diversified its production system with different production facilities to support the development of certain business lines. As result the firm has installed five production plants over the years starting from (1) the plant for the mixtures – also called ‘mixtures 1’ (1987–present) – followed by (2) the ‘textures plant’ (1992–2002), (3) the ‘breadcrumbs plant’ (1995–present), (4) the liquid-mixing or ‘sauces plant’ (1997–present), and (5) another plant for mixtures – ‘mixtures 2’ (2003–present) – but specializing in sweet flavours, and using the same structure as for mixture 1.

In the case of the plants for mixtures 1 and 2, which are the leading production facilities, mixers are the main production equipment. According to the managers of the firm the technology embedded in these devices has mainly evolved to have a better combination of efficiency levels, production capacity and homogeneity of the mixtures. And so, changes in this respect have been driven as a response to one or all of these requirements according to increases in demand.

When the ISF started its production in 1987 it first used a mixer called a tombola that basically had a rotatory movement. After a while the firm replaced the technology with paddle mixers (1989). Although this type of equipment was appropriate for responding to the market requirements at that time, it had some problems.⁹³ It was not until 1994 that the firm decided to invest in a ribbon blender, a more precise and efficient mixer in

⁹² Although the analysis focuses on these two aspects of the mechanics of production it is worth mentioning that other changes have clearly happened. These relate especially to the packing process where the firm has gone through trials and has installed different mechanisms to improve the efficiency of a process that is complicated by the need to deal with a variety of products and packing specifications.

⁹³ According to the production manager this mixer was not properly designed for pounding and therefore required some help to work properly: this meant stopping the machine two or three times during the mixing process and manually removing and then replacing the material for further mixing. Because of this situation mixing took 25 minutes to be completed.

production.⁹⁴ This type of equipment solved the previous problem of poor homogeneity of the mix. During the following years the firm kept using this equipment and only made changes to the mixing capacity according to increases in demand.⁹⁵ In 2008 double ribbon blenders were introduced and in 2010 the firm decided to jump into more advanced equipment and, at the time of data gathering, was going to purchase a turbo mixer.⁹⁶

This was the trajectory of the mixtures 1 plant and partly of the mixtures 2 plant: these two plants share similar technologies and routines. However, for the development of the mixtures 2 plant, the firm was able to jump from paddle mixers straight to double ribbon blenders.

As described above the firm's trajectory in terms of the mechanics of production also reflects the diversification of the production system through the operation of other production plants – i.e. textures plant, breadcrumbs plant and sauces plant.

In the case of the textures plant, the most important equipment for the production sequence was the extruder. This equipment was difficult to get and later to operate because it was not completely appropriate for this type of production and there was no one within the firm who fully understood its mechanics. Since the plant was put into operation (1992) very few changes in the equipment and procedures have been implemented. In 2002 the efficiency of the plant was assessed; as a result of the evaluation, the plant was closed and a multinational large firm started to supply proteins so that the ISF could proceed with its sales.

⁹⁴ One of the main motivations to look for better mixing technology was because of a major client of the ISF who had not been completely satisfied with the ingredients because of the lack of homogeneity of the mixes.

⁹⁵ Between 1994 and 2007 the firm bought six mixers with capacities of between 1000 and 1500 litres.

⁹⁶ At the moment of acquisition there were two competing technologies: the first was a mixer called a 'V' blender and the second (the one finally decided upon) was the double ribbon blender. In comparing the two mixers, the ISF had taken account of its production requirements, as well as obtained feedback from trade fairs and advice from the providers, and had found its needs were more closely matched by the double ribbon blender. When the information for the study was being gathered this type of mixer was about to arrive.

The breadcrumb plant, which started operations in 1995, did not have any complex process or equipment. Its efficacy was mainly related to the formula for the production of the crumbs. One of the most significant modifications in the process was a change that took place in 1998 – from the cutter to the disc mill – when, instead of cutting, the crumbs were ground up.

In 1997 diversification of production went a bit further when the firm decided to create a sauces (liquid-mixing) plant. This production plant was a challenge for the firm because its production experience had just been focused on the manoeuvring of poulder mixes (i.e. for solids) rather than liquids. This plant has mainly been used to produce sauces for third firms and so ISF has specialized in the design and development of formulas.⁹⁷

6.3.1.2 Development of formulas

Along with the mechanics of production, the second group of routines is related to the identification and selection of the artificial and natural components as well as the design process for the mixes. After the first products were designed through replication – from existing products in the market – the firm identified the need to develop capabilities for designing and validating products for existing and new clients according to market needs.

Consequently in 1990 the ISF installed a pilot plant for experimentation in the development of new products and making improvements to existing ones regarding colour, flavour and texture. Additionally this pilot plant was useful for conducting trials to identify new components for the mixes prior to their production and launch on to the market. This was the first attempt to develop an E&D area within the firm, and was because the managers realized that the creation of formulas would have a great impact on the firm's technological development and market recognition.

⁹⁷ This plant was installed with basic equipment, which has remained almost the same over the years since it was created.

In 1994 the ISF decided to go one step further and formalize a design area to systematically search for new components and combinations for the development of products – i.e. ingredients, additives, and preservatives. However, the strategy was mainly developed to respond for clients' requirements rather than for the design of products *de novo* with no clear market opportunity.⁹⁸

To obtain more technologically advanced components, the ISF set up collaborative agreements with large international suppliers of ingredients. These two combined technological strategies (external support/collaboration; developing an E&D area) have given to the firm sufficient capabilities to undertake the diversification process and to expand its technical reputation with a range of components that have allowed it to offer a great variety of technical solutions to the market. Hence, the groups of ingredients and formulas form the main knowledge and technological assets of the firm.

In another move to develop its formulas, the ISF promoted and supported its own R&D area. The very first research interest was on the topic of reaction flavours, starting in 2001 when a person was hired to develop this technology. This person worked alone on this topic until 2006 when the management team changed and decided to review the coordination and control process of the area, and from 2007 a more strategic approach to R&D was adopted. First, a group of dedicated research staff was hired; second, the research was much more closely connected with the long-term interests of the firm, one of which was to replace most of the ingredients that had come from international suppliers. As a result the firm added other topics apart from reaction flavours to its technological research portfolio – e.g. functional carbohydrates, antioxidants, preservatives and colorants and micro-encapsulation.

In summary, the ISF has based the development of its knowledge and routines on the identification and selection of artificial and natural components using a combination of

⁹⁸ According to the figures given by the ISF, by using this strategy during the period 1994–2010 the firm had designed over 9539 products, which on average represent 530 developments per year. However, according to the firm's effectiveness measure, its clients finally accepted only about 25% of those designs. Over the years this area has grown in personnel and at the time of data gathering (2010) accounted for at least 17 staff.

short-, medium- and long-term technological strategies over the years. First, the firm obtained technical support from well-known international suppliers with which it had collaborative agreements to use and commercialize their ingredients but also to receive training and technical assistance from them. Second, an E&D area was set up to connect the needs of the clients, through the salesmen, with chemical and biochemical engineers who were able to develop new combinations of products and expand the business lines of the firm. Finally, these earlier strategies were merged and a dedicated R&D area was added, with the intention of exploring new technological directions for the firm.

6.3.1.3 Quality analysis system

The last group of the core technological routines identified as required for the development of an ingredient supplier firm are related to the quality analysis system. The process for the quality analysis mainly refers to verification of the characteristics of ingredients according to previously defined standards, before a batch is approved for delivery. The firm started with microbiological laboratory facilities to offer an additional service to its clients, but it was not profitable enough to keep it as a commercial strategy and so it was closed.

Around 1993 the ISF began to strengthen its physicochemical laboratory to enable further analysis, even though regulation of the food industry was weak at this time. However, this started to change during the second half of the 1990s when a new regulatory system demanded the implementation of process and quality certifications similar to good manufacturing practices and Hazard Analysis Critical Control (HACCP) to guarantee safety and high standards within the food processing industry. As a result, the ISF reinstalled its microbiological facilities in 1997. By the end of 1990s the ISF had implemented a range of physicochemical analyses and microbiological controls to assure the quality of its own processes and products but more importantly to get recognition from the market that it was now accomplishing the established norms. Additionally in 2001 laboratory facilities for sensory analysis were implemented.

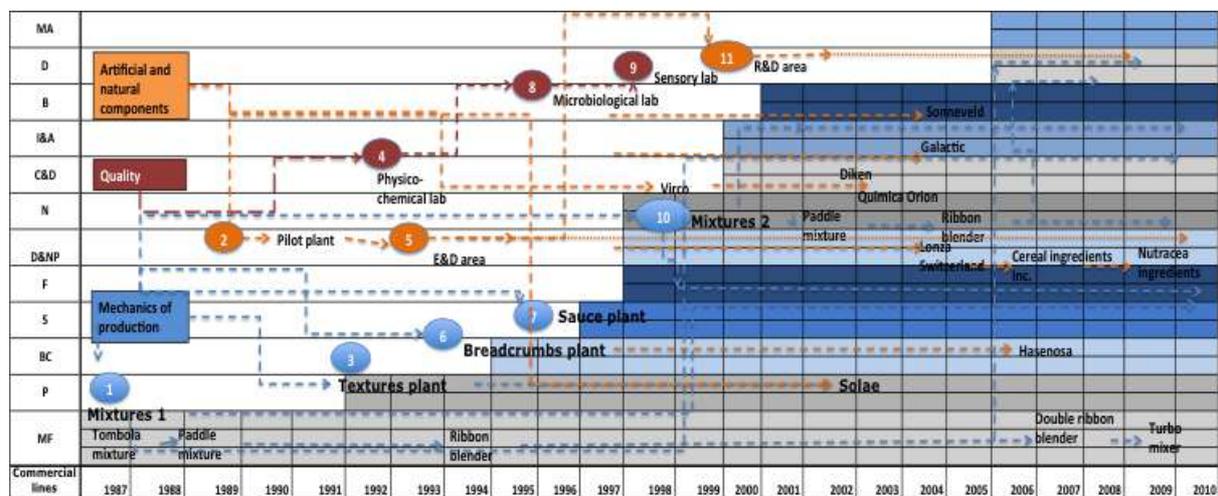
Furthermore, as part of the technological development of the ISF and the other firms of the ALICO group, an additional organization called Foundation INTAL⁹⁹ (Science and Food Technology Institute: acronym is in Spanish) was created. This organization started to work in 2000 and was a joint project between two other firms of the ALICO group and other food processing firms. The purpose of this technology and research centre was to support the scientific and technological development of the industry including the technological needs of the ISF. Bearing this idea in mind the ISF transferred to this organization its pilot plant and its microbiological and sensory analysis laboratories.

Overall, these three laboratory facilities along with the mechanics of production and the E&D area have given the firm a specific position in the market and therefore have completed the core group of technologies developed by the ISF over the years.

Figure 6.3 summarizes the technological progress of the firm along these three groups of routines across the business lines between 1987 and 2010. Starting from the mechanics of production, it can be seen how the firm's technological trajectory has moved over the years since it was created. But more importantly it shows how this technical progress has been consistently aligned and evolved to develop a technological system that has fitted the market requirements. Numbers 1 to 11 on the chart trace the technological trajectory over time and the coloured dashed lines show the interactions between each group of routines across the lines of the business.

⁹⁹ <http://www.fundacionintal.org>. 25/03/2013

Figure 6.3 Chart of the ISF's technological trajectory by business lines 1987–2010



* MF=meat and flavourings; P=proteins; BC=breadcrumbs; S=sauces; F=flavours; D&NP= dyes and natural preservatives; N=nutritional products; C&D=cleaning and disinfection; I&A=ingredients and additives; B=bakery products; D= Dairy (cows') milk; MA=meat analogues
 Source: Based on data given by the ISF

6.3.2 Peripheral technologies

In addition to the core technological trajectory, there is another group of routines that form the so-called peripheral technologies. These routines cover a set of supporting technologies including information system technologies, the metrology system and the maintenance system; the routines also include the development of a set of sales practices aimed at offering technological solutions to clients.

These peripheral technologies complete the whole set of routines required for the development of a supplier ingredient firm. These routines influence the coordination process, the conditions in which the technological system works and the linkages between clients and the E&D area. As with the core technologies, those that are peripheral were gradually developed over the years due to increases in market participation which demanded improvements in the conditions of production.

Information system technologies were the first peripheral type of routines to be developed. These technologies were used to assess the firm's knowledge but more importantly to coordinate and generate interactions between all the routines so to as improve the functioning of the of the business lines. In 1992 one of the managers developed the first program used to capture all the technical processes of the firm, from

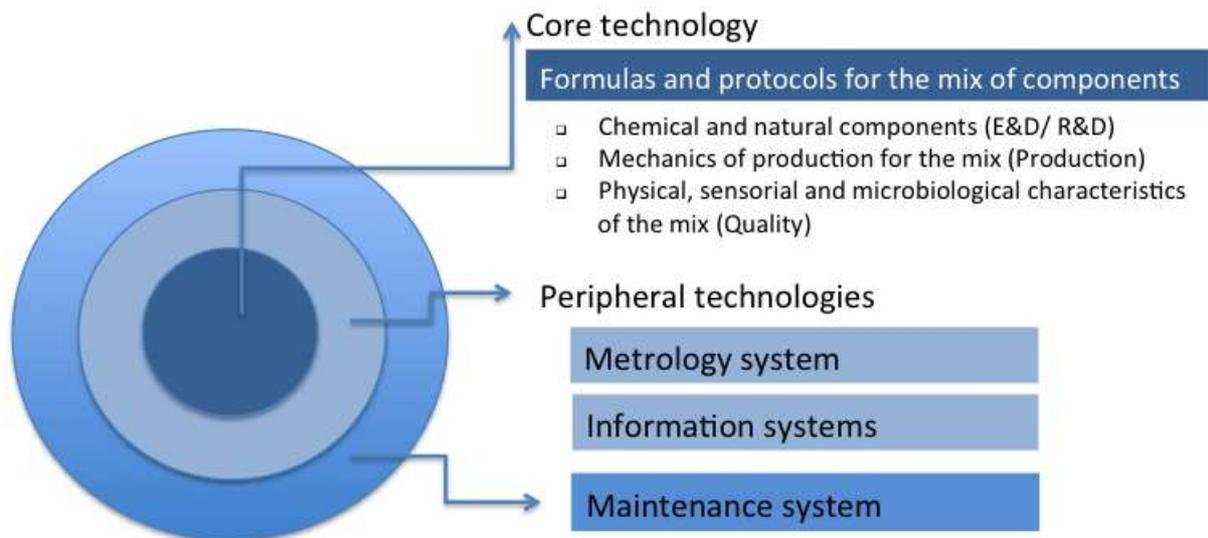
formula development to the production process. This program was known as “Proinfac”. Although it served its purposes, the interface was not easy to manage. Moreover, the information was centralized and so it was not widely disseminated across the firm, which created communication problems and misunderstandings; another problem was that the firm did not have enough computers at that time.

Around 1999 the quality certification process (ISO 9001) started to be implemented. As a result a more robust system was required. System engineers were hired for the design, development and implementation of a program specifically developed for the firm’s needs. The operation of this software, called “APLinsa” (2001), was intended to solve the problems mentioned above of centralization of information, and poor communication and coordination between routines. Implementation had a positive impact on the standardization and organization of the firm’s operational routines. Two significant modifications, one in the methods of analysis and diffusion of information (2004) and the second in development of a web application (2007), were made to the software to enhance the way the information was used. In 2010, once again, the firm decided to change the system, starting an ambitious project called “Everest” with the aim of creating a unified management information system for the whole firm taking full advantage of the Internet for real-time connectivity.

The second peripheral technology relates to the weighing process within the sequence of production. Although one of the main aspects of the mixing process is associated with the use of the right proportion of components for the mixes, it was only in 2001 that the firm paid attention to calibration of weights. When the implementation of the quality certification system started, all processes were revised. It was acknowledged that the lack of a precise and accurate measure of all components was affecting the quality of the mixes more than had been thought. As a result, the implementation of the metrology system started, but it took five years to be fully accomplished.

As shown in Figure 6.4 other peripheral technologies include the maintenance system and the wholesale and technical assistance process. The first of these was set up to support the mechanics of production but it became an important area as part of the operational routines to avoid bottlenecks in the process.

Figure 6.4 Core and peripheral technologies



Source: Based on data given by the ISF

Together, the core and peripheral technologies define the set of knowledge and interrelations that form the technological routine system of the ISF as part of the ingredient supplier industry. The trajectory, in the sense of both types of technology, has defined how the firm has adapted to the market over the years. Hence, the complexity of the firm's technology is seen through the development of conditions for production and a specialized quality system, the consolidation of a design area for the creation of formulas, and the incorporation of scientific engineering capabilities. The ISF's technological pathway has been consistently oriented towards a strategy for technological independence (especially from large multinational suppliers) as well as for international market expansion, while at the same time it was learning from, and developing the local market.

However, as was recognized with the previous case, two types of risk have increased the rate of change of the firm's technological trajectory. Firms like the ISF depend on a technical reputation based on highly specialized engineering knowledge. Standards and regulations have gradually increased over the years, but even so are still lacking in certain areas. As a result of improvement in standards, technological efforts are limited by the level of customers' understanding of the technology involved: where understanding is poor, there is a risk that there will be low recognition of different

standards in the technological settings. Another type of risk relates to the level of technological opportunities defined by the accessibility of the available knowledge locally embedded in universities and research and technological centres for instance.

The first risk, which leads to market recognition of different technological settings, could be shaped by three characteristics of the industry. First, as was acknowledged above, large multinationals firms have the technological lead, which means that any local firm has technological disadvantages compared to them, and so the market will have the tendency to go for products and services from the large firms, which are sometimes perceived as more advanced. Second, customers are likely to have different levels of engineering knowledge: those with a good understanding of the technology will tend to identify more closely with the more trusted firms; others will just follow the market conventions driven by prices. The third characteristic is related to the standards imposed by the norms and public regulations. In the case of this industry, the regulations – especially during the second half of the 1990s – have favoured firms that have achieved better technological standards. Consequently the ISF's market and technological strategy has been partially driven by the risks associated with market recognition.

Regarding technological opportunities, the ISF has gone through a process of developing its own ways of accessing knowledge and technology. When the ISF was created, the knowledge and technological availability in the food industry, within the local context, was only just emerging. Thus, the ISF has mainly searched for its knowledge internationally rather than locally, despite all the transaction costs involved. Nevertheless, the firm has also undertaken a process of collaboration, mainly with universities, to create the local technological knowledge that satisfied its needs. As a result the engineering-based knowledge has been accessible over these years through university degree programmes and basic technical assistance. However, this has not been the case for scientific engineering knowledge where further developments are badly needed even within the academic institutions.

Overall, this section has explored how the ISF has moved along the technological trajectory and the way the routines were performed over the years. The firm's

technological routines system, as the evidence shows, has responded to the development of a variety of business lines as part of its diversification strategy. Consequently, the firm has gone beyond the mechanics of production, focusing its business value on the E&D area where the identification of components and new ways of mixing them were the main driving forces of the technological changes, building up both technical recognition and market reputation. In line with the previous case the ISF has also combined 'path-dependent' changes with 'path-breaking' changes, in this particular case by the implementation of multiple production systems and incorporating a variety of engineering-based knowledge, capabilities and routines.

While this section has focused on the technological trajectory, the next two sections will explore the learning dynamics in which these changes occurred, emphasizing the interaction between external and internal knowledge as well as the orientation of that knowledge (exploitative or explorative), outlining the corresponding learning-capacity building process of the firm.

6.4 Technological learning schemes and the learning process

The analytical foundations of this research focus on the learning dynamics behind the technological changes explained above. As in the previous case these learning dynamics are described through what was referred to as the learning schemes, observed by a retrospective description of a series of learning events that occurred in the ISF during the years between 1987 and 2010. These events represent the means by which the action of learning took place within the firm. This section describes the variety of learning schemes used by the ISF as illustrated by the learning events and shows how the scope and outcome of each learning scheme are defined by the relationship with particular parts of the three-stage sequence of this learning process.

As was acknowledged above, the conditions in which the market is able to recognize different technological settings and the availability of accurate technology can generate risks for the firm's technological development. These risks defined to some extent the direction and rate of the KILS. According to the evidence, the development of this system was driven by a process of diversification, the development of market segments,

technical recognition and the search for assertiveness – i.e. accessibility to appropriate external knowledge.

As a chemical-engineering-based firm, the ISF has taken advantages of the applicability of its products and solutions over the years. Hence it has developed the conditions to technologically exploit new market opportunities. In other words, the level of diversification of the firm has partially been possible because of the versatility of its knowledge base. Since 1994 managers have become even more conscious of how to improve the use of components and the variety of combinations of those components to respond to market needs and so they have decided to strengthen the firm's E&D area, which today is considered as the centre of its technological progress.

Nevertheless, this level of technological versatility has been also limited by the mechanics of production. The ISF has resolved this situation by gradually introducing new production plant in response to increases in demand and recognition of market needs. Moreover, as long as the market grew, the firm expanded its knowledge base by also hiring food engineers, microbiologists, nutritionists and even chefs.

The ISF has undertaken some schemes to improve its reputation with external organizations with which it was collaborating in its pursuit of technical and scientific knowledge. The firm has created the routine of annually providing sponsorship for international trade fairs and has made agreements with international suppliers. It has also been involved with the development of the food engineers programmes with two universities¹⁰⁰ and had a joint-venture agreement to create a research and technological centre (Foundation INTAL). Thus, since 2001 when the use of information technologies were widespread across different areas within the firm, two pieces of software were installed that would forecast technological developments and monitored commercial opportunities for new ingredients. These events are examples of how the firm has searched for assertiveness in use of knowledge and technology.

¹⁰⁰ Both Universidad de la Salle and Universidad de Antioquia have open undergraduate and graduate degree programmes in food engineering to respond to the food industry's requirements.

The ISF went through 850 learning events associated with 23 types of learning scheme over its learning trajectory from 1987 to 2010 (see Table 6.2, in which the learning schemes are numbered 1 to 23; in the following discussion, they are considered in groups of related schemes, and each scheme is referred to by its number in the table). As with the previous case, these events are linked to a specific type of learning scheme and also are associated with a certain stage of the learning process – i.e. stages of reflection, assimilation and implementation. Moreover, they have embodied the content, the sources and orientation of knowledge and ensured the firm's technological continuity.

The first group of learning schemes includes events related to the integration of different methods and procedures with the aim of modifying, to a certain extent, the operational routines. These are technical adjustments (1), operational (2) and managerial practices (3). In terms of the learning process these three learning schemes are associated with either assimilation or implementation. Moreover, the events associated with these learning schemes are typically project-based and systematic; however, these events have not been routinized because they have usually been in response to contingencies.

The learning events associated with technical adjustments (1) are intended to modify certain protocols with regards to the sequence and distribution of the activities in the production plant and laboratories, the way in which the components were mixed and the introduction of new techniques and routines. Technical implementations are normally undertaken in response to technical problems and therefore these schemes are reactive. The knowledge to carry out these events is normally passive because it is embedded in the experience and skills of engineers, who are already engaged in the operational routines, and so it is expected that these events have had a more direct impact on the efficiency in production – i.e. the focus has been on exploitative knowledge. Technical adjustments are normally integrated into the production system without much experimentation, so the assessment is done *ex post*.

Operational practices (2) correspond to learning events in which the firm defined the registration and evaluation system to systematically assess and identify the standards

to improve its operational routines. This type of learning scheme contributes to the gaining of knowledge by properly logging its procedures, and therefore as part of the learning process is normally linked to assimilation. Specialists within the firm more commonly undertake this stage of the learning process; accordingly this learning scheme is considered as passive. In line with the technical implementations the knowledge contained is expected to have an impact on the condition of production –i.e. the orientation of the knowledge is exploitative.

While technical adjustments (1) and operational practices (2) both have direct implications on operational routines, managerial practices (3) refer to those learning efforts aimed at improving the integrative routines. These schemes intend to serve as a bridge between all operational routines; therefore this type of implementation has an impact on the coordination process including information system technologies, monitoring and quality system certifications as well as practices to formulate strategic processes. In contrast to information system technologies in which knowledge is acquired from external suppliers – i.e. information system engineers – learning events related to the first three learning schemes are commonly developed by the internal staff – i.e. their focus is on passive sources of knowledge.

Product development (4) was identified as another type of learning scheme, is compressed within the **second group**. As a vehicle of learning, product development involves the understanding and identification of current and new components, the development of mixes and the recognition of market needs. As described above the ISF moved strategically towards diversification, in which the design of new products was the main source for the development of the whole range of business lines; consequently this learning scheme is intended to be exploitative.

Among all learning schemes, product development was probably the most organized. As a result the firm formed an E&D area in which this activity became routinized. A systematic sequence of activities was organized, linking sales with production to guarantee a high rate of new product development. Given the composition of components (artificial and natural), the characteristics of the formulation process and the products, this sequence included a process of trials and errors before its

commercialization was considered and the product finally taken to market. Hence, regarding the learning process, this scheme is associated with both assimilation and integration. Once the product entered into production and the market portfolio of the firm¹⁰¹ it is considered integrated.

Existing clients within a relatively established market have normally been the main source of demand for these new products, so the firm has usually reacted to market needs. Nevertheless, some attempts were made to search for and open new markets as well. The firm also tried to develop certain products without having clients or even a clear market. Although it is not possible to compare the rate of success between reactive and proactive product development, these experiences encouraged the firm to take further risks: it recognized the need to do both activities and also to strength R&D within the firm.

The third group of learning schemes includes all events related to asset acquisition (schemes 5, 6 and 7). As explained in the previous section, the mechanics of production as well as the quality analysis area are both part of the core technological routines with an important role within the whole system. In consequence, the ISF has also made an effort to upgrade the equipment for its production plant and laboratories and improve the infrastructure so to as both expand its capacity and solve health and safety issues; the firm has also mobilized equipment between production plants. So, these learning schemes include equipment acquisition (5), equipment mobility (6), and the acquisition of specialized laboratory equipment (7).

Over the years the ISF has installed five production plants in total, and expended a great deal of effort in understanding the equipment needed to obtain the required efficiency of its routines (5). From the initial conditions of each plant to the firm's formation and its establishment, changes in technological devices have been driven by increases in the required capacity, enhancement of efficiency levels and the search for solutions to technical problems. It could be said that during these years the firm has developed a

¹⁰¹ The E&D area developed an indicator of efficiency that measured the success rate in relation to the design and what finally entered the market. According to the firm's figures, this ratio represents on average 25% of success per year.

good level of understanding of technical progress, at least for the main aspects of the production sequence – e.g. weighing and mixing – but has struggled with other aspects (packing for instance).

Moreover, the firm's managers have developed a systematic buying process, including accurate analysis of suppliers, getting information from the assistance of staff to trade fairs and by monitoring technological providers. Although some acquisition events have implied a simple commercial relationship – i.e. they are active sources of learning – between a buyer and a seller, the firm has also developed joint venture agreements – i.e. these are interactive sources of learning – with local suppliers to reduce transaction costs and develop customized equipment. The mobility of equipment (6) was a scheme that mainly referred to the operation of the mixtures 2 (sweet flavours) plant that in principle shared the same operational routines with the mixtures 1 plant.

The formation and establishment of the E&D area and the quality analysis laboratory have also required the acquisition of specific equipment (7). The equipment for the E&D area was intended for experiments in the development of formulas. In the case of the laboratory, equipment requirements responded to the introduction of new types of analysis or when more precision was needed. Almost all the equipment for these two areas were bought from external suppliers; however, the ISF also started to interact with Foundation INTAL to share equipment for activities like the testing of components and formulas and microbiological and sensory analysis.¹⁰² Agreements with the Nacional University were pursued for the same purposes.

Since 2001 the firm has also pursued R&D activities; as these activities developed over the years, specialized equipment was needed to carry out research projects independently of the operational routines. After 2004 a facility focusing on research only was slowly equipped as new projects were undertaken. The emergence of research within the firm also brought the need to establish collaborative processes with

¹⁰² After 2000, when INTAL was created, some of the facilities like the pilot plant, the microbiology laboratory and the sensory laboratory were translated to the physical facilities of INTAL for the service of all the industry.

universities and research centres, enabling the use of their facilities and equipment.¹⁰³ Hence, the firm combined active and interactive sources of learning to facilitate its technical progress for doing research.

Among all the learning schemes, probably the most particular and specifically oriented towards supplier ingredient firms is the use of representations of highly recognized products from multinationals to promote and develop markets (schemes 8 to 10), these schemes are included in **the fourth group**. These representations are used as a knowledge bridge between these large multinational firms and a local small- and medium-sized food processing firms.

Representations (based on commercial relationships) were used as a vehicle for the assimilation and implementation of knowledge with suppliers and in some small cases with buyers. This group of learning schemes includes: the use of supplier representations to either support market diversification (8) or incorporate more technologically advanced components in production (9), and the use of specialized service providers (10) and commercial integration with retailers and clients (11).

From 1991, when the ISF was in its infancy (initial conditions), it started to develop its business by using representations, having been able to take full advantage of their products by developing a consistent technical strength in parallel. Supplier representations (8) were mainly used as a way of getting new business lines to market but also to improve the characteristics of the mixes (9). The firm has represented 23 large multinational firms from which it has learnt about the technological characteristics of a variety of components and all their possible uses in the market.

In most of the cases these interactions have gone beyond a commercial relationship, and so, from this learning scheme the ISF has been able to assimilate further knowledge through specialized training, internships and missions, opening up the door to advance their technological progress. This learning scheme has been an important source for the

¹⁰³ The first agreements were made with La Salle University and a research centre called the Corporation for Biological Research (CID: acronym is in Spanish) and these agreements enabled the use of specialized equipment to develop the microencapsulation technology.

systematic exploitation of technical knowledge.

Two other commercial interactions have also played a role as a learning scheme for the firm's technological development. The first relates to the contracts for technical services (10) used by the ISF to start the assimilation process of the metrology system that was later integrated into the routines and which became one of the peripheral technologies. As a learning scheme, the contracting of technical services served as the vehicle through which a group of firms transferred their calibration methods to the ISF, these being among the most important aspects of the metrology. The alliance with specialized equipment providers for the supply of customized devices was also counted as part of this type of learning scheme.

The second type of interaction that can be considered as a learning scheme was the commercial integration with retailers and governmental organizations to facilitate the promotion of some of the firm's products (11). These commercial interactions allowed the ISF to learn how to approach potential clients through certain distribution channels. Through its cooperation with these organizations, the firm acquired skills in marketing methods and allocation (distribution) systems, especially for those market niches in which the ISF was not sufficiently knowledgeable – e.g. nutritional products to final consumers,¹⁰⁴ cleaning and disinfection products and products for the textures market.

The fifth group of learning schemes refers to the integration of knowledge through the hiring of key specialists (12), their internal mobility (13) to go from one area to another, the contracting of external advisors (14) and the hiring of research-oriented personnel (15) The ISF has placed importance on the hiring of qualified engineers for the support and development of the business lines throughout its routines – i.e. production, E&D, sales and quality analysis areas.

Chemical engineers, food engineers¹⁰⁵ and microbiologists have extensively supported

¹⁰⁴ The ISF does not sell products to final consumers; however, it developed a product that created the opportunity to reach this market. But this did not mean a change in the strategic orientation of the firm. To maintain this market the firm started collaborative agreements with specialized retailers.

¹⁰⁵ When the firm was created there were no locally educated food engineers. The first programme of food engineering was actually partly motivated and promoted by the ISF. La Salle University

the ISF's development; these three types of engineers make up the firm's knowledge base (12). As the ISF gained experience and the diversification process across different business lines became more dynamic, more qualified personnel were needed to maintain the standards of the firm's teams and also to expand their knowledge base according to new requirements. In other words, the qualification of the firm through new personnel has responded to the requirements of the business lines specifically in two of the main areas: E&D and sales (to give technological support to clients).

Positions like the main manager and the managers of the E&D area, production, sales, laboratory, and international relations are considered key for the firm's development. The staff who have occupied these roles have been highly influential in the learning and technological progress of the firm. The more dynamic position among them has been the director of E&D; four persons within the firm have had this role, each one coincidentally marking a period of transition within the firm. The other positions have been relatively steady over the years (13).

Technical advisors have also been influential in the knowledge-integration strategy of the firm (14). These advisors have assisted the firm in the assimilation of solutions for a variety of technical problems as well as in its 'assessment (reflection) of divergent technologies and markets. Since the firm started, it has systematically relied on external experts for the implementation of management and operational practices (HACCP, ISO) to evaluate and standardize processes in the laboratory and in production, to improve the use of certain equipment and develop components. Moreover, these experts have also been hired for the development of research projects to tackle the technological and methodological aspects of these projects.

Furthermore, atypically for a medium-sized firm, the ISF has hired staff for the sole purpose of doing research (15). The firm has made an effort to be coherent and flexible by giving continuity, support and autonomy to this activity, although unfortunately this has not been a very systematic process. The firm has struggled over how to connect these explorative learning events in divergent markets and technologies with the firm's

launched this programme in 1991, when the first group of food engineers started, and the firm received the first engineers from this programme in 1994.

strategic orientation.

Knowledge has also been brought into the firm in the form of training in a wide range of learning schemes, which are included in **the sixth group**. In order to consider possible alternatives or courses of action in terms of technologies and market opportunities as well to as assimilate the procedures for the implementation of new methods of production, equipment and regulations (through operational, managerial practices or technical adjustments), the ISF has exposed its personnel to a systematic process of technical training (16) also supported the attendance at trade fairs and conference (17) and technical missions (18). In specific cases the firm has allowed some staff to do internships in other organizations (19) and sponsored the qualification through postgraduate studies (20). According to one of the managers these learning schemes have created a dynamic atmosphere within the organization and an attitude to openness that would has not been possible otherwise.

Technical training (16) has been one the most common vehicles used by the firm to assimilate change. Consequently this type of scheme has served as a bridge between the intention to modify any capability or routine and its actual implementation through other learning schemes; therefore technical training has been mainly exploitative. During the initial conditions of the firm and the period of formation, technical training was set in response to specific contingencies regarding technical problems. It was only in 1998 that the process started to be more formalized with the hiring of a human resources manager. But since 2001, when the quality certification programme was implemented, a systematic technical training programme was standardized and routinized in line with the needs of the various areas of the firm. Processes like HACCP, the information systems (APLINSA), the metrology programme and good manufacturing practices were initially assimilated by hiring external trainers and sometimes by using internal staff as well. In other cases technical training was part of the agreements with the suppliers represented by the ISF – i.e. the training represented an interactive source of learning.

Along with technical training the ISF supported the attendance of its personnel at international trade fairs and conferences (17). The firm has used this scheme to

monitor the technological progress and market tendencies in the industry so that the latter could eventually be reflected in its strategic orientation. Despite there being a standard annual routine to assist staff attendance at key trade fairs, this learning scheme was neither structured nor systematic and therefore staff were not able to take full advantage of it. It was only in 2005 that the firm started to plan this activity, a change in the procedure that created new business opportunities – for instance for the development of the new products and the use of better components.

In contrast to the previous types of training scheme, ISF has gone a bit further and has made some attempts to promote more effective flows of knowledge by sending staff on technical missions (18) and allowing them to do specific internships (19). In both types of learning event the firm has mainly gone to visit other organizations for the assimilation of alternative methods of production or the understanding of how to introduce new routines – e.g the metrology system. But it has also gone to research centres to explore new technologies, in this case to understand how natural flavours and natural dyes are used, which seems to be one of the next moves of the firm in the use of components.

The firm with this last scheme (of this group) had the intention of qualifying a group of people with the proper engineering skills, the firm has taken advantage of locally available postgraduate programmes specializing in food engineering (20). Chemical engineers in key positions, especially those who have been the director of the E&D area, have been supported in their pursuit of a formal qualification in food engineering, so that these engineers have been able to properly develop their new knowledge to respond to the conditions of the firm's technological routines.

The seventh group of observed learning schemes during the period of analysis refers to research activities (20, 21 and 22). The need for research arose because the firm was searching for technological independence from its suppliers; initially the research was more directed towards the identification of natural components from endogenous species for the formulation of the ingredients. The two main areas of research have been oriented towards flavours and dyes. The ISF has had a consistent approach to these explorative events over the last ten years. Regarding the scope in terms of the

methods and outcomes, the firm has developed three types of research projects: technical experimentation (20), experimental research (21) and engineering research (22).

The first attempt by the firm to do research is described as technical experimentation (20); it was intended to identify alternative solutions for technical problems arising out of the core technological routines. The events related to this type of research used trial-and-error methods for the experimental process, and they lacked rigor in the collection and analysis of data. The E&D area developed most of this first group of projects – i.e. the learning was passive – and they were far more market oriented rather than technologically based. However, these projects were considered as the first step towards understanding of research as part of the technological strategy of the firm.

As previously described, after 2001 the firm hired the first person to be fully dedicated to research. This particular event opened the door to the development of experimental research (21), which was separate from just solving operation and technical problems in production. This group of explorative events aimed to go one step further in the use of alternative technologies to obtain natural flavours and dyes. Given the time and effort put towards for the research process, these projects were more carefully conducted in terms of the methods of study. Moreover, the formation of the research area also coincided with the operation of Foundation INTAL, and in this way the collaborative research activities between these two organizations was started – i.e. this event represented an interactive source of learning.

In 2005 the ISF decided to strengthening its research area by forming a research team, creating the mechanisms to align its long-term strategic orientation with its research needs and creating a specific facility with specialized equipment for this purpose. Also the firm improved its collaborative relationships with local universities to develop joint research projects. These engineering research-oriented projects were cautiously designed to advance the technological knowledge regarding methods of extraction and micro-encapsulation. The result of this work was also aimed at the intellectual production of engineering knowledge beyond the specific requirements of the firm, allowing the firm to connect with the scientific community in these topics. However,

according to the research staff they are still in a process of acquiring research capabilities and these events are just the starting point in them becoming fully competent in research.

Table 6.2 summarizes the similarities and differences across all types of learning scheme through which the ISF has reflected, assimilated and implemented knowledge. The distinctions between all learning schemes can also be seen in terms of the orientation of the learning process (explorative or exploitative), the sources of knowledge (passive, active or interactive), the type of action implied (proactive or reactive), the implications of the knowledge to be integrated and the degree of formalization of the related events.

Table 6.2 Learning schemes and learning process

Learning schemes	Stages of the learning process			Orientation	Source	Type of action	Implications	Degree of formalization
	R	A	I					
Technical adjustments (1)		*	*	Exploitative	Mainly passive	Some proactive / some reactive	Adding techniques / adjusting routines	Tend to be project based / non-standard routine / systematic
Operational practices (2)		*			Passive		Evaluation and organization of production	
Managerial practices (3)		*	*		Mainly passive / few active	Proactive	Management-related issues, control and planning	Project based / non-standard routine / systematic
Product development (4)		*	*	Exploitative	Mainly passive	Mainly reactive / few proactive	Respond to existing market requirements / adjust components / market diversification	Project based / standard routine / systematic
Equipment acquisition (5)			*	Exploitative	Mainly active / few interactive	Mainly reactive / few proactive	Increasing capacity / efficiency / filling technological requirements	Tend to be project based / standard routine / systematic

Equipment mobility (6)			*		Passive		Efficiency	Tend to be project based/ non-standard routine /systematic
Specialized laboratory equipment (7)			*		Mainly active / few interactive	Proactive	Research purposes	Project based / standard routine/ systematic
Supplier representations (sales) (8)			*	Exploitative	Interactive	Proactive	Market diversification	Non-structured / non-standard routine / systematic
Supplier representations (production) (9)			*		Active		Adjusting components of the mix	
Contracting technical services (10)		*			Active		Quality purposes	
Commercial integration (retailers and clients) (11)		*	*		Interactive		Filling market and technological requirements	
Hiring key technical specialists (12)			*	Exploitative	Active	Mainly reactive	Adding techniques / adjusting routines / design products	Non-structured / standard routine / systematic
Internal mobility of key technical specialists (13)			*		Passive	Mainly proactive /few reactive		Non-structured / non-standard routine / systematic
Technical advisors (14)	*	*		Mainly exploitative	Active	Mainly proactive /few reactive	Evaluating technologies / adjusting routines / design products	Non-structured / standard routine / systematic
Hiring key researchers (15)			*	Explorative		Proactive	Identifying new extraction and preservative technologies	Non-structured / standard routine / systematic
Technical training (16)	*	*		Mainly exploitative	Mainly active / some passive / few interactive	Reactive	Creating skills	Structured / standard routine/ systematic
Assistance to attend conferences (17)			*	Exploitative	Active	Proactive	Market diversification / evaluating technologies	Non-structured / standard routine /

							tend to be systematic
Technical missions (18)	*	*	Mainly exploitative	Mainly active / few interactive	Proactive	Adjusting routines / evaluating technologies	Non-structured / non-standard routine / systematic
Internships (19)	*	*		Active		Adding techniques / evaluating technologies	
Specialized formal training (20)		*			Reactive	Creating skills	Non-structured / non-standard routine / systematic
Technical experimentation (21)	*		Explorative	Some passive / some interactive	Proactive	Evaluating components according to market requirements	Project based / non-standard routine / systematic
Experimental research (22)	*					Identifying new components	Project based / non-standard routine / non-systematic
Engineering research (23)	*					Identifying new extraction and preservative technologies	Project based / non-standard routine / systematic

Reflection "R"; Assimilation "A"; Integration "I"

Source: Based on data given by the ISF.

The evidence suggests it is possible to understand the KILS from the perspective of the learning schemes. According to the data provided and the description of the learning events, these learning schemes are certainly linked to particular stages of the learning process and they describe the characteristics of the type of knowledge they mobilize.

A more detailed explanation of the results shows that exploitative types of learning scheme tend to be associated with the process of assimilation and integration, while explorative types of event are linked to the reflective part of the process. Although it is possible to give evidence in some particular situations of the efficiency of the knowledge integration, the evidence does not reveal that a clearly conscious knowledge-integration strategy has been pursued by the firm. In line with the previous case, the relationship between the learning schemes and the learning process from

reflection to integration was effective in some of the reported events but weak in others. However, a historical analysis does reveal the logic that lay behind the sequence, as will be shown below in section 6.5.

This section has described the variety of learning schemes used by the ISF over its technological development. In addition it has provided evidence that each learning scheme has tended to be associated with specific stages of the learning process. The next section will explore the extent to which the complementary dynamic of these learning schemes, through the learning events, has leveraged the knowledge-integration strategy along the technological trajectory, resulting in a build-up of a variety of learning capacities over time.

6.5 Learning-capacity building and the technological trajectory 1987–2010

This section aims to offer a comprehensive picture of the firm's KILS from a historical perspective. So, it analyses the extent to which there was an interdependent relationship between different sources and orientation of knowledge through the learning schemes. The analysis is intended to give an understanding of the importance of learning-capacity building for the effectiveness of the technological transformation of the firm at each stage of its life cycle.

The interaction between the sources of knowledge – i.e. sources that were passive, active or interactive – and the orientation of the knowledge – i.e. whether it was exploitative or explorative – by the means of the learning schemes, as was shown in the previous case, illustrate the learning capacities. This section explores how the ISF has built up these learning capacities throughout the 850 reported learning events associated with the 23 learning schemes.

The evidence reveals how the ISF has gone through a particular path along the six learning capacities – i.e. those that are formative, adaptive, transformative, inventive, created and renewed – over the years (1987–2010). All these learning capacities were implicated in each stage of the firm's life cycle along the trajectory.

When the firm was first set up – i.e. during the stage of initial conditions (1987–1991) – it started to learn by using knowledge that could be considered exploitative from both passive and active sources. In other words, formative and adaptive learning capacities interacted during this first stage. In terms of learning dynamics the firm’s aim at this time was to achieve a sufficient level of efficiency for the establishment of operational routines that would guarantee market entry.

At this point previous management experience of the firm’s partners in the food industry combined with their knowledge of chemical engineering was determinant for the learning dynamics (i.e. for the comprehension of the knowledge required and the way it was integrated).

Groups of learning schemes that had **formative capacity** were undertaken by internal staff taking the initiative to make improvements based on their own knowledge and previous experience. This type of learning, when linked to implementation as part of the learning process, was frequently improvisational and took place ‘on line’, meaning it occurred while the operational routines were running. The evaluation happens *ex post* and so it could also be considered as a trial-and-error process. However, the reported events associated with formative-type capacities are not necessarily considered risky for the firm’s development even if further implementation was required as a consequence of adjustments in production.

According to the evidence, formative capacity also contributed to the assimilation of new capabilities and their integration into the routines, the development of formulas to fill gaps in the market and the diffusion of existing capabilities for the configuration of new business lines. So, this type of capacity and its corresponding learning schemes are linked to the assimilation and implementation of knowledge.

Formative learning capacity over the initial conditions in the firm’s life cycle was initially developed through two types of event. The first relates to the implementation of a market monitoring system to identify potential clients and set up the commercial strategy to break down market barriers – i.e. the events relate to managerial practices –

and the second was intended to develop the first type of products through imitation – i.e. to product development.

In advanced stages of the life cycle –i.e. formalization, establishment, expansion – the variety of formative learning schemes also included the flow of knowledge through equipment mobility, technical implementation, operational management implementation, internal mobility of key specialists and technical training; thus the learning capacity evolved in intensity and diversity over the years.

As long as the firm progressed, formative types of scheme were more frequently developed as a result of a systematic sequence. In these situations formative schemes were followed by schemes linked to other capacities (e.g. created or adaptive). In other words, when the firm lacked certain knowledge the reflection and assimilation part of the learning process involved active or interactive types of learning scheme, closing the loop in the integration process with passive type of schemes – i.e. those that had formative capacity.

Besides the influence that this type of capacity had on operational routines, formative learning capacity continued to play a key role in the development of market segments and the firm's diversification process along its life cycle. At the point of formalization, the emphasis of the formative learning capacities was on the assimilation and implementation of new products, which placed a significant responsibility on the firm's E&D area.

Adaptive learning capacity includes all learning schemes in which the firm intentionally searched for knowledge that was available in the market. This knowledge generally came from organizations such as equipment suppliers, research centres and independent technical advisors. Therefore market prices and contracts govern the value, scope and outcome of this knowledge flow.

As part of the learning dynamics and sequence, adaptive events are associated with the assimilation of alternative techniques and the integration of new capabilities for the mechanics of production and development of the business lines.

Adaptive learning events had been used for knowledge mobilization from when the firm's initial conditions were developed. At this stage the events related to this type of capacity aimed to foster production capabilities through the integration of equipment for supporting the mechanics of production and the quality and design area. Moreover, during this period the first supplier representation (see scheme 8 in Table 6.2) was acquired, in this particular case for purposes of obtaining better components for the mixes. In this sense adaptive- and formative-related learning events acted complementary to the KILS during the early years of the firm.

These types of learning scheme usually required more careful attention regarding their implications for the firm's strategic orientation, especially because of the way in which financial resources were allocated. So, after the formation stage, the firm started to formalize and introduce more procedures to justify these investments. In consequence the pattern of the interactions (between learning schemes) tended to be more systematic than discretionary over the transition periods. Also the evidence shows a complementary effect with other types of learning scheme.

As long as the firm grew and strategically decided to expand and diversify its market, more advanced techniques and equipment were required. While the learning dynamics (between formative and adaptive capacities) over the formation period just focused on the improvement of the efficiency and capacity of production, over the subsequent stages learning was also pursued to introduce new plant and business lines – i.e. learning then followed a complementary interaction pattern. So, additional adaptive types of scheme were used – e.g. contracting technical services, allowing internships, acquiring specialized laboratory equipment, hiring technical advisors, and assisting staff to attend trade fairs and conferences, go on technical missions and receive training (including of a specialized formal nature).

The use of adaptive types of scheme increased along the life cycle in intensity and variety. However, because the firm's operational routines were capital-intensive, equipment acquisition was the most influential learning scheme over the whole technological trajectory. The firm had also relied on technical training and the advice of

experts as vehicles for knowledge assimilation to further implement alternative techniques.

During its formation stage (1992–1996) the firm also started to carry out interactive-exploitative types of learning scheme to develop the so-called **transformative learning capacity**. The learning events associated with this type of capacity involved collaborative agreements through which the ISF intended to complement its lack of knowledge related to the development of certain routines. Among the purposes of using transformative-learning-related schemes was the implementation of alternative technologies embodied in the components to create better market recognition and the development of commercial capabilities by using other firms' distribution channels in which the ISF was not sufficiently knowledgeable.

The first collaborative agreements were with a specialized technical service supplier who provided customized equipment for production; the idea was to allow the ISF's engineers to be involved in the design of the machines and devices used for the production process and develop a kind of collaborative knowledge exchange between itself and the supplier. The interaction pattern between learning events to customize equipment could be considered discretionary.

During the same period the ISF undertook a technical mission: it visited a Cuban university in collaboration with the Nacional University (Columbia) for the purpose of developing an alternative technology for the production of breadcrumbs. This collaborative agreement was followed by a systematic sequence along the learning process. Hence, to accomplish the implementation of an alternative technology for a breadcrumbs plant and develop new capabilities for the generation of a new business line the sequence also involved the acquisition of equipment, the contracting of technical assistance (adaptive capacity) and technical adjustments (formative capacity).

The ISF also had an interactive agreement with INTAL allowing the transfer to the ISF of INTAL's technology on sensory analysis and microbiology. Through this joint agreement INTAL took over of the ISF's laboratory facilities and the ISF became a user of the technology. All in all, the link between the ISF and external organizations for this type of

learning exchange tended to become more stable over time, at least in the case of medium-term collaborative projects.

The transformative-related learning events were not particularly crucial for the ISF's technological trajectory, but the interaction model for the exchange of knowledge was considered an efficient 'win-win' learning dynamic. The sharing of equipment and facilities among organizations with complementary interests, and the use of distribution channels of one firm to sell recognized products from another firm, can be considered as two examples of the possibilities that interactive knowledge exchange has for the upgrading of capabilities for partners.

Moreover, large multinational ingredient supplier firms, as mentioned above, had a specific type of interactive learning dynamic with the ISF through a type of scheme referred as 'supplier representation' (see scheme 8 in Table 6.2). This scheme has allowed the ISF to have access to technologically recognized products from international firms, but more importantly, through these agreements the firm has had the opportunity to receive specialized training and get closer to how this technology has developed by going on technical missions. This type of scheme was considered as a technological bridge between international and national firms. According to the evidence transformative types of event revealed a systematic interaction pattern, especially with formative- and adaptive-relative learning events over the subsequent stages of the firm's life cycle.

Up to this point (1987–1996), the ISF had focused on building up its exploitative learning capacities. During this first decade its learning-driven motives were mainly oriented towards guaranteeing the sustainability of the business. The firm believed that sustainability could be achieved by understanding and improving the operational routines required to efficiently perform as a supplier ingredient firm and by developing a specific market segment in which it could be recognized for the quality of its products and technical support against its competitors. Despite the incipient learning trajectory the events depicted a systematic and in some cases a complementary interaction pattern between the three learning capacities – i.e. formative, adaptive and

transformative – in which the firm, although not completely consciously, combined passive, active and interactive knowledge.

From 1997, when the firm reached what could be considered an established position in the industry, the managers started to search for new market segments. The firm's learning-driven motives were shifted towards market and production diversification in combination with the search for technological independence from suppliers.

This period (1997–2004) marked the first explorative learning events. As described above the firm's research activities could be considered as falling into three categories: technical experimentation, experimental research and engineering research.

The firm initially approached research through technical experimentation motivated by the identification of new components from natural and endogenous sources through a project developed in 1997. The process was rather arbitrary with regards to the trajectory, but the capabilities of the firm to undertake this endeavour and its earlier strategy made the research feasible and enabled it to be part of the technological projection. Significantly, this project represented the first step towards developing the firm's **inventive learning capacity**.

Over this period the ISF's managers started to receive more international exposure; this was increased over the years by the firm paying for their attendance at trade fairs and by them visiting international suppliers' facilities (these events showed adaptive and transformative capacities). Through these events the ISF had the opportunity to learn from other firms' experiences, from which it understood the need to formalize its own R&D area.

Moreover, although the earlier inventive type of event did not have the expected results, it made them recognize the implications of doing engineering research in terms of the capabilities and dedication required. Then, based on what the firm had seen during visits to international firms, and its own experience, in 2001 the strategic decision was taken to incorporate research capabilities into the firm.

The firm gave more support and importance to research through the hiring of a person solely for this activity, developing what has been defined as the **created learning capacity**. This event was intended to properly initiate the development of research capabilities within the firm. Nevertheless, two problems were identified from the evidence. First, this person did not have previous research experience, meaning that he learnt at the same pace as the firm. Second, this activity started to be undertaken completely separately from the other routines, without a strategic plan behind it.

The newly hired person focused on the exploration of a new technology for flavour extraction, initiating a project in this area – i.e. undertaking experimental research. From these two events the presence of two types of interaction patterns was revealed. The hiring of a full-time researcher and the subsequent support to develop an experimental research project exposed a systematic interaction pattern between these two explorative events (active– passive sources of learning). But the firm did not pursue the learning sequence any further in the following years through other exploitative learning schemes, and so, after the first two events (which turned out to be arbitrary), the interaction pattern between explorative and exploitative learning capacities was rather non-existent.

Over the following period of expansion (2005–2010) research activities became more formally developed. During these years the firm also obtained external support to improve the direction of its research projects regarding the development of technological knowledge and methods through technical training, specialized formal training and by using advisors from universities. Moreover, from 2006 a new group of engineers were hired as researchers to foster the development of new projects and increase the pace of the identification of components – these events are examples of created capacity. As a result the projects responded better technically and methodologically to the engineering progress of the firm and started to contribute to the technological problems of the industry, and so this research was considered experimental and engineering.

The firm also developed the initial conditions to better align and coordinate these activities towards the strategic direction of the firm. Consequently, the interaction

pattern between passive and active explorative events became more systematic. Considering explorative and exploitative interaction, the evidence shows that the interactions between R&D and E&D was also more comprehensive.

The ISF also began to develop closer relationships with technological centres and universities which enabled it to undertake research activities. In the specific case of the universities, although the ISF promoted and pursued these interactions, not all of them went beyond project design stage. INTAL became the natural partner for this purpose. This group of events enabled the ISF to make scientific progress towards solving engineering problems for the food industry at least as fast as other local knowledge providers.

According to the ISF's managers, the purpose of the firm's interactions with universities, apart from gaining proper scientific support for its research projects, was to take advantage of their research facilities and get access to specialized equipment that would have been less feasible otherwise. Furthermore, the ISF was keen to improve its technical recognition, which it could achieve through this type of interaction, and therefore to gain a good reputation not just with current clients but also with potential clients who might even be among graduate students.

Hence, **renewed learning capacity** was mainly developed through experimental and engineering research projects undertaken between the ISF and INTAL. But this interaction began to be more useful for the management of the research rather than for the engineering support that these external organizations might provide for research problems. The engineering research experience offered by the ISF in these group of projects was by far more important for the scope and outcome of the research than the input the firm received from its external partner.

As a result, in essence there was little difference between these types of interactive explorative events and those that were inventive. These projects therefore did not offer the platform and the proper engineering understanding to enable the firm to jump to the next step in its technological strategy (as the firm had hoped they would), and from this observation, the events can be regarded as examples of renewed learning capacity.

Even though these interactive research experiences did not generate the projected outcomes, the firm gained experience of how to coordinate this activity within itself. All explorative events at this last observed stage of the firm's life cycle differ from the previous stage (establishment) in that they were formulated to respond to a long-term technological strategy. The firm also created other means – e.g. monthly reporting meetings, advisory committees – to generate a higher level of awareness over how to take proper advantage of these explorative events in changing the firm's trajectory, but more importantly to advance its technological independence.

As explained above, over these last two periods the firm kept mobilizing knowledge for the creation of new business lines and developing new capabilities through the design of products, and simultaneously implemented alternative techniques so that its operational routines could efficiently respond to current and new market demands.

The evidence reveals how each learning capacity contributed to the KILS, but not independently. The interaction patterns between exploitative passive, active and interactive learning events along the firm's life cycle were in some cases complementary (stage of initial conditions) but in others (stages of formation and establishment) the evidence revealed a systematic interaction. Discretionary learning events were also identified over the whole learning trajectory. In contrast the explorative interaction pattern was initially discretionary and then slowly moved towards being systematic.

Moreover, the exploration–exploitation interaction pattern has mainly been discretionary. Nevertheless, the firm has been moving over the last periods of its life cycle towards a strategic approach in which short- and medium-term requirements are distinguished from long-term orientations, and so managers have been carefully creating the conditions to introduce the required learning dynamics to promote changes in the operational routines based on the outcomes of the explorative events.

The evidence supports the existence of a sequence that links the learning schemes with the learning process and the iterative relationships of all learning capacities along the

trajectory. Exploitative and explorative learning schemes from different sources – i.e. passive, active and interactive – once started, were deployed simultaneously.

Therefore, the importance of the evidence relates to the complementary and iterative dynamic between the six learning capacities throughout the learning trajectory. However, in line with the previous case, the learning trajectory was not necessarily a comprehensive process for the firm’s managers as shown in Table 6.3.

Table 6.3 ISF’s learning-capacity building 1987–2010

Learning capacities	Learning trajectory			
Renewed capacity				Engineering research Experimental research Technical experimentation
Created capacity			Technical training Hiring key researchers	Technical training Hiring key researchers
			Specialized formal training	
				Technical assistance Internships Technical missions
Inventive capacity			Technical experimentation Experimental research	Technical experimentation Experimental research
				Engineering research Technical training
Transformative capacity		Commercial integration Technical missions	Commercial integration	Commercial integration
			Equipment acquisition	Equipment acquisition
			Supplier representation	Supplier representation
			Technical training	Technical training
			Product development	
				Specialized laboratory equipment
				Technical adjustments
Adaptive capacity	Equipment acquisition Hiring key technical specialists Supplier representation	Equipment acquisition	Equipment acquisition	Equipment acquisition
		Hiring key technical specialists	Hiring key technical specialists	Hiring key technical specialists
		Supplier representation	Supplier representation	Supplier representation
		Technical training	Technical training	Technical training

		Assistance to attend trade fairs and conference	Assistance to attend trade fairs and conference	Assistance to attend trade fairs and conference
		Technical missions		
		Technical assistance	Technical assistance	Technical assistance
		Specialized formal training	Specialized formal training	
			Infrastructure improvement	
			Specialized laboratory equipment	Specialized laboratory equipment
			Managerial practices	Managerial practices
			Internships	Internships
Formative capacity	Managerial practices	Managerial practices	Managerial practices	Managerial practices
		Technical adjustments	Technical adjustments	Technical adjustments
	Product development	Product development	Product development	Product development
		Equipment mobility	Equipment mobility	
		Operational practices	Operational practices	Operational practices
			Internal mobility of key technical specialists	Internal mobility of key technical specialists
	Technical training	Technical training		
Firm's life cycle	Initial conditions: 1987 - 1991	Formation: 1992 - 1996	Establishment: 1997 -2004	Expansion: 2005 - 2010

* The parts of the table marked in red represent the period in the firm's life cycle in which each learning capacity started to be developed and shaped the learning trajectory of the firm

Source: Based on data given by the ISF

In summary, the learning interaction pattern between the six learning capacities over the ISF's life cycle describes its knowledge-integration strategy. As discussed in this section, the evidence largely depicts a 'path-dependent' trajectory regardless of the operational and commercial breakthroughs. The main shift in the trajectory is seen through plant diversification, the extraction and use of natural components to replace those that are artificial, and the use of alternative and more advanced preservative methods (micro-encapsulation). Thus, the firm has been encouraged along its learning and technological trajectories by the enhancement of its technological routines but, more importantly, by the development and diffusion of capabilities allowing it to take advantage of all the technical possibilities and to fulfill new market requirements.

This functional relationship between the iterative sequences in which the KILS occurs exhibits three features in relation to the firm's technological trajectory – i.e. efficiency, coherence and flexibility.

The extent of efficiency describes the degree of interdependency along the sequences of the knowledge-integration strategy over time. The evidence reveals three types of interaction patterns between all the learning capacities. During the initial conditions the two types of capacities had a complementary interaction regarding the implications for the firm's technological requirements. During the following stage (formation) the interaction was mainly systematic, although in some events the evidence shows a discretionary pattern between the three types of capacities (formative, adaptive and transformative). Up to this point the firm's learning endeavour was exploitative.

Explorative events were introduced over the succeeding stages as was described above. While exploitative capacities kept moving systematically, explorative events were first discretionary before showing a complementary pattern.

The explorative–exploitative interaction pattern was certainly discretionary; only at the very end of the observed period did the firm adopt a strategic approach in which short-term requirements were aligned with medium- and long-term technological opportunities. Hence, in line with the previous case, this sequence exhibits an iterative knowledge-integration process.

The way in which there was movement from one context to the next provided evidence of some coherence with regards to the strategic intentions of the firm. At each stage of the life cycle there was a specific context in which the firm went on to develop the learning conditions to respond to that single technological demand. Nevertheless, strategic choices were also combined with contingencies (situations that were not intended by the firm) and opportunistic situations.

The direction of the technological strategy – i.e. whether the strategy considered (or placed importance on) core competence, was addressed to develop market opportunities, or showed evidence of strategic focus– was also identified. In line with

the technological requirements, at each specific stage in the life cycle the firm focused on certain strategic choices. During the stage of initial conditions, achieving a minimal operational efficiency for the established routines was the firm's main concern, and so the learning efforts were made to constitute the core competences. Once this stage was over the ISF searched for new products as well as industrial applications; at this point the learning choices were also driven by new market opportunities.

Over the next stages in its development, the ISF started to move towards technological divergence of its operational capabilities, including taking a long-term technological perspective. All in all, along its trajectory the ISF has combined short-, medium- and long-term strategies. Table 6.4 summarizes the implications of the learning-capacity building on the technological trajectory at each type of learning capacity over the firm's life cycle.

Table 6.4 Learning-capacity building and the technological trajectory 1983–2010

Learning capacities	KILS			
Renewed capacity				Technology: natural components
				Knowledge integration strategy: assessment of new technologies
				Knowledge and capabilities:
				- Alternative techniques to use natural/endogenous components
				- Evaluation of natural components - Technologies for micro-encapsulation
Created capacity			Knowledge integration strategy	Assessment of new technologies
				Routines: - R&D routines
			Knowledge and capabilities:	
			- Alternative extraction techniques to use natural/endogenous components	
			Inventive capacity	
Knowledge integration strategy	Assessment of new technologies			
Knowledge and capabilities:	Knowledge and capabilities:			
- Alternative extraction techniques to use natural/endogenous components				

Implementation of alternative techniques>>>>>>			
Routines:	Routines:	Routines:	Routines:
- Production routines to process mixes for the meat market	- Production routines to process mixes for the breadcrumbs and textures market	- Production routines to process mixes for the sauces market	
- Technological assistance to clients	- Trials for the development of formulas	- Metrology analysis	
	- Coordination and resource management routines	- Commercial routines for the development of new business lines (nutritional line, ingredients and additives, dairy milk)	- Communication and marketing routines
Knowledge and capabilities:	Knowledge and capabilities:	Knowledge and capabilities:	Knowledge and capabilities:
- Protocols of production	- Protocols of production (advanced equipment for efficiency)	- Adjustment of protocols of production (alternative techniques, new components, advanced equipment)	- Adjustment of protocols of production (new components, advanced equipment)
	- Technology and market monitoring system	- Commercial protocols for generation of new business lines (nutritional line, ingredients and additives, dairy milk)	- Commercial protocols for generation of a new business line (gastronomy)
- Minimal requirements of quality analysis	- Use of advanced equipment for quality analysis	- Use of advanced equipment for quality analysis	- Use of advanced equipment for quality analysis
		- Protocols for metrology analysis	- Protocols for metrology analysis
	- Protocols of production for a new plant (equipment to produce breadcrumbs)	- Protocols of production for a new plant (equipment to produce sauces)	

	- Commercial orientation and identification of the market opportunity	- Protocols of production for new plant (knowledge diffusion: mobilizations)	- Protocols of production for new plant (knowledge diffusion: mobilizations)	- Communication and marketing protocols
		- Coordination management system (PROINFAC)	- Coordination management system (ISO 9001; good manufacturing practices, sales system, APLINSA)	- Coordination management system (new strategic orientation of the firm, web applications and sales forecast mechanisms)
		- Development of formulas through market requirements		
			- Development of new formulas for the market	
Direction	A focus on core competences	A focus on core competences Complementary direction on: Market opportunities	A focus on core competences Complementary direction on: Market opportunities Strategic focus	
Firm's life cycle	Initial conditions: 1987-1991	Formation: 1992-1996	Establishment: 1997-2004	Expansion: 2005-2010

Source: Based on data given by the ISF

This section has described the process by which the ISF went through the learning capacities over the learning trajectory, providing evidence of the interdependency and functional relationship of the different capacities with the technological trajectory as part of the KILS. The final section will offer conclusions on, and a summary of, the case's analysis to provide a comprehensive picture of how the evidence reveals the ISF's KILS as illustrated by the learning dynamics (i.e. learning schemes, learning processes, learning sequences), and learning capacities (i.e. their sources and orientations).

6.6 Summary

Along with the previous case, the evidence provided in this chapter helps to complete a comprehensive explanation on how the sources and the orientation of knowledge interact over time.

By using a historical perspective, the learning trajectory was traced, outlining the process of capacity building, the learning sequences and the functional relationship with the technological trajectory and discussing whether this relationship showed efficiency, coherence and flexibility. This approach has allowed an understanding of how the firm – from its inception and throughout its lifecycle (i.e. during stages of initial conditions, formation, establishment, expansion) – required a variety of learning events for the KILS under different technological settings. This analysis has also enabled some reflection on the level of interaction among the different learning schemes.

The co-evolution of the firm's learning and technological trajectories has been in line with the conditions of the market and showed the technological context in which the ISF has played a key role over these years. On the one hand, the ingredient supplier industry has moved from a small number of large multinationals firms to a greater number of small- and medium-sized local firms. On the other hand, the market has moved from being concentrated into a small number of larger food processing firms with a focus on the meat industry to a larger number of small- and medium-sized firms in a variety of industrial applications.

These situations have also created challenges for knowledge and technological providers who started to learn and develop the technological requirements hand in hand with the emerging local industry. Although the market and technological context have become more demanding, consistent and systematic over the last years, most of the firm's learning and technological trajectories have occurred within a 'moderately dynamic market' and out of incipient 'technological opportunities'.

Within this context, over the observed 23 years (1987–2010) The ISF has pursued its market and technological development throughout 850 learning events grouped into 23 learning schemes. The evidence supports the previous proposition that there is a dependent relationship between the learning schemes and any of the stages of the learning process which defines the scope and outcome that a particular event has on the conditions of change of the core and peripheral technologies.

However, the evidence also describes that the learning process through the learning events does not need to have a continuous progression. Some learning events were characterized for being improvisational, on line and having an *ex post* assessment; other events related to the introduction of alternative techniques started from an assimilation process which led to a more careful understanding of the capabilities required before they were implemented into the routines. According to the data, reflective events were more closely related to the assessment of new technologies and the search for long-term technological opportunities that were not necessarily ready to be implemented. These events were associated with learning schemes defined as technical experimentations, experimental research and engineering research.

The historical analysis has helped to describe how the ISF went through a particular learning path over its life cycle, starting from the development of formative and adaptive capacities, moving through to having transformative capacity, and once the firm was established, displaying inventive, created and renewed learning capacities. In line with the previous case the development of each level of capacity through the learning schemes was not the most important aspect, rather what mattered was the relationship between the capacities.

The learning trajectory was explained in terms of the efficiency, coherence and flexibility of the technological trajectory. Although the firm experienced some contingencies and opportunistic situations, the rationale behind the learning dynamics and technological changes were consistently followed by technical recognition and market diversification. By looking at the level of efficiency the evidence revealed three types of interaction patterns among all learning capacities. Between exploitative types of capacities the firm combined complementary and systematic learning interaction patterns with some discretionary events along the trajectory. In contrast explorative capacities moved from discretionary to complementary interaction patterns. The explorative and exploitative interaction pattern was still discretionary.

As illustrated by the evidence, organizational features such as the decision-making process and the MLMs also condition the KILS. Although the evidence suggests that the firm did not follow a comprehensive KILS, through its actions it has been searching for assertiveness. Also, the type of knowledge base – e.g. chemical engineering – has to a certain extent allowed the firm to have some versatility and therefore to advance further in the diversification process. At the same time, given the conditions of the production system the evidence suggests that the technological settings are sensitive to the learning dynamics. These characteristics explain to some degree the rate and pace of change along the technological trajectory.

In terms of the coordination process, the firm has experienced three main organizational transitions. Regarding the administrative procedures, the ISF went from administrative dependency towards autonomy (1987–1991 onwards). In terms of the management of information, the firm developed the tools and protocols to go from centralization to dissemination of information (1992–1999 onwards). Finally, regarding the decision-making process, the firm moved from a restricted to an inclusive management approach (1992–2005 onwards). Although the structure was arranged to mainly respond to the requirements of the production system, it has been adapted to fit in with the creation of new areas and certification requirements. All these changing conditions in the organizational settings were also generated in response to the growing process of the firm over the years.

The cases in Chapters 5 and 6 complete the empirical evidence that provides the basis for the cross-case analysis that will be the focus of the next chapter. This analysis compares two engineering-oriented, established SMEs, one in the food industry (chemical and food engineering) and the other in the agricultural fruit industry (agricultural engineering), both with similar market and technological contexts, and with slightly analogous organizational settings, with the aim of identifying certain patterns in the process of learning-capacity building and the relationship between the learning and technological trajectories.

7 TWO ESTABLISHED SMEs: PATTERNS IN THEIR LEARNING-CAPACITY BUILDING AND TECHNOLOGICAL TRAJECTORIES

7.1 Knowledge-integration and learning system (KILS): singularities and shared conditions

The empirical evidence just provided by the two individual cases presents the interaction of two combined characteristics of the knowledge-integration process: the first is referred to as 'knowledge reconfiguration' and the second as 'knowledge orientation'. The analysis highlights the relevance of these two characteristics for knowledge integration and learning, emphasizing the process of learning-capacity building. It aggregates knowledge integration, learning and capacity building in the same analytical complex.

The analysis of the cases proposes to define the term 'knowledge-integration and learning system' (KILS) as the platform in which evolving processes of the learning capacities occurs through the use of a variety of learning schemes at their disposal. By developing the KILS, firms are able to internalize new knowledge from different sources to mobilize their operational interpretative system to fit their strategic orientations. Indeed, firms develop their KILS based on how able managers are at different moments in the firms' life cycles to coordinate new internal and external knowledge and maintain their production system competency in the market. As a result technological developments and commercial opportunities fit together.

The KILS indicates that firms have different levels in their learning capacities based on the evolving process not only of their capabilities and routines but also of the market and technological conditions. Moreover, it emphasizes the importance of retrieval and diversity of the learning events in the building up of these learning capacities.

The firms, as described, were strategically chosen as case studies because of the potential they offered for the understanding of the KILS under atypical learning

conditions for the technological and market context.¹⁰⁶ The selected firms showed two important conditions. First, they carried out collaborative R&D projects; in this sense evidence of knowledge reconfiguration through interaction was provided. Second, although each of them had made use of mature technologies to perform in their respective markets – i.e. the propagation of plants and the mixing of ingredients for food processors – they had searched for emerging complex technologies - i.e. inurement techniques through etiolation in the case of the NSF and technologies for micro-encapsulation and techniques for the extraction of natural/endogenous components in the case of the ISF -, and the subsequent transition in their knowledge orientation from exploitative to explorative was observed.

The relevance of these two cases for the analysis of the KILS departs from the distinction made by Boer et al (1999) between mature industries and emerging industrial complexes. While firms within mature industries normally focus on a single technology, firms that are part of industrial complexes use technologies from various science or engineering knowledge bases which converge into hybrid forms. Commenting on the work of Van den Bosh and De Man (1997), Boer et al (1999) claimed that single mature industries with well-established production systems, steady directions and competition tend to be defined by cost. In contrast, complex industries where standardization is low and the levels of uncertainty are higher, competition is dependent on differentiation (ibid. p. 388).

These two firms were making the transition towards an emerging technological-industrial complex (as biotechnology can be defined), although they were in the very early stages. The analysis has focused on the evolutionary processes that caused these firms to move towards this transition at a certain point in their life cycles.

The understanding of this evidence also shows how these firms moved forward to adapt their interpretative system in a way that enabled them to arrive at a point where they could diversify their component knowledge. This could be identified as a real challenge for well-established firms, which in the case studies for this thesis happen also to be

¹⁰⁶ The two firms perform within a market considered as ‘moderately dynamic’ (Eisenhardt and Martin, 2000) and emerging in its ‘technological opportunities’.

SMEs. The evidence suggests that the way in which established firms are able to cope with technological discontinuities so to as anticipate or confront competition from new entrants allows them to maintain their strength and position within the market. Consequently, the development of related learning experiences give firms a 'sense of opportunity' and advantage over new competition.

Although both firms were still considered SMEs, they have survived for more than 20 years; also both firms had increased their sales over the period of observation by an average of 15% (NSF) and 52% (ISF) per year. Additionally, these firms were considered pioneers and technological leaders in their local industries.

Considering their level of performance, the question for the study focuses on how they managed to coordinate their KILS to fit their technological platform (capabilities and routines) to the market requirements. As evidenced by the cases, learning motives were not all about achieving performance; they were also about exposing the firms' knowledge bases and understanding their operational routines and experimentation. In both cases assuring credibility and making the best use of the routines to reduce their risks were the main learning-driven motives, and even in the early stages of their life cycles there was a combination of efficiency and technical satisfaction (Winter, 2000). Moreover, from their beginnings both firms defined quite differentiated market segments and business models focused on offering technological support rather than just products (see table 7.1). This shows that technological development for achieving competitive advantage (considered the result of knowledge integration and learning) is a considerably more complex behavioural phenomenon for firms than just economically driven motives.

Table 7.1 Learning motives

Features	NSF	ISF
Risks	<ul style="list-style-type: none"> • Lack of market recognition of the technological settings • Uneven technical, engineering and scientific knowledge 	<ul style="list-style-type: none"> • Low recognition of different standards in the technological settings • Emerging technological

	available in the local opportunities context ¹⁰⁷
Learning-driven motives	<ul style="list-style-type: none"> • Search for market recognition and access to knowledge • Search for versatility of their knowledge bases • Limiting the unpredictability of the production system <ul style="list-style-type: none"> • Technical recognition and the search for assertiveness • Diversification and the development of market segments

Source: the author

Through their increasing learning dynamics and retrieval of some of the learning events these two firms showed to some extent two main attitudes. Both firms had an attitude towards learning where failures were not necessarily considered obstacles; they both also displayed an attitude of constantly searching for technological and market opportunities. In the nursery seedling firm (NSF) it was more relevant as they did not have a role model to follow, unlike the ingredient supplier firm (ISF), at least during the first two stages. In any case these two attitudes of both firms' managers were considered decisive for acquiring and developing learning capacities.

Other similarities between these two firms have been already acknowledged, such as their position in the value chain (as specialized suppliers), which is associated with the business model (being focused on offering technical solutions), and their tendency towards a specific organizational form (the machine bureaucracy), which is related to their engineering orientation. Nonetheless, their main distinction lies in their principal engineering knowledge base and the characteristics and use of their technological platforms as shown in table 7.2.

Table 7.2 Characteristics and use of the technological platform

Features	NSF	ISF
Mature single technologies	<ul style="list-style-type: none"> • Agricultural engineering (principal) 	<ul style="list-style-type: none"> • Chemical engineering (principal) • Food engineering (principal)
Technology/market	Production of certified propagated plants of perennial fruits; consists of	The development of formulas and protocols of production to provide all

¹⁰⁷ According to Huber (1991) knowledge available in the context can be characterized by its completeness, lack of bias and clarity. When this knowledge is considered uneven this means that it is incomplete, biased and ambiguous.

	the identification of the appropriate varieties, and multiplying them under certain environmental conditions and replicating their genetic characteristics to guarantee to farmers a specific level of efficiency, resistance of the plant and quality of the fruit	kinds of technical solutions for flavouring, consistency, durability and texture of a variety of products for the food processing industry for human consumption
Core routines	<ul style="list-style-type: none"> • Plant propagation technologies • Selection and collection of varieties • Cleaning of the mother plants of potential virus 	<ul style="list-style-type: none"> • Mechanics of production to manufacture mixes • Development of natural and chemical components • Quality analysis system
Peripheral routines	<ul style="list-style-type: none"> • Substratum development • Irrigation system • Agricultural practices • Production plan 	<ul style="list-style-type: none"> • Information system technologies • Metrology system • Maintenance system • Development of a set of sales practices
Alternative complex technology	<ul style="list-style-type: none"> • Advanced biotechnological techniques for propagation • Chemical engineering (complementary) • Microbiology 	<ul style="list-style-type: none"> • Biotechnological techniques for extraction of natural components and micro-encapsulation techniques • Microbiology (complementary)

Source: the author

Clearly these specific peculiarities create differences in the dynamics of the KILS regarding the intensity of, and specificity in, the use of certain learning schemes to assure the firms' technological transformations, as was described in the analysis of the individual cases. However, the underlying question refers to what counts as each firm's learning capacity in the KILS at any point in time once the interaction of knowledge reconfiguration and orientation is understood.

Thus, the evidence suggests that the way firms coordinate their KILS by developing a balance-imbalance in the knowledge reconfiguration and orientation could be considered a very important factor in their survival. The following sections focus on exploring the evolving dynamics of the KILS of the two established SMEs that were chosen for the study so to as develop theoretical insights into how these firms have managed to coordinate their KILS and develop a sense of opportunity.

7.2. Coordination and the learning schemes: transferability and appropriability

The argument as discussed so far proposes that the learning schemes are the foundation of the KILS. As shown by the evidence, the dynamics of the KILS are represented by the intensity of the learning events and the variety of learning schemes that these firms used and have had at their disposal at certain points in time for knowledge integration.

For nearly 30 years each of these firms managed to develop a broad range of mechanisms from which they were able, through the learning process, to combine embodied (tacit-individual), embedded (tacit-collective) and encoded (explicit-collective) knowledge to make the transit between cognitive and behavioural changes. Coordination at this level refers to how the learning schemes, as a vehicle to integrate new component knowledge, are used to solve the problem of transferability and appropriability.¹⁰⁸ But more importantly, it relates to how firms are capable of understanding the particular role of each scheme within a specific temporal and strategic context and how it fits their interpretative system.

The evidence from these two cases implies that firms' learning efforts aim to diminish the ambiguity in their interpretative system, which is translated into how they maintain or modify their operational systems. In this sense it is suggested that differences between competitors are based on how ambiguous the operational system is for key members of the firm. It is inferred somehow that the faster the firm achieves common ground in its operational interpretative system in line with its strategic intentions the better it recognizes the direction taken in the market and the technological trajectory. This part of the suggested evidence is in line with Szulanski's (1996) proposition in which firms enhance their learning system if they are able to avoid 'causal ambiguity' and became more rational in the process of testing the usefulness of the component knowledge with regards to the applicability of their routines and the strategic possibilities.

¹⁰⁸ Knowledge in both firms mainly remained as embedded but it came about in multiple forms.

During the building of their learning capacity, firms tend to understand that learning events are not isolated from each other. The way an interrelated sequence throughout the learning process is assumed is likely to depend on the type of knowledge and how far this knowledge is from the cognitive characteristics of the firm in order to modify behaviours. The descriptions of the firms' learning events show that learning tends to be conceived in action and practice; therefore decisions are taken as part of the learning process. Learning-before-doing, as Pisano (1994) has suggested, is not that common a practice although when firms follow it, as evidenced through some events, they are more likely to achieve efficiency in their technological transformation.

The cases give evidence on which learning schemes served which purposes at different moments in time, and also show how the firms tended to rely more on certain mechanisms over others (see tables 5.4 and 6.4). Three factors are particularly relevant to the understanding of how the firms differed (or not) in the way the schemes were deployed and coordinated. The first relates to the mobilization among different forms of knowledge – i.e. knowledge conversion. The second refers to whether the methods were driven by a formal or informal individual – i.e. was an expert used as the point of reference or was a participative system used, or indeed a combination of both? (See Prencipe and Tell (2001) and Hislop (2003).) The third refers to the dynamics and interaction patterns over the stages of the learning process – i.e. reflection, assimilation or implementation – in relation to how far is the cognitive (information) from the behavioural (know-how) component of knowledge. Whether the schemes were formally routinized as a learning practice and consistently used for different purposes also demarks a key aspect that should be acknowledged.

As engineering-based firms, learning transfer in both of them tended to move from any form of knowledge towards embedded knowledge. The inclination was then for routines to be conceived under the same technical principles or, as engineers, this is what they believed had happened. However, as routines became firm-specific because of experience and strategic market orientations, asymmetries in individuals' interpretations became greater. And so, the challenge for these firms was related to them understanding how to move from embodied (tacit-individual) to embedded (tacit-collective) knowledge, as maintaining a certain level of tacitness was relevant while

they implemented new knowledge – i.e. ensuring its appropriability. Thus, information which entered these firms tended to be objectively transformed because the technical engineering principles had to be maintained, but it was socially approved when it was satisfactorily absorbed into the routines.

This movement from individual to collective-tacit knowledge became an intuitive behaviour in these firms' learning patterns with regards to how they managed the learning schemes.¹⁰⁹ SMEs that are engineering based particularly tend to protect and value technical achievements through learning schemes in this way. Tacitness is even more relevant if the regulatory framework with regards to market standards and recognition from customers are poorly facilitating imitation from competitors or even from clients who might be able to pursue an integration strategy. Nonetheless, in both cases the focus of both firms was to have the same state of knowledge about the operational routines; their concern was not imitation, but recognition and value, and they did not consider competitors.

In the case of the NSF, maintaining a high level of tacitness was even more justified than in that of the ISF, as propagation technology relies more on a soft type of knowledge (know-how). As a result technical adjustments were the predominant scheme for the NSF over its learning trajectory but this was also the case because these events became part of the firm's common practices, and therefore its culture. It was expected that individuals would avoid conformity regarding the performance of the routines and that they would search for satisfactory ways to get better results.

Technical adjustments were in general terms quite a successful form of scheme in the NSF. These types of event are considered tacit and embodied in the expertise of individuals; however, the challenge throughout the coordination process consisted of incorporating this knowledge into the routines – i.e. making it embedded. This scheme

¹⁰⁹ Other types of firm might face different problems in terms of knowledge transfer. Firms face different ways of achieving coordination according to the nature of their technology, the regulatory framework in which they are immersed, and the market conditions. For instance firms might apply coordination mechanisms in which they need to mobilize explicit types of knowledge to codify knowledge so the market will recognize the standards, and there is an understanding that one of the implications of technological development is that firms are willing to pay through licence or other forms of market governance.

worked very well because of the decision-making process and the level of autonomy of the staff members. The firm's manager empowered the workers to put into practice their own experiences at solving problems regarding the functioning of the operational routines. Also, the decision-making process in the NSF was considered to be participative in the majority of the cases, and therefore the expertise of each staff member did matter.

In the case of the ISF, technical adjustments were important but not that common; as an ISF, its focus was more on the development of the hard parts of the technology, the mechanics of production being the most important aspect of the technological development. In addition, because learning was mainly pursued by the main managers, adjustments in the operational routines were more carefully undertaken and less frequent. As a result equipment acquisitions were the most common scheme for the ISF, favouring in this case the transfer of learning from embrained to encoded knowledge. Advantages regarding the appropriability of this type of knowledge came from the investment in advanced technological devices leading to efficiency and production capacity. Clearly this was not the case for the NSF.

The evidence suggests that in general firms should attempt to develop mechanisms and processes at the level of the component knowledge that allow them to run online and offline tests to their operational routines, as learning-by-doing might not be a sufficient process to achieve a clear understanding of how the technology in used and procedures (production) in connection to market efficiently work. Thus, learning-by-reacting processes which could be understood as technical adjustments, and which imply a problem-solving approach, are highly complementary to assuring efficiency in the technological transformation in a way that creates embedded knowledge.

Other schemes like the hiring and mobilization of key engineers are considered as points of reference in relation to how the KILS developed. These two firms had the tendency to keep their personnel for as long as possible within their boundaries. These findings support the argument that knowledge and learning are actually more complex than Simon (1991) has suggested. Firms actually develop through learning a balance between embodied, embedded and embrained knowledge.

As explained above, asking personnel to put into practice their abilities to identify problems and push forward new ideas and solutions pushed them into exploiting their cognitive knowledge as much as possible when they were looking to enhance a practice. Nevertheless, for this to happen expertise should be highly concentrated in the functioning of the routine. Thus the hired engineers and technicians who stayed with the firm for a long time were those able to exercise this level of autonomy and responsibility in achieving solutions to problems.

Moreover, both firms developed a clear profile of their members by somehow standardizing the process to find personnel that fitted their standards. The firms promoted an environment in which satisfactory performance of the routines was always tested, and for engineers and technicians this was one of the main incentives to remain with the firms beyond economic stability. The ISF also started to mobilize people across different areas, a scheme that helped to create better understanding of different conditions, especially when the firm started to grow and create new areas and routines, but also when it was recognized that the main source of technical asymmetry and ambiguity when new knowledge was implemented came from the lack of perspective between the different areas of the firm.

In this way these firms sought to prevent leakage of information and know-how but they also accumulated experience within their interpretative system – i.e. the knowledge became embodied knowledge. Technical adjustments and the hiring of engineers were well-connected schemes that served as a bridge between the cognitive tacit knowledge embodied in the new engineers and the behavioural tacit knowledge immersed within the firms' routines. This combination brought more than an understanding of the operational routines; it also created one of the conditions to promote change.

Through these learning events these firms developed common ground in their interpretative system. The transfer of knowledge from embedded to embrained was actually coordinated through the use of technical adjustments along the firms' technological transformations. This learning scheme might be considered the

foundation for knowledge reconfiguration, especially in the case of the NSF. Most of the new knowledge was assimilated and implemented by using these technical adjustments, based on the cumulative experience that the firm's members developed.

Among all the learning schemes, product development provided the greatest contrast between the two firms. Its importance relied on the fact that both firms pursued a diversification strategy in which the identification of new products and markets was part of their strategic intentions. In line with previous empirical evidence, product development in these firms was one of the most relevant driving forces for the search for new capabilities. One of the technological advantages of these firms was the versatility of their operational routines in which the same principles could be applied to a variety of market options. In both cases product development, which is a type of learning scheme, was the second most intense learning event, which provides evidence of the link between process and product technologies.

In the case of the NSF, an expertise-based approach led the decisions for new product development; the development of these types of events was mainly the responsibility of the most experienced technician (which in the case of this firm was one of the owners). Consequently, the knowledge was embodied in a one-person interpretation. In contrast, product development in the ISF was collectively developed through a rational and routinized sequence; therefore the learning schemes intended to encode the information came from a group intentionally formed for this purpose – i.e. this was a formal participative system.

Moreover, the way in which product development was conceived should be understood as well. In the case of the NSF it refers to varieties and breeding whereas in the case of the ISF it relates to the development of formulas through the mix of ingredients. Despite these differences both firms managed to successfully enter different markets with a broad range of products.

Both firms also sought to encourage the development of explicit and codified knowledge; therefore, some learning events were also conceived for this purpose. The use of learning schemes such as managerial and operational practices aimed to create

the conditions to encode knowledge.¹¹⁰ Also, these learning events allowed the flow of information to be coordinated between areas of the firms. Through these events these organizations managed to systematize and filter some useful information to record some of their experiences, as well as assess the performance of the operational routines.

Within the context in which these firms were analysed, learning events related to operational and managerial practices were sequentially implemented after the firms had gained some understanding of their operational routines. As analysed from the evidence, these schemes were used for the assimilation of knowledge and so they could be considered as methods to create bridges within the KILS. In contrast to the other schemes, managerial support and the development of participative systems were decisive in making these practices work within the organizations. As observed in each of the cases, these schemes were complementary and aimed to create the conditions to make the transformation process more efficient and coherent.

However, in firms such as the two studied for this thesis – where technical concerns are normally of great importance – as the evidence indicates, communication and understanding between production and other areas such as marketing are not solved by just implementing technical schemes. In both cases coordination capabilities were implemented by creating formal interactive practices between managers from different areas. In the case of the ISF some standard procedures were also implemented to make the flow of information from one area to another more assertive and commonly understood – i.e. this demonstrated system capabilities. In addition, as described above, the fact that the ISF favoured the mobilization of managers from technical to marketing area showed that the firm had aimed to improve and facilitate its knowledge integration and learning.

Technical training was another type of scheme in which alignment with system capabilities at the organizational level was required to gain efficiency in technological

¹¹⁰ On the one hand, registration, measurements and evaluation systems are part of the learning events that comprise operational practices; on the other hand, standardization processes of the production system, implementation of quality systems and the introduction of information technologies are events related to managerial practices.

transformation. This scheme served to mobilize knowledge throughout the learning process in those events in which there was a high cognitive distance between current and new knowledge. Technical training thus functioned as a bridge for assimilating new knowledge and reinforcing some adjustments that had previously been implemented. However, this was especially the case for the ISF, as the NSF hired the technical assistance of external experts for this purpose. It was only after a structured platform had been implemented for the purposes of consistently and formally addressing this technical training that the advantages of this type of scheme were fully aligned with the conditions of the component knowledge; this also happened with events such as the provision of assistance to attend trade fairs and congresses. In these situations the implementation of rules and procedures – i.e. system capabilities – generated the conditions under which these schemes were performed.

Among all the schemes, technical adjustments – especially in the case of the NSF, as was acknowledged above – were used as the foundation of the whole system. The ISF, on the other hand, also supported its KILS by using supplier representations, even though it was not the most frequently used scheme of all. This could be considered to be one of the most marked differences between the two firms. It could be assumed that learning dynamics in the NSF were more associated with ‘technology-push’ whereas in ISF they were more linked to ‘demand-pull’.

Supplier representations, as explained in chapter 6, consisted of the use of well-known ingredients from multinational firms. This scheme was very important to maintain progress towards the firm’s diversification strategy; the ISF had usually used other firms’ ingredients to start and develop new business lines.

The ISF actually got its initial reputation through the use of these products. As was recognized from the evidence, potential clients in this industry tend to rely on firms in which confidence has been placed by other globally established firms, especially in markets such as those in which the ISF was involved, where a few large local firms define the standards for the rest. This type of interaction in which a firm commercializes a product from another firm, at least for this industry, requires a high level of technical synchrony because of the complexity of the solutions that these types of products offer

to their clients. And so, in the case of the ISF, a certain level of technological development from the host firm was required.

In the case of the NSF, schemes such as supplier representations were not possible because the technology developed worldwide had shifted in a different direction (i.e. towards the use of advanced biotechnology) and it had progressed faster than this firm and the local market and other institutional conditions could afford. Moreover, the conditions of the market, which comprised commercial farmers, meant there was a certain resistance to the introduction of advanced agricultural biotechnology – which is the orientation of large multinationals firms in this field (i.e. the production of technologically modified seeds for propagation). As a result the characteristics of the NSF's technological development as well as market conditions inhibited the possibilities of using schemes of this type as part of its learning system.

Nonetheless, the evidence from one of the two firms studied here suggests that the use of supplier representations (a type of schemes) could be considered very useful for firms that are lagging behind others with regards to the technology and routines that are used worldwide. Through the use of these sorts of learning scheme, the ISF gained a market reputation and also kept attracting better, and also a greater variety of, representations.

Hence, through the exploitation of other firms' businesses, the ISF began to address its knowledge. Along with the representations, this firm gained access to technical assistance, training, internships, etc. The interaction between these knowledge providers and the ISF opened up the opportunity for it to get to know how other similar firms developed and created products elsewhere, and their capabilities. Therefore, it was a more complex knowledge exchange than just the technical aspects of the ingredients supplied.

To gain more confidence from international suppliers and reduce some technical asymmetries, the ISF started developing an internal R&D facility. Then, in order to maintain its diversification strategy in this way, it started to develop its research capabilities initially through learning schemes such as technical experimentations and

experimental research (see table 6.3). However, its first efforts were rather futile in terms of the effectiveness of the technological transformation; the way this firm started to develop this learning dynamic was through the tacit know-how of individuals and completely out of the operational interpretative system, and so during its first years the firm was not able to appropriate any knowledge that was sourced from these mechanisms.

However, what started as a way of maintaining reputation became later a way of consistently identifying new technological directions. Slowly but surely research activities became more significant within the firm, and thus technologies such as flavour extraction and micro-encapsulation (to maintain flavours for longer periods) that usually were embodied in the ingredients that the ISF commercialized, were more carefully studied. In this way the firm gained access to information about the soft parts of its technology to foresee new ways to create technological and market opportunities. This exemplifies how the initial strategic intentions represented through some learning schemes unexpectedly create further intentions that lead to the development of new learning capabilities and so eventually to new cognitive and behavioural conditions.

The exploration of new knowledge in the NSF, on the other hand, were initially motivated because of the need to improve the level of assertiveness at which technical adjustments were pursued. The firm realized that learning-by-reacting and learning-by-doing (these being learning methods that technical adjustments are normally linked to) were not quite sufficient to enhance the levels of technical efficiency in its operational routines. As a result, starting from technical experiments (learning-before-doing types of event) through to the use of the engineering expertise already in place, the firm also began to follow a systematic learning dynamic. In contrast to the ISF, these activities were initially developed to respond to the requirements of the current operational routines. Indeed, research activities were conducted as part of well-established routines and not completely apart from the interpretative system.

The firm then immediately took the risk of developing further and more complex types of research (engineering and experimental). In fact, by using these types of scheme, more complex technological developments such as micro-grafting and inurement

techniques through to etiolation started to be implemented. These are examples that illustrate a systematic and complementary pattern of knowledge integration from reflection through to technological implementation.

Nevertheless, once research capabilities begin to be developed – whatever the initial reasons are – it is more likely that firms (as with exploitative-related learning events) will decide to keep exploring new technological and market alternatives to create the conditions that allow them to move their interpretative system towards divergent technologies if needed. Thus, along the firm's life cycle the relation between exploitative and explorative learning events depicts a linear sequence at first but later, although effects on the technological transformation are expected at different moments, events addressing the two orientations might be deployed in parallel and iteratively.

In the case of the micro-grafting technology within the NSF at least, several events were sequentially developed. Starting from experimental research and technical experiments, the firm assessed the technologies; the development of capabilities was then possible by the hiring of specialists and the acquisition of specialized equipment, and finally technical adjustments were made to diffuse those capabilities. In this case the decided strategic orientation of the firm motivated this endeavour that finally gave added value to the firm's products, but more importantly it also added technologically flexibility to the firm. The NSF ended up by embedding this knowledge through the formalization and routinizing of the procedures resulting from this technology.

The analysis compares how these two firms used the most representative and relevant leaning schemes in terms of how they managed to coordinate the integration of different types of knowledge. It provides indications of not only how interdependent these learning schemes were but also how the meta-learning mechanisms (MLMs), decision-making processes and strategic orientations explain to some extent the learning dynamics they created. Some arguments are raised from the interpretation of how these learning schemes evolved.

The combination of a variety of learning schemes, which are represented through learning events, create the conditions to make a balance between embodied (tacit-

individual), embedded (tacit-collective) and encoded (explicit-collective) knowledge. The coordination system develops the incentive to influence individuals to use their capabilities to synchronize the interpretative system of the firm to collectively achieve the right technological choices for the good of the operational system. In the case studies, the learning events were the means through which individuals exposed and contrasted their cognitive knowledge and challenged their behaviors in relation to the operational routines. The learning events in different degrees and scope were intended to modify individual and collective cognitions and behaviours; the process involved in the learning events created to a certain extent an interactive dynamic to move the organizational conditions in which routines were performed.

Interaction practices along with participative learning systems were implemented in both firms to enable the participation of staff members from different parts of the organizations at different levels in the learning process. These two organizational mechanisms facilitated the balance of different types of knowledge, and the transition from individual cognition to routines throughout the learning events. Coherence and flexibility in the technological transformation was then observed through the alignment between the learning schemes and the MLMs.

Each learning scheme through retrieval and experience started to be part of the KILS, contributing to an understanding of the firms' strategic orientations. Beyond intentions these learning schemes were actually the actions and practices that represented what the firms wanted and how they addressed their operational systems. Learning schemes were not run as isolated events; based on the evidence, they linked process and product technologies as well as orchestrated core and peripheral routines.

The way these learning schemes were used for knowledge integration tended to be firm-specific; related learning experiences are embedded in the memory of the organization and represented in the routines. As a result other firms might not be able to replicate the same pattern to implement information and know-how about certain technologies. Tacitness in the learning pattern becomes important, according to this argument, to assure appropriability especially in situations of poorly regulatory frameworks.

Nevertheless, the more a firm is able to systematically and formally learn from previous learning events and to make sense of the combinative efforts of a variety of learning schemes in relation to its competitors, the greater the effectiveness of the technological transformation and so the firm's absorptive capacity.

The next sections focus on the analysis of the (six) learning capacities and the transitions from one to another over the firms' life cycle to distinguish, through the interaction between knowledge reconfiguration and orientation, how firms gained absorptive capacity through time and enhanced their interpretative system over time.

7.3 The learning capacities: reconfiguration and orientation

While the previous section compared the cases at the level of the learning schemes, this section focuses on the evolution of the learning capacities. As indicated by the evidence knowledge integration, as the framework proposes, has a distinctive characteristic for the interpretative system if the source of the learning event is passive, active or interactive knowledge and if it is oriented towards exploitation or exploration. From the commonalities exhibited by the learning events, based on these two characteristics the six categories of learning capacity (numbered 1 to 6 below) were identified in the two cases.

The evidence indicates that interaction between knowledge reconfiguration and knowledge orientation varies across the firm's life cycle. **Knowledge reconfiguration** refers to how firms create the conditions to synchronize their operational routines with knowledge and technology produced elsewhere. According to the evidence firms mostly rely on their internal knowledge, mainly because it gives them the foundation for their interpretative system to gain a greater understanding of their operational routines. The evidence suggests that the more firms adjust and experiment with new methods of production and the solution of new problems the more they are able to understand the direction of their routines and the technologies at their disposal in their external environment.

Firms search for knowledge and technology that is externally produced according to how they understand, and have learnt about, their operational system. The evidence suggests that firms expose themselves to external knowledge when their cognitive system for the understanding of the technological and market directions is limited to producing behavioural changes. It is expected that firms fit their operational system with more advanced technologies when they relate to external knowledge-and-technological producers. One important aspect indicates how firms decide the direction in which the technological trajectory will be taken.¹¹¹

The evidence suggested many differences in the learning dynamics between passive, active and interactive attitudes to sourcing knowledge. Dissimilarities are related to the coordination process of transferring knowledge of different kinds to assure appropriability, to the mechanisms used to mobilize knowledge, and to the outcomes of each of these attitudes towards the external knowledge produced. As a result each attitude leads to a different way of learning, therefore to a specific learning capacity.

In contrast to knowledge reconfiguration, **knowledge orientation** refers to whether the learning dynamics are developed to challenge the established interpretative system or create a new one through market and technological breakthroughs. As acknowledged above, the way firms decide to start shifting their learning efforts from exploitation to exploration can be motivated by completely different reasons than just wanting to go ahead in their technological development. In the case of the firms studied for this thesis these motivations ranged from maintaining reputation and substituting ingredients from suppliers (integration of downstream activities) to assuring assertiveness.

In the case studies, the way the firms faced the knowledge integration process from exploitative and explorative learning events was also quite different from each other. One of the main differences is defined by the implications of both types of event. The former were closely related to the needs and expectations that the firm's members had regarding improvements in the operational routines whereas the latter were normally

¹¹¹ The evidence suggests that the less firms have a selected exposure behaviour – which means avoiding all types of knowledge that creates noise in their interpretative system – the more likely they are to take the right technological direction and achieve effective technological transformation.

considered as peripheral of the production's activities of the firm with no clear understanding of their effects. While exploitative learning events are visible within the firm's figures within a reasonable assessment period, explorative events cannot easily be evaluated under the same criteria.

In both firms the KILS evolved according to how they faced the interaction between knowledge reconfiguration and knowledge integration, and therefore the building up of the learning capacities along their life cycles. However, the shape of the learning trajectories in which these two characteristics of knowledge interacted differed slightly in each of the two firms as is shown in table 7.3. Two of the main differences relate to the intensity with which learning events were developed and the focus given to specific learning capacity in each stage of the cycle along the KILS.

Table 7.3. The learning trajectory through the firms' life cycles

Firms' life cycles	NSF						ISF					
	F	A	T	I	C	R	F	A	T	I	C	R
Initial conditions	*	*					*	*				
Formation	*						**	***	*			
Establishment	***	**		***	*		***	***	*	*	*	
Expansion	***	**	*	**	*	*	***	***	*	*	*	*

F=formative; A=adaptive; T=transformative; I=inventive; C=created; R=renewed

*/**/** Represent the level of intensity of the events associated with the specific learning capacity in the related period: less than 20 events (*); more than 20 and less than 40 (**); more than 40 events (***)

The brown colour corresponds to the exploitative learning capacities and the blue colour to the explorative learning capacities.

Source: the author

The patterns in which the learning capacities evolved can be analysed in two ways: first, by comparing the significance of each learning capacity for these firms as part of the KILS; second, by analysing the extent of their interaction at each stage of the life cycle. Each learning capacity emerged and evolved through the use of a particular group of learning events and played a singular role in the effectiveness of the technological transformation throughout the transitions periods. In this sense what the evidence suggests is that, according to the nature of the technology and the market, firms give

emphasis to one specific capacity over another. And so, the interaction patterns between capacities might diverge from one organizational and industrial context to another.

In both firms the emergence and further development of the **formative learning capacity** (1) allowed them to create the conditions under which the process and product technologies were understood with regards to the market conditions. The learning events within this capacity generated the conditions to transfer embodied knowledge from individuals into the routines. This was a fundamental learning capacity in which these firms basically formed and shaped their interpretative system beyond learning-by-doing in relation to the know-how of the operational routines. The earlier the firms began to engage in these learning dynamics the better they were able to react to and anticipate problems. The argument that emerged from the evidence is that without a proper development of learning schemes associated with the formative capacity firms might not be able to address their technological development towards the right direction and reconfigure their knowledge any further by exposing themselves to other sources – i.e. active and interactive. The evidence highlights the importance of passive learning for exploitation in order to assure transferability and appropriability of additional knowledge.

Formative capacity was relatively more intense in the NSF than in the ISF. As explained above the main source of knowledge for the NSF resided in the engineers who also developed their experience within the firm. So, this firm developed most of its knowledge along its life cycle by using schemes such as technical adjustments, operational practices, and product development pursued by the key engineers of the firm. In the case of the ISF, on the other hand, the importance of the formative capacity lay in the design of new products; this firm created a well-established and routinized system in which a group of individuals purposely worked together to transfer their knowledge for the creation of formulas and conversion into products – i.e. knowledge moved from embodied to embedded.

There were two common aspects in the development of the formative capacity in both firms. First, the component knowledge implemented through these learning schemes

was cumulative. Second, these learning schemes served as a bridge to link the conditions of the operational routines with the requirement of the commercial routines, as development in both functions at least in the studied firms were pretty much related, also most of the learning events were carried out by the same individuals. Although experiences were not properly codified for most of the firms' lifetimes, they resided in the memory of these groups of engineers.

The **adaptive learning capacity** (2) came in the form of new recruits, advisors and technical training (cognitive and tacit knowledge) but also in the acquisition of equipment and infrastructure (behavioural and codified knowledge). The realization of this capacity allowed the firms to absorb embrained and encoded information and know-how from the experiences of others. For the transfer and appropriability of the knowledge coming from these schemes three factors were relevant in these two cases: one refers to the decision in which active knowledge was chosen to address the technological change, the second to how the firm's members comprehended – i.e. its interpretative system - the need for the new knowledge, and the third to the distance between the new and existing knowledge.

The emergence of the adaptive learning capacity in these two firms started with the interaction between the knowledge from hired specialized engineers with complementary expertise and the knowledge from the founders. In both firms the recruitment of new personnel was relevant to taking advantage of technological and commercial opportunities. New engineers were usually hired to promote the development of a new technology or business line. In the case of the ISF this was reinforced also with the acquisitions of representations from multinationals. The combined effects of these two adaptive learning schemes for this particular firm then opened up the conditions to support the its diversification strategy.

The development of this capacity was more fundamental for the technological progress of the ISF than for the NSF. The ISF reconfigured most of its knowledge by constantly exposing its interpretive system to explicit and codified knowledge mainly to incorporate new conditions for the production system, which needed to be efficient and flexible enough to respond to productive opportunities. Considerable learning effort

was then made to upgrade the hard part of the technology to diminish possible differences in production (in scale and scope). Other forms of learning scheme such as technical assistance and training (these being methods for assimilation) helped to support the implementation of new equipment or the incorporation of new routines for the development of new business lines.

The **transformative learning capacity** (3) in both firms was an odd but efficient mechanism for provoking technological transformations. Firms develop this capacity, as suggested by the evidence, when they are able to align and complement embedded knowledge to transfer know-how into the firm through sharing processes. However, in the two cases studied here, appropriability problems made this capacity difficult to develop. For this type of scheme to be worthwhile the partner organization should have different interests or knowledge that would represent a real advantage and be difficult to get otherwise.

The ISF developed this capacity more than the NSF. The learning schemes related to this capacity were used for different purposes ranging from agreements to shared specialized equipment to the development of customized devices for production. Agreements of this type were made with technological providers, research and technological centres, specialized suppliers and trading firms. One of the most influential schemes for knowledge integration, learning and capability development over the technological trajectory was the supplier agreements with multinationals. Through these events (13 in total) the ISF gained access to encoded and embedded knowledge from these multinationals, which was actually used to develop new products as well as promote the creation of new business lines. The access to this technology was one of the major learning dynamics that contributed to the understanding of the direction of the firm's technological orientation, as already mentioned above.

The NSF seldom used interactive learning events; this was because knowledge was highly tacit and it wanted to avoid the leak of information and know-how. Nevertheless, one of the major technological developments – in particular greenhouses for the multiplication process – was assimilated through an interactive event – i.e. a technical mission – in which this firm gained access to embedded knowledge that was later

implemented into the production system. Thanks to this knowledge the firm was able to introduce a new technique that helped it to considerably increase its efficiency levels. Nevertheless, the result of this particular learning event cannot be just associated to way in which this knowledge was sourced but to the prior knowledge that managers have with regards to how to address the technological direction and the manner in which decisions were made – i.e. it was a participative decision making process at the time of the event.

As mentioned earlier explorative-related learning capacities emerged for different reasons than just developing new interpretative systems in advance to shift the technological and market trajectory towards new fields of application. As a result the main motive behind the pursuit of research by both firms was the search for assertiveness, reputation and technological substitution (which in the case of the ISF is translated into technological independence). Research events were developed earlier and more intensely in the NSF than they were in the ISF.

The NSF decided to be more objective in its interpretation of the methods of production by studying them in more detail instead of just making online changes as had been the practice up to then. Consequently, the firm started to use more rigorous methods of analysis and to take more time to identify solutions to current and future problems in production; this was done through what has been defined as technical experimentation. These research activities were undertaken using the prior experience that the main managers had of the production system, so the activities were more easily transferred to production to modify behaviours in routines. These learning dynamics, interpreted as learning-before-doing, contributed to developing the **inventive learning capacity** (4).

The ISF also began to develop the inventive learning capacity by using the cumulative cognitive experience of its most proficient engineers to conduct technical experiments. Through these learning events, the firm searched for chemical ingredients that could be substituted for natural ones so it could find a way to break its dependency on some of its suppliers (multinationals), especially because it wanted to pursue external markets.

Consequently, this firm also decided to expose itself to external organizations for the purposes of undertaking R&D, mainly so it could take advantage of their knowledge and thus strengthen its own explorative learning capacity. Although the firm intensified its research dynamic it was not possible to assess the efficiency of these events, but they helped to develop a sense of opportunity over the years, and therefore coherence and flexibility. After five years of consistently developing both **created learning capacity** (5) and **renewed learning capacity** (6), the ISF was able to routinize and formalize its research activities by forming a group of highly skilled individuals dedicated solely to the search for new technological alternatives. The creation of groups to collectively undertake learning dynamics was a common pattern for this firm, especially in such complex functions as engineering and design (E&D) and R&D.

The NSF was more proactive in searching for external research expertise with universities and research centres in that it used a project-based learning approach; in contrast the ISF did not organize either a routine or a group for this purpose. Misalignments in the interpretative system (or values) alongside the technical characteristics of the technology – as Leonard-Barton (1998) has noted – regarding the way these learning events were understood by each of the parties involved were the cause of the lack of effectiveness in the knowledge integration process. In the case of the ISF problems were more related to differences in the appropriability of the technology.

While exploitative and explorative events were mainly passively developed in the NSF, the ISF mainly undertook them actively. This statement confirms again that when the main part of the technological development relates to its soft parts, individual and collective cognitive knowledge passively developed through experience is more relevant than the codified and already-made technology that has been developed externally. In contrast, in firms like the ISF, where the focus of technological development is on the mechanics of production (i.e. the hard parts of the technology), embodied technology produced elsewhere becomes highly important; knowledge of technological suppliers available in the market then represents an advantage for the KILS.

More than simply distinguishing the learning capacities that organizations have developed throughout their life cycles, the argument raised from the evidence also intends to indicate to what extent they are interrelated. The previous analysis led to the interpretation that learning schemes are not isolated events. The evidence shows that firms experience different learning dynamics through the use of exploitative and explorative types of learning scheme by sourcing information and know-how passively, actively and interactively. By using any one of these sources, exploitative events tend to be linked to learning-by-reacting, learning-by-anticipating and learning-by-doing, whereas explorative types of events are better associated with learning-before-doing. The KILS in firms, as shown by the cases, is developed in fact as a combination of all these processes, the patterns of which mostly depend on how far the new knowledge is from the current interpretative system. The further the knowledge the keener the firm is to follow a learning-before-doing process.

The interaction pattern between levels of capacity also depends on how experienced the firm is in understanding the technological applications to the market but mainly on how the firm defines its strategic orientation. This gives some prerogatives to time and context for the pursuit of learning and the development of certain capacities. The strategic orientation along with the cognitive distance and the state of knowledge then define which learning sequence and pattern firms follow. Also, the firm's relative position with regards to how the industry has evolved should be recognized. This illustrates the relative importance that the market and technological context have for the firm's learning capacity. If the firm is coherent, learning dynamics are determined by the scope of the strategic orientation.

As important as it is for firms to engage in a variety of learning dynamics, jumping into more complex type of learning capacity – e.g. renewed capacity – (which implies developing learning events with greater cognitive distance and higher recognition of the state of knowledge) does not necessarily mean a better absorptive capacity or a more effective technological transformation without considering the alignment–misalignment with the organizational and industrial context and the process that firms have followed over recent years. These findings suggest that it is perhaps inappropriate to define a

general assessment for the firm's absorptive capacity without acknowledging the internal and external context of the firm and the evolving process of the KILS.

The analysis of the two cases studied for this thesis revealed three interactions patterns between learning capacities throughout their development and evolution process, these being discretionary, complementary and systematic. Within a specific time and context the firm might favour one or the other or combine them all together. A **discretionary pattern** was found in situations in which events did not take into consideration the implicit strategic intention and were not related to one another at all over the learning process. A **complementary pattern** was shown when these firms searched for the implementation of parallel technologies or routines requiring the use of learning events at different moments in the learning process. A **systematic pattern** was revealed when firms used an almost linear sequence of events to implement a specific technology or routine. Apart from the discretionary pattern in which learning events could be considered random and contingent from a strategic point of view, both, complementary and systematic patterns are expected to have an alignment with the firm's strategic orientation.

This last issue opens an important debate, which is indicated within the scope of this thesis, but as will be suggested (Chapter 8) requires further and deeper analysis, which defines the contrast between chaotic learning versus planned learning dynamics for the effectiveness of the technological transformation. Although the results of this thesis favour complementary and systematic patterns (planned learning dynamics) over discretionary patterns (random learning dynamics) between learning events, it suggests that a kind of randomness is also needed within the KILS because of three possible reasons: (1) to get unexpected learning experiences and outcomes, (2) to comprehend error (as an important aspect of learning) and (3) to get the chance to be open towards unexpected directions. Additionally, the evidence suggests that learning events that are discretionary are probably inevitable, as managers not necessarily understand all the time the strategic perspective of their decisions and actions.

The next section then expands the analysis by making a closer examination of the relation between learning capacities at different stages of the firm's life cycle. This way

to evaluate the evidence permits to take one step further in the search for interaction patterns between the learning capacities and their functional relation with the technological transformation – i.e. efficiency, coherence and flexibility – and other explicative conditions such as the MLMs and the decision-making process.

7.4 The co-evolution of the KILS and the technological trajectory: gaining absorptive capacity over the firms' life cycles

The six learning capacities have also been analysed in relation to each other at each stage of the firms' life cycles. In consequence, the functional relationship between the learning and the technological trajectories across the capacities points to four specific technological contexts which also defines four stages in the life cycle of the firms (initial conditions, and periods of formation, establishment and expansion), demarking a sequence in the development of the learning and technological trajectories. The distinction of these four contexts supports Nonaka's (1994) suggestion regarding the intention and consciousness of information and know-how; the KILS at each stage of the firms' life cycles differed according to how these firms understood how to act in relation to their problems and the demands of the market and technological context.

7.4.1 The KILS at initial conditions of the firms

Both firms started doing business approximately under the same conditions. They began with very low capacity and minimal technological facilities but with high levels of knowledge and related experience with regards to the required technology and market. Congenital learning was essential during the first stage of the firms' development. Knowledge during the first years of these firms embodied high levels of embrained knowledge – i.e. individual/tacit knowledge – in the form of know-how.

Clearly, previous technological experience, and the distinction of the market orientation to start with, were decisive in them comprehending how to move. What mattered the most under these first years was the setting up of the operational routines; in the case of the NSF this was related to the propagation process, and in the ISF to the mechanics of production. And so, learning-by-doing was the basic learning process that enabled an

understanding of the basic sequence and foundation of routines. However, the market conditions at the time that the two firms started were not fully explored by any other firm, and there were also other gaps to fill in the market, which these two pioneering firms identified reasonably well.

During this phase, the firms combined their interpretative system with conscious and objective information in the form of formally trained engineers and proven technical devices. In the cases of the ISF formative and adaptive learning events were systematically used to establish the routines to run the operational system to produce the mixes, which included also the development of initial E&D capabilities. In the case of the NSF both learning capacities complemented each other, as formative learning events were used to install the first technological generation and a skilled engineer was hired to develop capabilities in grafting technology.

During this period both firms concentrated their markets in one business line, and learning was aligned with their strategic orientations to establish the initial conditions to run their operational systems and respond to their corresponding markets. However, learning dynamics at this stage were limited, as the firms tended to rely more on their initial cognitive knowledge and on the ability of their founders to mobilize knowledge. This period continued until certain conditions were met that stabilized the firms' market positions. The decision-making processes referred to what and how to learn, and the direction was conditioned by the founders' knowledge – i.e. they each depended on a one-man institution. (Table 7.4 summarizes the features of the KILS during this first period.)

Table 7.4 Characteristics of the KILS at initial conditions

Features		NSF	ISF
Period		1983–1986: 4 years	1987–1991: 5 years
Learning capacities		Formative and adaptive capacity	
Interaction patterns		<u>Complementary</u> learning events to start developing the capabilities to substitute the initial technological settings	<u>Systemic</u> sequence of learning events for developing the meat and flavouring market
Coherence: orientation	strategic	Creating the initial conditions and enhancement of capabilities of production	Achieving sufficient efficiency levels for the establishment of the operational routines to

Efficiency: core technological routines (behavioural changes) Flexibility: diversity-intensity Decision-making process MLMs		guarantee market entrance
	Favouring exploitation and development of <u>core competences</u>	
	<u>Establishing the routines</u> to produce growing bags under soil of substratum	<u>Establishing the routines</u> for the mechanics of production to produce the mixes
	<u>Developing new capabilities</u> for grafting technology capabilities	<u>Developing new capabilities</u> for formulation facilities (pilot plant)
	Low learning experience and limited options available	
	One-man institution	
	Non-MLMs were installed	Non-MLMs were installed

Source: the author

7.4.2 The KILS at the formation period of the firms

During this period these firms, which had already defined their market positions and technological settings, moved forward with the consolidation and understanding of their routines. While the NSF did not go much further in terms of the learning dynamics and kept its focus on understanding its production system through experience – i.e. learning-by-doing – the ISF went one step further and started moving forward by developing technological and commercial flexibility.

Over the formation period the NSF was very cautious and the few events the firm did take part in were discretionary, as they were not very well connected with the strategic intentions of the firm. In contrast, it was during this period that the ISF began to build conditions to take its route towards diversification.

The ISF realized the risks involved in having a dependent business in terms of products, suppliers and clients, within a highly versatile industry such as the food processing industry. Formative learning events were oriented to implement new methods of production as well as identify and develop new formulas for the firm's clients, whereas adaptive learning events sought to strengthen the technological platform through the acquisition of better equipment and devices for the existing and new production system to give operational support for the new commercial opportunities. So, formative and

adaptive learning capacities complemented each other with their purposes being to expand and diversify the firm's market.

During this period the first big group of skilled engineers was hired and the firm made a clearer division between production, product development, and market. The recruitment of this group of people along with a more distinctive structure for developing the operational routines made the KILS more dynamic compared to the previous period. This was certainly not the case for the NSF.

The organizational settings did not change in either of the firms with regards to the manner of decision-making. It must be said therefore that changes in the learning dynamics are more related to how strategic orientations are interpreted in relation to the market requirements than to who makes decisions and how they are taken.

Additionally, as the ISF started to grow and the flow of information became greater and more complex to manage, the first information system was implemented, but it was more or less centralized in the head of the main manager at that time.

In summary, the KILS in the ISF compared with that in the NSF differed in three aspects: first, the new group of engineers reconfigured the knowledge base of the firm; second, the understanding of the need for technological and market diversification was the starting point for the firm's strategic development; and third, the better organization of the functions clarified the characteristics of the whole system and the implications of the required changes. These features explain the dynamism of the KILS in terms of intensity and the development of more alternatives for learning, creating the conditions for the next stages of the firm's development. Even though efficiency was not completely achieved because many of the new components of knowledge were still in the process of being assimilated during this period, the firm was coherent and developed operational flexibility. (Table 7.5 summarizes the features of the KILS during this second period.)

Table 7.5 Characteristics of the KILS at formation period

Features		NSF	ISF
Period		1987–1991: 5 years	1992–1996: 5 years
Learning capacities		Formative capacity	Formative–adaptive–transformative capacities
Interaction patterns		<u>Discretionary</u> learning interactions between learning events	<u>Complementary</u> learning interactions between learning events
Coherence: orientation	strategic	Establishing a better propagation technique to enhance efficiency levels in production	Expanding the technological versatility
Efficiency: technological routines	core	Favouring exploitation and development of <u>core competences</u>	Favouring exploitation by balancing the development of <u>core competence</u> and <u>market opportunities</u>
Flexibility: intensity	diversity–	Assimilating grafting technology	Assimilating new techniques for the mechanics of production for new production plants
Decision-making process MLMs		One-man institution	
		Non-MLMs were installed	The firm started to develop <u>system capabilities</u>

Source: the author

Up to this second period these firms focused on the building up of exploitative learning capacities. During this first decade the learning-driven motives were mainly oriented to guarantee the sustainability of the businesses; this meant them understanding and improving the technology in used in relation to the market conditions required to efficiently perform their operational routines and develop specific market segments in which they could be recognized for the quality of their products and technical support against their competitors. Despite the incipient learning trajectory the events depicted a systematic, and in some cases complementary, interaction pattern between the learning capacities developed up to this point in which these firms combined passive, active and interactive knowledge, albeit not completely consciously.

7.4.3 The KILS at the establishment period of the firms

During this period both firms structured their paths towards market and technological diversification. The NSF had introduced a more reliable propagation technique – i.e. grafting plant production – through which it gained more confidence in offering added value to commercial farmers; therefore it took the risk of searching for and introducing new varieties and breeding methods. The ISF reinforced its E&D area in relation to its operational routines by setting up new production plants along with the introduction of improved methods of production to make the system more versatile. In brief, from this period these firms reached what could be considered as an established position in their industries and the managers started to search for new market segments.

Learning events within the NSF were systematically prompted to diffuse and implement this new technological generation across the new varieties and assess the usefulness of a complementary technology – i.e. micro-grafting technology. Learning events in the case of the ISF were complementarily shifted towards market and production diversification and combined with discretionary events with the aim of searching for technological independence from suppliers. Both firms thus expanded their options by using new learning forms to be able to respond consistently to the new strategic orientations.

The decisions to open up the firms towards other directions came from the knowledge they developed about their routines but also from the inclusion of different interpretations of how to deal with the market contingencies and problems related to the increasing scale in production. In both firms the decision-making system was shifted from what is recognized as a one-man institution to a participative and information-seeking-culture system in the NSF, and a formal management system in the ISF. Although the expert voices of the main managers were still given prominence, technical and strategic advice coming from other members of the firms were taken into account and there was growing recognition of their expertise. This level of internal openness allowed for a broader perspective of the firms' routines and enabled them to define

their directions in correspondence with a more dynamic KILS.¹¹² In consequence, explorative events started to take place within the firm.

During the first two periods (initial conditions and formation) the KILS within these firms focused on two aspects. First, these firms consolidated a KILS with the ability to understand the implications that the technology in use had on their established routines with regards to the market. Second, through the KILS, these firms had integrated new information and know-how until the run for efficiency of production were in principle satisfied. So, over the first two periods of the firms' life cycle a linear pattern from exploitation to exploration was first traced.

Once these firms expanded their KILS to also search for complementary and substitute technologies, both exploitative learning events and explorative learning events were deployed. As a result an iterative interaction pattern was exposed instead. Indeed, these two firms combined both exploitative and explorative learning events marked a different pattern from the previous periods in the learning dynamics that continued over the period of expansion.

In each firm, the use of exploitative and explorative learning capacities had a different pattern in their development. In the NSF, learning-by-doing was the main learning pattern throughout the previous periods, whereas the ISF had developed more learning experience and greater understanding of some learning schemes. So, during the establishment period these firms reconfigured and oriented their knowledge by simultaneously using the learning schemes at their disposal but it was a time when both firms also expanded their KILS. The development of research activities took place under different learning conditions.

Moreover, the exercise of explorative events in both cases was not based on a single interpretation of how research should be undertaken and the direction in which efforts of this kind should be addressed. Top managers created the conditions but decisions to engage in research activities came from the initiative of the engineers in charge of the

¹¹² This was possible in the situation of the ISF because of the hiring of engineers during the previous stage. Incidentally, the NSF recruited new engineers at the very beginning of the establishment period. The reconfiguration of knowledge along with the establishment of more open and participatory decision-making systems were decisive to the pursuit of learning.

firms' activities who were also part of the middle management teams. Research processes and outcomes were initially misinterpreted: the firms understood the need to do research but probably it was not the right timing for it. Appropriation of results was at that time based just on short-term rewards and performance measurements; the firms then still had to overcome the ambiguity of success and superstitious learning, as was noted by Levitt and March (1988).

Explorative events in these two firms differed in the way they were deployed, showing a distinctive pattern for the pursuit of R&D. In ISF, research events were unstructured but consistently and systematically developed (the firm pursued R&D initially with the aim to identify alternative technological solutions that were more or less linked to the needs of the current operational routines). The NSF on the other hand, developed research events by using a project-based approach (this firm had the intention to modify their current technological platform).

In the NSF there was no specific group of individuals or an individual dedicated to this task as in the case of the ISF. This difference can be explained, as the two firms had different decision-making approaches. The NSF created a participative system along with the development of an information-seeking culture. In contrast, the ISF maintained the one-man institution approach, but it developed a formal management system with structure, dedication, incentives and procedures, therefore this firm created an area and assigned one individual to carry out research activities. This also influenced differences in the dynamics in which exploitative learning events were run within the firm.

Efficiency in the technological transformation was also better achieved over this period. On the one hand, the implementation of technologies that were previously assimilated during the establishment period were finally implemented. On the other hand, these firms sought to assimilate complementary technologies to expand their interpretative system. While some technologies were then implemented, others were in the process of being understood.

In correspondence with the technological requirements both firms expanded their KILS by making use of new learning schemes, and in the case of the ISF by developing a greater expertise through retrieval of some events. Neither of these two firms, however,

collected and codified past learning events; flexibility was therefore limited to how well staff members remembered good and bad practices from past situations. (Table 7.6 summarizes the features of the KILS during this third period.)

Table 7.6 Characteristics of the KILS at establishment period

Features	NSF	ISF
Period	1992–2001: 9 years	1997–2004: 8 years
Learning capacities	Formative–adaptive–inventive–created	Formative–adaptive–transformative–inventive–created
Interaction patterns	<u>Systematic</u> interactions between exploitative learning events <u>Complementary</u> interactions between explorative and exploitative learning events <u>Systematic</u> interactions between explorative learning events	<u>Complementary</u> interactions between exploitative learning events <u>Discretionary</u> interactions between explorative and exploitative learning events <u>Complementary</u> interactions between explorative learning events
Coherence: strategic orientation	Market diversification	Market and production diversification
Efficiency: core technological routines	Implementing and diffusing the grafting technology throughout the production system Assessing the micro-grafting technology	Implementing the mechanics of production for new plants to support the technological versatility Assessing extraction of natural ingredients
Flexibility: diversity-intensity	Expanding the KILS by using new forms of learning	Retrieval of previous learning experience and expanding the KILS by using new forms of learning
Decision-making process	Participative system Information-seeking culture	Formal management system One-man institution
MLMs	<u>Coordination capabilities</u> by creating technical meetings <u>Socialization capabilities</u> by creating a sense of identity	<u>Socialization capabilities</u> by creating a sense of identity <u>System capabilities</u> by distinguishing the functions and relations between areas

Source: the author

7.4.4 The KILS at the expansion period of the firms

While the establishment period was defined by production and market diversification the expansion period was characterized in both firms by pushing forward a long-term strategy based on achieving technological independence, the development and consolidation of new markets and internationalization. The way the KILS evolved over these years created a dynamic of change within these two firms and gave them

sufficient information to understand how to keep moving forward to new technological developments.

At this point both firms at least developed the bases for the KILS. These firms were able to transfer and appropriate knowledge from experienced staff members that was embodied to it being embedded –i.e. this demonstrated formative capacity – and created the conditions to capture embodied and encoded knowledge from external sources – i.e. this demonstrated adaptive capacity. To some extent these two learning capacities represented the foundation of the KILS from which the firms developed their interpretative system in order to understand better how to address the operational routines in relation to their markets.

Incidentally, once most of the technical problems were solved these firms were able to focus on how to anticipate and renew their businesses. As a result a more compelling combination of events was simultaneously pursued to maintain the efficiency of the production system and support the transition towards emerging complex technologies and markets. So, over this period of expansion these firms were searching for a breakthrough in their technological development.

Thus, the interaction between exploitative and explorative learning capacities indicated how these firms were complementarily engaged with events in which the firms searched for cognitive and behavioural changes at different levels of understanding of the technological developments in relation to the operational routines.

In the case of the NSF, while it was assimilating and implementing the micro-grafting technology across all the fruit varieties, engineering research projects were undertaken to reflect on the technical and economic implications of inurement techniques through etiolation. This instance hints that engineering research was justified when advanced technologies were distant from the current technological platform in place, which is also related to how knowledge was sourced; in this case the development of renewed capacities was the most suitable option to initially approach the understanding of this type of technology.

A similar situation was portrayed by the ISF. In this case the business lines were clearly defined and structured in order to have a portfolio of products and services that would be sufficiently attractive to the market. More importantly, the firm intentionally formed well-defined groups divided by business lines to develop internal and external interactions and create symmetry and alignment in the interpretation system between production, E&D and marketing. In this sense technical adjustments in the production system responded to developments in the E&D area and the requirements of the clients.

Additionally, research activities were formally oriented and collectively undertaken in this particular firm. A group with similar cognitive conditions and attitudes towards research was then formed to move forward two research fields of interest for the firm to create an alternative trajectory. Therefore, explorative events were developed to generate future feasible options from which the firm could develop technological and market opportunities.

At this point the analysis suggests that efficiency of the technological transformation goes in line with the level of understanding that firms have of a certain technology which also implies having an appreciation of the timing between cognitive and behavioural changes. Some of the technological generations and specific capabilities with a certain level of complexity and ambiguity in the nature of the knowledge that were assimilated during previous periods were finally implemented during this expansion period.

Additionally, the KILS in both firms refined the decision-making system and the MLMs to coherently respond to the strategic orientation and the learning demands it caused. So, the firms were more openly managed but at the same time more structured in their functions to assure a better level of understanding of the overall challenges faced by them (as can be seen in table 7.7 below). The cases also provide evidence of the alignment between the dynamics of the learning schemes and the characteristics of the organizational principles. (Table 7.7 summarizes the features of the KILS during this fourth period.)

Table 7.7 Characteristics of the KILS at expansion period

Features	NSF	ISF
Period	2002–2010: 9 years	2005–2010: 6 years
Learning capacities	Formative–adaptive–transformative–inventive–created–renewed	Formative–adaptive–transformative–inventive–created–renewed
Interaction patterns	<p><u>Systematic and complementary</u> interactions between exploitative learning events</p> <p><u>Discretionary</u> interactions between explorative and exploitative learning events</p> <p><u>Systematic</u> interactions between explorative learning events</p>	<p><u>Systematic</u> interactions between exploitative learning events</p> <p><u>Complementary</u> interactions between explorative and exploitative learning events</p> <p><u>Systematic</u> interactions between explorative learning events</p>
Coherence: strategic orientation	The development and consolidation of the market through better technologies and internationalization	Technological independence, consolidation of new markets and internationalization
Efficiency: core technological routines	<p>Implementation of the micro-grafting technology</p> <p>Implementing the method of protecting the production</p>	Implementing the routines to integrate production, E&D and marketing among the business lines
Flexibility: diversity-intensity	Advance biotechnological techniques for propagation	<p>Biotechnological techniques for extraction of natural components</p> <p>Technologies for micro-encapsulation of flavours</p>
Decision-making process	Participative system Information-seeking culture	Formal management system Participative system
MLMs	<p><u>System capabilities</u> by developing more formal and structured means of communication</p> <p><u>System capabilities</u> by distinguishing the functions and relations between areas</p>	<p><u>Coordination capabilities</u> through:</p> <ul style="list-style-type: none"> • Job rotation • Establishment of monthly reporting meetings and advisory committees <p><u>System capabilities</u> by developing more formal and structured means of communication</p>

Source: the author

The process of learning-capacity building shows a cumulative and simultaneous (iterative) combination of all the learning capacities. The more the firms exposed themselves to learning the more they were able to understand the next step of their technological trajectories and reconfigure their knowledge base accordingly.

The evidence also shows how the KILS evolved in terms of how the micro-components of learning, as represented through the learning schemes, pushed forward the need to create the conditions at the level of the organizational principles, therefore outlining a co-evolution process between the learning schemes, the extent of interaction of the learning capacities and the MLMs. As a result, the firms were able to expand their learning intent towards advanced technologies and at the same time increase the effectiveness of their technological transformations.

8 GENERAL DISCUSSION

8.1 Introduction

The research in this thesis provides an understanding of the growth of the firm from the co-evolution of its learning and technological trajectory by focusing on the micro components of learning and the process of capacity building. To do so, the research takes an integrative and historical view to analyse the dynamics between knowledge integration, learning and capabilities and routines. The chapter describes the main arguments from the thesis and the findings, highlighting the contributions to theory derived by the evidence and their implications for policy and management.

To approach the analysis of knowledge integration, learning and capabilities, the research proposes to focus the attention on SMEs in an emerging economy. However, several characteristics were defined to select the SMEs for the study. First, these SMEs should have undergone explorative learning processes. Second, they had proven intentions of moving from the use of single technologies to what is defined as emerging complex technologies; this particular aspect of these firms' evolving processes suggested that it would be possible to observe the inside details and the causes of an initial transition of this kind. In addition, the learning dynamics of exploitation and exploration that eventually led both firms to path-dependent and path-breaking changes were considered to be interesting aspects to observe for the sake of the research. The third characteristic that made these SMEs interesting as case studies was the relative success they had both achieved in their respective markets, assessed by their long-term survival, the constant increase of their sales rates, and the fact that both firms were considered pioneers in Columbia in their own markets and technological fields. So, the characteristics of these SMEs ideally suited the purposes of this research. In this sense these two SMEs were considered atypical and distinguished as high growth SMEs.

A two-case study approach was defined as a research strategy. The use of this strategy allowed getting a deep understanding of the link between knowledge integration, learning and capabilities for the firm's evolving process that would have not been possible otherwise. First, the evidence relates three levels of analysis, including the micro-components of knowledge integration and learning, the formation of capacities and the identification of the meta-learning mechanisms (MLM) and the decision making process. Second, by taking a long-term explanation the research searches for the causes and consequences of the process of learning-capacity building. And finally, the research relates the learning trajectory with the technological trajectory describing also the emergence and development of capabilities and routines. As a result the research strategy responds to the level of detail of the required evidence and the complexity of the analysis.

A deductive-inductive approach over the research process was also applied. The discussion was initially developed based on previous concepts (e.g. knowledge reconfiguration, knowledge orientation, component knowledge, knowledge forms and knowledge transfer) and assumptions derived from the knowledge management, organizational learning, absorptive capacity and the dynamic capabilities literatures (deductive). Once the evidence was collected, an evaluation of the data was made to match the description of the learning events with the learning schemes and a specific learning capacity. Additionally, the transitions over the growth of the SMEs (i.e. firm's life cycle), the interaction patterns among the learning events and the learning capacities as well as the emerging concept of the KILS as a reflection of the integrative view of the micro and macro components of knowledge integration and learning came up from the discussion of the evidence which gave sufficient elements for theory generation (inductive). Some other concepts were further discussed in the theoretical and conceptual analysis (e.g. the decision making process, effectiveness of the technological transformation, sense of opportunity, technological flexibility, the distinction between cognitive and behavioural changes) after having identified important aspects during the data collection process to complete the integrative approach. So, the theoretical discussion (see chapter 2) was constantly revised along the research process to make it consistent with the analysis of the evidence.

The debates, which refer to the main and supporting research questions of this thesis, have focused on investigating the evolving dynamics of knowledge integration and learning within firms, and so, the main research question ask for:

To what extent does the integration of external and internal knowledge for either exploitation or exploration explain the organization's learning-capacity building and its functional relationship with its technological trajectory?

According to the evidence provided by the two SMEs, the scope and direction in which the firm's capabilities and routines changes over time along the learning trajectory are related to how firms use different sources of knowledge through the learning schemes based on their technological and market requirements which, in these cases, were mainly bounded by local demands.

Hence, the research in this thesis has proposed an integrative view of the way in which firms develop their capabilities and routines over time. Through the evaluation of the literature and analysis of the evidence provided by the case studies, the research supports the argument that the knowledge-integration system (Tsoukas, 1996) and the learning system (Shirivasta, 1983) are connected through the actions that individuals do by the means of the learning schemes. As a result cognitive and behavioural changes occur when a series of (learning) events relate knowledge from different sources –i.e. passive, active and interactive – with a process in which the interpretative system is problematized in terms of the current conditions of the production system – i.e. from exploitation or its future possibilities – i.e. to exploration. The nature of the component knowledge, the form it takes and the learning dynamics for its implementation define to some extent the implications for the technological transformation.

The research therefore argues that the way in which firms develop their learning capacities and capabilities is influenced by how individuals and managers are able to make sense of these two systems together in response to the firms' strategic orientation. In this sense firms achieve their 'absorptive capacity' when they are able to pursue an iterative and systemic process of knowledge integration and learning. Only then do firms reach the point of fully comprehending the technological and commercial

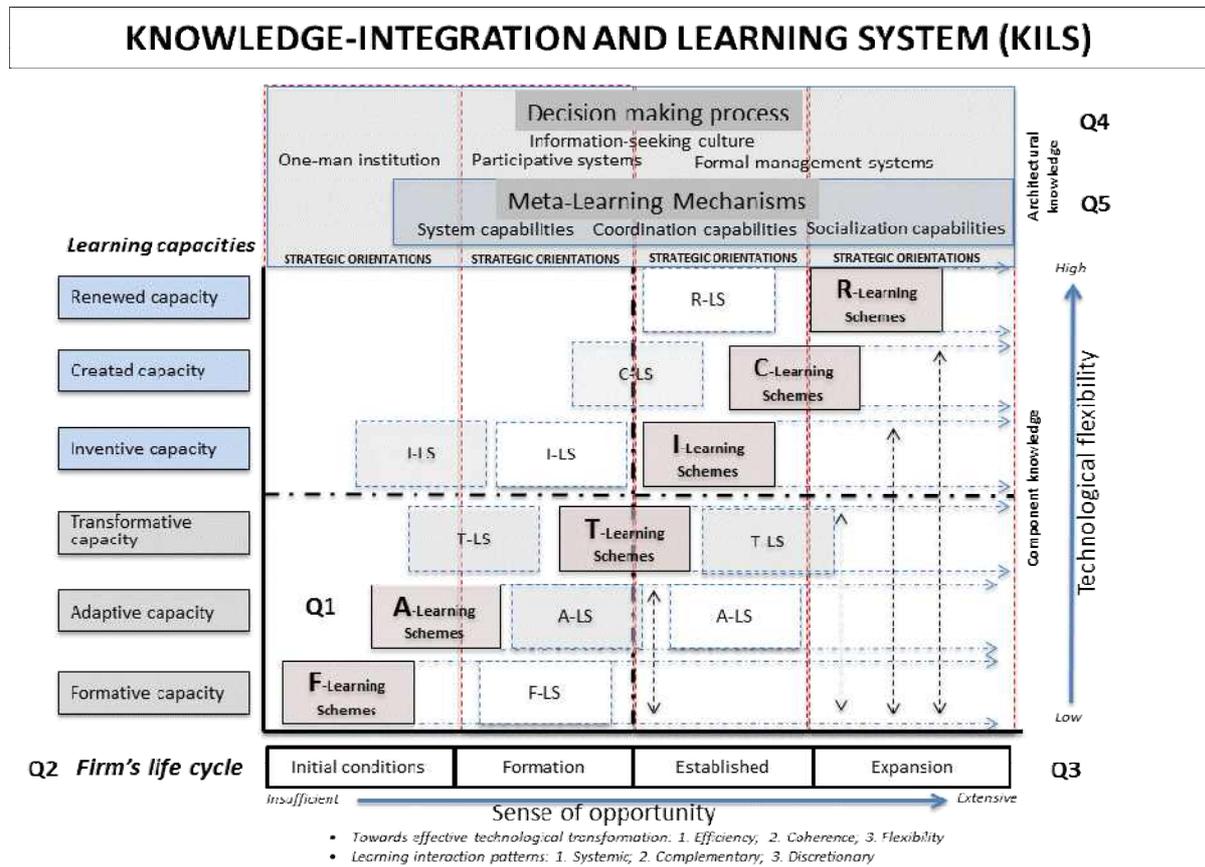
opportunities that are available to them. This integrative perspective has been defined throughout the thesis as the knowledge-integration and learning system (KILS).

So, firms make a transit from passive to active and interactive as well as from exploitation to exploration to the point in which they acquired the learning capacities not just to balance sources and orientations but also to iteratively combine them for different learning purposes -changing capabilities- to respond to specific strategic orientations. As a result firms get learning experiences, therefore, learning capacities.

The assumption behind is that firms evolve over time according to how they are able to use and combine their passive knowledge with different external sources -for learning- to make a better use of their capabilities and address their technological platform towards new directions. If firms do not take the pace to make sense of their routines and do not build their learning capacities over time with regards to the market and technological conditions, their development will be constrained; under these circumstances, firms might drop into a stage of vulnerability, therefore, their survival and sustainability will be uncertain and at risk.

Based on the evidence provided by the two cases the figure 8.1 shows a general pattern from which the SMEs built their learning capacity in relation to the technological trajectory which is reflected through the knowledge integration and learning system (KILS).

Figure 8.1. The knowledge integration and learning system model (KILS)



Source: The author

The figure 8.1 also describes each of the integrative aspects that define the KILS along the firm's existence which also correspond to each of the supportive questions:

(1) To what extent does the combination of different FLMs enable the organization's learning dynamics?

Through the sequence of learning events constructed as learning schemes the process that involve the transfer of different knowledge forms and the transition from cognitive to behavioural changes in the component knowledge of the firm it is exposed to at different stages of the firm life cycle and strategic needs.

(2) To what extent do different learning capacities (sources and their orientation) trigger the organization's technological transformation process?

The combinations of the learning schemes trace the learning dynamics and trajectory along the firm's evolution. The conditions that enable firm's to decide (when, why and how) to integrate passive and/or active and/or interactive knowledge and to create a balance from exploitation to exploration (if possible) without disrupting the strategic orientation of the firm help to comprehend the variety of learning capacities that firms can acquire over time and their relation with the technological transformation, each of them having a completely different but related dynamics. Section 8.2 discusses this in the light of the dynamic capabilities and the absorptive capacity literature the first and the second research question.

- (3) To what extent do the efficiency, coherence and flexibility of the learning trajectory influence the scope and outcome of the knowledge-integration process?

The effectiveness of the technological transformation was assessed through the efficiency, coherence and flexibility generated by the KILS over the stages of the life cycle. The research proposes that firms tend to gain efficiency in the KILS over the first stages of the firms life cycle and then the effectiveness increases by adding coherence and flexibility over the establishment and expansion period. And so, as long as the firm is able to increase its learning capacities both its sense of opportunity and the technological flexibility tend to become extensive and higher which are defined correspondently as the scope and outcome of the KILS. The former is reflected through the portfolio of learning schemes at specific points in time of the firm and the latter through the versatility of the technological platform to respond to emerging market needs. Section 8.3 expands the explanation of the scope and outcome of the KILS.

- (4) How does the decision-making process and patterns of growth explain the scope and outcome of the technological learning dynamics?
- (5) How do the MLMs explain the scope and outcome of the technological learning dynamics?

The evolution of the KILS, although focusing on its micro components, considers those macro components which refer to the organizational principles as relevant aspects for

enabling or restricting the evolution of learning and capabilities. The research applies the decision-making taxonomy proposed by Shrivastava and De Boer et al (1999) framework of meta-learning mechanisms (MLM). It is proposed through the evidence that the development of the learning capacities at each stage of the firm's cycle proceeds in line with the increasing level of participation and formality of staff members at different levels of the organization in the firm decisions. In this sense the research proposes that firms must combine a routine and practice based approach to learning in which decisions and actions emerge from the operations with a strategic based approach in which conditions for learning are oriented from high ranged managers. The evidence suggests that firms should move from a strategic based approach towards a more routine and practice based approach to learning, and they should find a point of alignment between the two levels. Section 8.4 analyses this point further in line with knowledge management and organizational learning literature.

(6) How do industrial differences (e.g. agro and food processing) affect the pattern of the organization's learning and technological trajectory?

To understand the extent to which the transition from single to emerging complex technologies follows similar or different learning and technological patterns the research compares two SMEs which make part of two different industries. One of the SMEs supplies the agricultural industry and the other the food consumption industry, both of them located at the bottom of the value chain. The point of reference that links these two firms in the case of the research in this thesis is the integration of knowledge in the biotechnological field, considered here the emerging complex technology.

To analyse the context specific conditions, aspects such as the regulatory framework, the technical sophistication of the demand, and the distribution of competitors by market segment were acknowledged regarding the market context. These aspects were analysed from the firms' perspective as each of them were market and technological leaders in Colombia. In the case of the regulatory framework in both cases there were failures in the market structure –prices- and standards. Both firms also faced similar situations in relation to the sophistication of the clients, who lacked of sufficient technical knowledge to properly understand the benefits of new technological

developments. In contrast to the previous conditions these two firms were involve in different competitive conditions. While the ISF competed with large and, in some cases, multinational firms, the NSF participated in an atomised and populated industry compound of SMEs.

The other extrinsic condition of importance relates to technological opportunities. Both SMEs confronted limitations in accessing new knowledge e and capabilities. Although this condition slightly changed over time it explains the importance of the use of passive learning schemes as the foundation for knowledge integration. Another aspect that differentiates both firms refers to the nature of the technology (hard or soft) and the attention of the learning efforts (technology-push or demand-pull). All these aspect are discussed in more detail in section 8.5.

The reminder of the chapter presents the general and main arguments from the thesis. The first section offers a general evaluation of the results in light of the literature on absorptive capacity and dynamic capability to give a more detailed answer to the first and second supportive question. In this section, the main arguments and claims provided by the evidence are assembled. The following section analyses the link between the learning capacities and the effectiveness of the technological transformation to complement the answer to the second supportive question. The section 8.4 presents the particular implications of the research for the literature on knowledge management and organizational learning which reflect on the fourth and fifth supportive research question. The fifth section explains the intrinsic and extrinsic conditions that framed the decisions taken by managers to pursue the KILS to define similarities and difference between the two SMEs in each of the industries offering an answer of the final supportive question. The sixth section proposes some managerial and policy recommendations arising out of the research. The last section acknowledges the limitations of the research and some suggestions are made for future work in similar and related areas.

8.2. Combining absorptive capacity and dynamic capabilities: sense of opportunity and technological flexibility

One of the general discussions in this research refers to the implications of the findings for the absorptive capacity and dynamic capabilities of the firm. Researchers in these two streams of the literature have been interested in the roles of the integration of external knowledge and the development of learning dynamics in the mobilization of the firm's capabilities (Lane et al, 2006). These studies have acknowledged not only what absorptive capacity and dynamic capabilities are but also which conditions enable their development. Overall, researchers in these two areas have recognized the importance of creating cumulative and dynamic changes in capabilities to assure market sustainability.

The framework and the findings are in line with some of the previous claims with regards to this literature and consider firms as creating-processing knowledge organizations. The proposed terms of KILS actually emphasizes that what matters the most for the firm's learning capacity relates to how they are able to get the right information and give meaning to it in order to develop better routines (know-how) in relation to its strategic orientation. In this sense the evidence supports the importance of coherence for the effectiveness of knowledge integration. Moreover, the more open and exposed firms are to learning, the more able they are to avoid ambiguity in the direction of their technological development and expand their technological platform.

Based on the analysis provided in this research in which the learning trajectory is seen through the lens of the learning-capacity building, an assessment of the firm's learning capacity can be understood by looking at two factors. One refers to the **sense of opportunity** and the second to **technological flexibility**. These two factors might be combined to make up the interactive relationship between the learning and the technological trajectories. And so, firms that consistently develop both conditions aligned with their strategic orientation develop higher levels of absorptive capacity. What can be interpreted from the evidence is that when the conditions to learn are developed, new forms of learning that create synchrony in the interpretative system of the firm are possible.

In this sense, the evidence argues for, and favours, the view that firms who develop a sense of opportunity through their learning dynamics open up their choices and alternatives¹¹³. If firms accumulate information and know-how through learning, they increase their technological flexibility¹¹⁴. Throughout the development of the learning capacities firms move along these two dimensions over their life cycles to maintain a sustainable competitive position in their industries.

On the one hand, the **sense of opportunity** is defined through the portfolio of **learning schemes** that firms have at their disposal to reconfigure their knowledge structure and balance the orientation of knowledge, and it is characterized by the diversity of learning schemes and the intensity and retrieval of them in the development of learning events. In terms of **the effectiveness of the technological transformation** the sense of opportunity is linked to coherence and flexibility. It has been argued through the evidence that the more firms expose their own interpretative systems by questioning or introducing new external knowledge the better they become at acting on, and responding to, contingencies or intentionally addressing new options to appropriately compete within a specific industry.

On the other hand, **technological flexibility** refers to the composition of core and peripheral routines (in terms of hard and soft technologies) in which different specialist knowledge converges (e.g. chemical engineering and microbiology). It is suggested that firms with a production system that is flexible enough (e.g. as demonstrated by the NSF when it introduced the laboratory in biotechnology), can easily move towards new commercial lines (e.g. the introduction of sauces in the ISF) or market segments in response to strategic challenges. Technological flexibility is associated with the efficiency of the technological transformation. This type of flexibility, although

¹¹³ The intensity in the use of learning events and their diversity in terms of type of learning schemes increased in both firms over time. Both firms, one more than the other, identified different routes to get knowledge from either of the three sources and for different purposes. As a result these firms developed a versatile learning dynamics.

¹¹⁴ The NSF and ISF developed a technological platform that allows them to support their diversification strategy. So, a complex routines system was created by the means of the learning schemes. In the case of the NSF the most significant example was represented through the laboratory of biotechnology and in the case of the ISF the technological flexibility was evidenced through the implementation of different types of plant production with different commercial purposes.

represented through the embedded (tacit–collective) knowledge, is realized if firms' managers can easily put this knowledge into perspective to get access to strategic markets.

By focusing on the learning schemes so as to assess the sense of opportunity and the technological flexibility, the research for this thesis sought to redefine the (learning) routines in which dynamic capabilities are located. The learning schemes, as explained using the evidence provided by the case studies, focus on satisfying and gaining perspective on the firm's potential to learn in relation to its technological options.

The evidence suggests that firms create a sense of opportunity by following a pattern in the learning trajectory in which the sequence of the learning events define the evolution of the learning capacities from passive to interactive and from exploitative to explorative. Nevertheless, this evolution is not necessarily linear. Additionally each level of capacity is developed to achieve an interactive role in the KILS.

In developing the **formative capacity** firms look to use all the potential of their tacit knowledge (individual and collective) to understand how to improve the conditions under which, by the use of certain technologies, operational routines can be better performed to strategically locate themselves in a competitive niche. The successful use of this capacity allows firms to position themselves in an initially advantaged situation ahead of their competitors. The sequence in the learning pattern defines the formative learning capacity as the first step in the process as well as well as in the most important (or significant) group of schemes that support that support the development of the KILS.

If the formative capacity is the support of the interactive process to integrate knowledge, the development of the **adaptive capacity** creates the conditions for firms to understand how to identify advanced codified knowledge to improve conditions of the technology in use. This capacity creates a relation with expert advisors and organizations such as technological providers (of hard and soft technologies) and universities through the engineers they train. This adaptive capacity represents the first step in opening the firms' interpretative systems to new technology which allows them to go further in the understanding of new ways of integrating knowledge. Adaptive and

formative capacities normally complement each other in relation to their sequence in the learning process.

Complementary and systematic interactions between learning schemes that make up part of these two learning capacities (formative and adaptive) were the basis for the most reliable patterns for these firms to follow so as to be efficient in their technological transformation in developing their technology-routine systems. Differences in the intensity but more importantly in the complementary use of **transformative**-related learning schemes between the two firms in the development of the next step in the learning-capacity building were clear (see table 7.3).

The historical analysis helped to describe how these firms went through a particular learning path over their life cycles.¹¹⁵ Starting from the development of formative and adaptive capacities, the NSF and ISF initiated paths to develop their learning capacities, in the case of NSF moving through them to having transformative capacity. Once the firms were established, they displayed **inventive**, **created** and **renewed** learning capacities – i.e. explorative learning capacities. The evidence suggests that before firms consider going for explorative learning capacities, they should achieve an established position in the industry, in which a well-defined market segment, an understanding of their technology and the possible alternatives they may follow are relatively well resolved by and transparent to the firms' managers.

In the case of building up explorative learning capacities, going through passive-related events helps firms understand the implications and nature of this type of knowledge where results cannot be expected and where there is 'a mismatch between these learning events and the current operational routines. So, the inventive capacity as suggested should be developed first. In contrast to the exploitative learning events, interactive learning events are more suitable for integrating knowledge of this kind, if the partner firm involved has already developed proper research experience that can be developed further through the interaction with the other firm. Inventive capacities are

¹¹⁵ The ISF followed the expected pattern of learning-capacity building (as proposed in the framework) in which firms first develop all the learning possibilities by complementarily using the three different sources of knowledge – i.e. passive, active and interactive.

developed to get closer to more scientific knowledge in order to attract (good) universities and research centres to help the firm to change its technological path. The table 8.1 compiles the characteristics of each learning capacity for the KILS.

Table 8.1 The KILS and the learning capacities

Learning capacity	Singularities	Challenges	Conditions	Representative learning schemes
Formative	<ul style="list-style-type: none"> • Tacit knowledge embedded in staff members • Efficiency-driven learning events • Basis for the implementation process • Focused on the development of core competences • Prompted by a participative learning system and socially based methods 	<ul style="list-style-type: none"> • Reducing superficial learning and causal ambiguities 	<ul style="list-style-type: none"> • Creating a sense of autonomy and empowerment among staff members • Development of socialization capabilities. • Developing an Information-seeking culture 	<ul style="list-style-type: none"> • Technical adjustments • Operational practices • Product development
Adaptive	<ul style="list-style-type: none"> • Explicit and codified knowledge • Efficiency and efficacy-driven learning events • Focused on the development of core competences and market opportunities • Prompted by an expert learning system and formal communication methods 	<ul style="list-style-type: none"> • Recognition of the state of knowledge of the production system • Matching selected technologies with commercial opportunities 	<ul style="list-style-type: none"> • Developing system capabilities • Formal management system 	<ul style="list-style-type: none"> • Hiring key technical specialists • Technical advisors • Technical training • Equipment acquisition
Transformative	<ul style="list-style-type: none"> • Tacit knowledge under different interpretative systems • Risk-sharing of a complementary technology • Focused on market 	<ul style="list-style-type: none"> • Avoiding unprovenness and casual ambiguity • Complementary values between parties to avoid leakage of information 	<ul style="list-style-type: none"> • Developing system capabilities • Formal management system 	<ul style="list-style-type: none"> • Shared specialized equipment • Supplier agreements • Technical mission

	<ul style="list-style-type: none"> opportunities and strategic focus Prompted by a participative learning system and socially based methods 			
Inventive	<ul style="list-style-type: none"> Tacit knowledge for development of in-house research expertise Experimentation to provide divergent technological solutions Focused on strategic focus Prompted by a participative learning system and formal communication methods 	<ul style="list-style-type: none"> Advoiding unproveness and casual ambiguity Formalized and routinized the research activities 	<ul style="list-style-type: none"> Developing Coordination capabilities Developing socialization capabilities Developing an Information-seeking culture Combining formal management system with a participative system 	<ul style="list-style-type: none"> Technical experimentation
Created	<ul style="list-style-type: none"> Explicit knowledge embedded in specialists Development of productive opportunities Prompted by an expert learning system and formal communication methods 	<ul style="list-style-type: none"> Advoiding unproveness and casual ambiguity 	<ul style="list-style-type: none"> Developing system capabilities Formal management system 	<ul style="list-style-type: none"> Hiring key reaseachers Technical advisors Interships
Renewed	<ul style="list-style-type: none"> Tacit knowledge under different interpretative systems Searching for divergent technological and market directions Prompted by a participative learning system and socially based methods 	<ul style="list-style-type: none"> Advoiding unproveness and casual ambiguity (assimetries in the interpretative system between parties) Complementary values between parties to avoid appropriability problems 	<ul style="list-style-type: none"> Developing Coordination capabilities Developing system capabilities Developing an Information-seeking culture Combining formal management system with a participative system 	<ul style="list-style-type: none"> Experimental research Engineering research

Source: The author

The concept of absorptive capacity and dynamic capabilities have been linking to a varieties of ways in which firms can create the conditions to recognize new knowledge, select it properly and finally implemented to modify the firm's knowledge based and capabilities. This research proposed to expand the mechanisms that firms exercise for the mobilisation of knowledge which in these two literatures have been limited to R&D, product development and advanced training. But rather than just recognising further important mechanisms this research analytically and empirically through the two case studies gave an important contribution in to how all these mechanisms are related to each other. By linking the FLMs with the learning process the research in this thesis defined the learning schemes as a more comprehensive vehicle for knowledge integration offering a broader explanation for the building up of the firm's learning capacity, especially for SMEs which operate in traditional industries as Spithoven, Clarysse and Knockaert (2010) previously acknowledged.

So, the construct of the learning schemes is constituted as a mechanism that represents the absorptive capacity and the dynamic capability of the firm. This research posited the idea that firms have to use the proper schemes to mobilise knowledge across the organization enable the development of the firm's learning capacity. These schemes represent then the means through which firms are able to reflect and assimilate knowledge (PACAP -potential absorptive capacity-) and implement knowledge (RACAP-realized absorptive capacity-) (Zahra and George, 2002, Camisón and Forés, 2010). Then, the thesis provides a more interactive view in which the sequence between PACAP and RACAP is defined, distinguishing three possible patterns, 1) Discretionary, 2) Complementary and 3) Systematic.

Moreover, for the understanding of the process of absorptive capacity and development of dynamic capabilities for the KILS two frameworks were combined in the research for this thesis. The first relates to knowledge sourcing strategies and the second to the knowledge exploration and exploitation framework. Although similar works like the one developed by Rothaermel and Alexandre (2009) and Dixon, Meyer and Day (2014) have already identified the importance to relate these two frameworks to differentiate their effects on firm performance, do not suggest much about their interaction and do

not have a clear understanding about how a process of capacity building is developed through different transitions periods in the firm's life cycle.

In relation to exploitation-exploration framework researches within the organization learning literature have claimed the importance for firms to create a balance between these two orientations for the development of the firm's capabilities. The findings in this research evidenced that exploitative related mechanisms purposes are beyond getting efficiency for the known technology but also serve as a pipeline to integrate knowledge from explorative related schemes in to the routines. As a result firms need to poses the learning capacities to assimilate and implement the technological opportunities before they learn how to reflect on new technologies, otherwise exploration became a continuous futile effort for the firm's technological development. More than balancing exploitation and exploration this research suggests that firms should be develop a symbiotic learning interaction between these two distinctive orientations, which is just possible when firms also develop unbounded interactions with their business environment through any of the three attitudes towards external knowledge –i.e. passive, active and interactive. And so, firms might not be able to create an ambidextrous interaction between exploitation and exploration without exposing themselves to external knowledge¹¹⁶.

8.3 The learning capacities and the effectiveness of the technological transformation: scope and outcome of the KILS

In the analysis of both cases the development of each level of capacity through the learning schemes was not the most important aspect; rather what mattered was the relationship between the capacities and how the development of each of the capacities led the firms to develop a sense of opportunity and advance in their technological flexibility. So the sequence in the learning pattern through the learning capacities in relation to the technological trajectory over a firm's life cycle is what determines the level of the firm's absorptive capacity and the dynamics in its capabilities.

¹¹⁶ In this sense this research also includes Lane and Lubatkin (1998) construct that they termed as 'relative absorptive capacity'.

The argument behind this research is therefore that firms evolve over time if they create the conditions to develop their sense of opportunity and through it gain technological flexibility. If firms' managers decide to not (or minimally) exercise any form of learning dynamics, even through formative learning events, besides learning-by-doing, their sense of opportunity is considered **insufficient**. In this case the technology is attached to the initial knowledge base, and therefore the flexibility is considered **low**. So, the interpretative system in these firms tends to be highly dependent on the restrictive cognitive and behavioral conditions of individuals, and the understanding of routines is normally quite ambiguous with regards to the market needs.

In cases where firms start to modify the technology in use by identifying techniques of production and transferring encoded knowledge from external knowledge providers, the firms move towards having a **limited** but expanding sense of opportunity until they become better at knowing how to search for the best possible option for their technical, cognitive and socially constructed conditions. Ambiguity in their interpretative system is reduced as they become clear about how already-made technology from external providers – i.e. an active source of knowledge – fits with their current capabilities; such firm could also become more flexible in terms of the possibilities they open up for the use of routines to find new market opportunities. In these cases a limited sense of opportunity can lead the firms towards **medium** technological flexibility of their operational systems.

If firms' managers decide to continue their learning trajectories beyond what is expected, their firms start to develop what is called an 'ambidextrous KILS' where exploitative and explorative learning events from different sources are systematic and complementarily deployed. At this point firms might also start moving towards making path-breaking changes although these changes might not yet be effective. This is a point of **sufficient** sense of opportunity and **high** technological flexibility. According to the analysis, the ISF achieved this point in the KILS (2010). Although the NSF had a sufficient sense of opportunity its technological flexibility was still considered medium.

There is no evidence in the case studies used for this research for situations in which explorative learning events in the form of engineering research were efficient in leading to technological transformation, as both cases were in the first stage of making the transition towards becoming emerging complex technologies. Nevertheless, it is expected that firms of this kind create at some point in their technological trajectory, technological and commercial breakthroughs (path-breaking changes). In cases where the results of this engineering research start to make sense for the firm's interpretative system and lead to changes in the technological dependence in the routines, the sense of opportunity can be considered **extensive**. Using the two case studies as examples, table 8.2 describes the relationship between technological flexibility and sense of opportunity, and the possible patterns in the evolution of the KILS.

Table 8.2 Assessment of the firms' KILS

Case studies	Life cycle	Initial conditions	Formation	Establishment	Expansion
NSF	Technological flexibility	Low	Low	Medium	Medium
	Sense of opportunity	Insufficient	Insufficient	Limited	Sufficient
ISF	Technological flexibility	Low	Medium	Medium	High
	Sense of opportunity	Insufficient	Limited	Sufficient	Sufficient

Source: the author

Even though this analysis is not within the scope of this research, it could be useful for mapping the asymmetries at the industrial level of a group of firms so as to understand the type of KILS that fits their development. For instance, firms with insufficient and low technological flexibility should focus on deploying learning schemes that allow them to develop their formative learning capacity (e.g. technical adjustments, operational practices and even exploit the possibilities of product development). In these cases firms should create the conditions at an organizational level to generate a decision-making process in which all their members feel free to decide the routines in which they are to be involved. In contrast, firms with a sufficient sense of opportunity and high technological flexibility might be able to undertake collaborative R&D with universities, and in these situations these types of firm might be ready to make a breakthrough in

their technological trajectories (i.e. path-breaking changes). This type of analysis could also reduce opportunistic situations in the firms' technological development.

This proposition therefore implies that the position of firms in the map defines their approach to passive, active or interactive sources and exploitation and exploration, but also the result in terms of the effectiveness of their technological transformation with regards to the learning events they decided to encounter. Although this cannot be seen as a limitation on firms developing their KILS it could be useful as a tool for understanding the best route to take (see table 8.3).

Table 8.3 Patterns in the evolution of KILS and strategic orientations

High		?	ISF (2010)	*
Medium			NSF (2010)	*
Low				?
Technological flexibility	Insufficient	Limited	Sufficient	Extensive
	Sense of opportunity			

*Expected trajectory in the assessment of the KILS in both firms

The blue lines in dashes represent the possible route to follow and the red lines in dashes question if those possible routes could happen over the firms' life cycles.

Source: The author

The explanation arising out of the analysis in this research has sought to emphasize the importance of advancing the creation of a sense of opportunity as well as developing technological flexibility. Then, firms that search for a path to gain an extensive sense of opportunity and high technological flexibility will perform better and survive.

The research in this thesis then goes beyond previous conceptions of the absorptive capacity and dynamic capability of the firm by adding and combining further characteristics for the explanation of how the learning capacities are developed and their relation with the firm's technological transformation along different transition periods. The general idea is that although firms learn from their internal dynamics, their interpretative system evolves when firms are also able to strategically select knowledge from external sources to modify their capabilities and routines.

Nonetheless, others factors are looked for to explain how the KILS could evolve; these

also relate to the alignment between the functional learning mechanisms (FLMs) and the meta-learning mechanisms (MLMs), which create the conditions for learning to happen. Questions for further research should be aimed at firms that have managed to survive, despite not developing a sense of opportunity and technological flexibility. Such explicative features might be of higher importance for the KILS in comparison to what this research proposes.

8.4 The macro components of the KILS, a necessary but not sufficient condition.

From the debates in the literature on knowledge management and organizational learning, this research has distinguished between architectural and component knowledge. The former relates to the platform that firms develop on which the structure, hierarchies, incentives and communication processes are situated (De Boer et al, 1999). The latter refers to the structure of the production base, in which capabilities and the operational routines are situated. Although the KILS emphasises the relevance of the micro-components of knowledge and learning, as an integrated system it incorporates the architectural knowledge of the firm.

The general proposition for debate, derived from the analysis in this research, claims that firms over the development of KILS, tend to adjust their architectural knowledge as a response to how the results from learning events in relation to changes in capabilities are interpreted. And so, the dynamics of knowledge integration and learning through the learning schemes inform managers about how they should pursue the way decisions are made and how the flow of knowledge across the firm's members should be distributed.

Through the findings in the research, a bottom-up perspective to understand how firms develop their learning capacities is suggested. In line with the discussion in the literature, the research considers two main characteristics of architectural knowledge, the decision-making process and the MLMs (Khoja and maranville, 2010). Based on the findings in this research these are constituted elements of the KILS, suggesting their relevance in the construction of the firm's interpretative system in relation to the development of the routines and capabilities. So, the research has also discussed from

the evidence the implications of these two related features of the firm's architectural knowledge to explain the evolution and direction of the KILS.

The evidence from the cases suggests that the characteristics of the **decision-making process** are particularly influential in creating the conditions that spark the learning dynamics. The proposed framework used by Shrivastava (1993)¹¹⁷ has served as a categorization that has been used to explain differences in the evolution of the learning capacities over the firm's life cycle.

Both cases provided evidence that firms begin, under their initial conditions, with a decision-making process defined as a one-man institution where congenital learning (Huber, 1991) is still important and where having a figure of reference as a technical expert gives the required confidence to push the firms' strategic decisions forward. However, once firms start to hire knowledgeable staff and they began to develop some expertise through learning-by-doing, the decision-making processes are likely to turn towards more structured, inclusive and participative systems. This particular change as indicated by the evidence switched part of the decision-making process from the main manager to the staff members who are closer to the day-by-day running of the operational routines and empowers them to take responsibility for the efficiency in production (e.g. Sun and Anderson, 2011). The evidence suggests that this particular move generates the conditions under which learning dynamics could emerge that result in people being pushed towards a proactive attitude and being more open to change. While the ISF made the transition from a one-man institution (initial and formation periods) to a participative system and an information-seeking culture (established and expansion periods), in contrast the NSF moved its decision-making process to a more formal management system. In both cases this transition coincided with a systematic interaction between learning capacities and an increase in the intensity of events and diversity of the learning schemes. In other words, the sense of opportunity in both firms improved as well as the technological flexibility (see table 8.1).

Regarding the MLMs, it was decided that the research would follow De Boer et al's

¹¹⁷ (1) one-man institution, (2) mythological learning system, (3) seeking culture system, (4) participative learning system, (5) formal management systems and (6) bureaucratic learning. system.

(1999) proposition which defined these mechanisms as system capabilities, coordination capabilities and socialization capabilities. System capabilities refer to all the formal mechanisms with which the firm makes an effort to generate encoded (explicit-collective) knowledge by using codes, working manuals and information systems. Coordination capabilities are related to the mechanisms that firms create to develop interaction practices between individuals and groups (from different areas, for instance). To generate these mechanisms, firms can facilitate job rotation, decentralize information or develop a project-based learning approach, all of which can help them deal with ad hoc situations. These types of mechanism allow the diffusion of embedded (tacit-collective) knowledge. Socialization capabilities, on the other hand, are defined through the sense of identity that a firm's members have in relation to the mission and goals of firm also called shared mental models (e.g. Ellis, Margalit and Segev, 2012).

In line with previous research in this field (e.g. Cepeda-Carrion, Cegarra-Navarro and Jimenez-Jimenez, 2012) the evidence suggests that learning conditions are favoured when any of these forms of mechanism start to be installed in firms. The need to use these MLMs appears in firms once they gain a better understanding of technologies in relation to their markets. In other words, these mechanisms emerge once firms have gone through a period in which formative learning capacity has been developed. Nevertheless, the evidence does not suggest the existence of a single pattern in the development of these MLMs as both firms studied presented differences in the ways these mechanisms were created. While the ISF started from the development of system capabilities and then moved to make use of socialization and coordination capabilities, the NSF decided to first introduce coordination and socialization capabilities and afterwards introduced system capabilities.

To sum up, the particular implications of the research regarding these aspects of the KILS suggest that changes in the architectural knowledge emerge as a response to the evolution of component knowledge. Firms then become aware of the importance of creating the environmental conditions to facilitate learning dynamics. Therefore, movements at the micro-level should be synchronized with movements at the macro-level of the firm – otherwise tensions might be created and the integration of new knowledge might be obstructed. The evidence suggests that in order to develop a sense

of opportunity along with technological flexibility, firms should be prepared to move towards participative forms of decision-making processes and develop MLMs to facilitate the diffusion of encoded and embedded knowledge as well as create a system in which convictions, although shared, are also challenged.

8.5. Industry conditions affecting the dynamics of the KILS in engineering based SMEs

Apart from being focused on SMEs, the findings of the research relate to firms, which are bounded within particular conditions specifically referred to in terms of **the market context, the technological opportunities** and **the firms' industrial activity**. These extrinsic conditions defined, as indicated by the evidence from the two cases, some risks and limitations that affected to a certain degree the manner in which managers decided to undertake their actions within the KILS, and therefore the direction and evolution of capabilities in these two firms.

The first extrinsic condition refers to the context of the market was defined in this research through three features. These are the regulatory framework, the technical sophistication of the clients and distribution of competitors by market segment were important in managers' decisions over how to move these two firms forward.

The **regulatory framework** in each of the two industries, although it became stronger over these firms' life cycles, did not impose clear norms and protocols of how acceptable the technological standards should be (to produce propagated plants in the case of the nursery seedling firm (NSF) and ingredients in the case of the ingredient supplier firm (ISF)). Therefore, there were certain ambiguities in how the reliability of the products with minimum acceptable characteristics for the market was defined. As a result investments in learning to improve the capabilities and routines for the use of better technologies did not seem to guarantee for their appropriability. Nonetheless, one of the advantages of these types of product relied on the possibility of having a (positive) impact on their clients' production systems, once the products could be proven right in the market – this meant that reputation (good or bad) played an

important role in defining the standards of the technology despite the deficiencies of the regulatory framework.

These two firms chose to make gains in their markets through reputation, and therefore their search for knowledge and learning was the sensible route to follow. As the evidence from these two cases suggested, when the regulatory framework has failures, the standards could be defined by using these means. As a result, firms might adopt three principles for their KILS, which are consistency, endurance and transparency in relation to how they encounter their markets. So, in order to maintain consistency and endure, firms should be able to maintain the pace of learning and create a reliable system to solve technical problems in production and keep one step ahead in the identification of technological solutions.

Transparency is related to the second feature of the market context referred to above as the **level of technical sophistication of the clients**. The situations in both firms were also quite similar in this respect. Commercial farmers for the fruit industry in the case of the NSF and small food processors in the case of the ISF were not technically knowledgeable about the benefits that better technologies could bring to their processes. Apart from the efforts made by both firms to have reliable technological solutions, they also developed a socialization and assistance programme to teach their clients how to make the best of their production systems. Over time this market strategy focused more on the clients' technical solutions rather than the selling of products as such, and this strategy started not only to show its value in maintaining the relationship between these two firms and their customers but also to expand the market. The NSF and the ISF recognized the value of their learning efforts when their markets appropriated their technological developments.

In contrast to the other two features of the market context, **the distribution of competitors** was different in each of the two cases, and was manifested by the number of firms, size and technological dynamism.

The distribution differed in terms of the number and size of their competitors. In the situation of the NSF, due to the lack of regulatory framework, competition grew in

number (the ICA (Columbian Agricultural Institute, acronyms in Spanish) listed 123 nursery firms in Columbia in 2008) but not in size (competitors were also SMEs) or in their technological dynamism. One characteristic of these competitors was that they did not have the same technological standards as the NSF has; therefore, their plants were much cheaper than the NSF could even produce. This was an obstacle that also challenged the dynamism of KILS in the NSF.

The competitors of the ISF, on the other hand, were fewer but larger (some were multinationals) and more dynamic than the competitors in the NSF in terms of their technological development. Because of this situation the decisions in the ISF regarding the KILS were also highly motivated by the desire to overcome the firm's technological disadvantages compared with the large multinationals and to develop an advantage over local competitors. A big move in its strategic development to create a difference against its competitors was to develop through the KILS a diversification strategy. So, these extrinsic conditions were also a factor to consider when analysing the way that managers in the firms decided to address their firms' learning and technological trajectories.

The second extrinsic condition refers to the technological opportunities. In terms of the technological opportunities there were clearly some limitations for both firms that, although they were gradually overcome over the firms' evolution, were perceived by the their managers as obstacles in the way of gaining access to new knowledge. Technological opportunities are represented by the engineering and scientific knowledge produced by organizations such as universities, R&D centres, consultants and other technological providers. One complementary explanation of the relative importance of passive knowledge for the firms' technological development, suggested in this research, could be related to the inconsistency of, and/or unreliable, knowledge that these organizations used to produce (based on the firms' managers perceptions about their experiences with some of these organizations). However, as has also been argued throughout the thesis, there were more important reasons for the intensity of the use of passive learning events (rather than active and interactive events) than the limitations of the technological opportunities; these reasons are related to how the

dynamics of the firms' learning capacities evolved, and the role of these learning capacities over the learning trajectories.

The third condition refers to the firms' economic activity. While the NSF is part of the agricultural industry and focuses on the propagation of plants for fruit production, the ISF belongs to the food industry with its activity centred on the production of ingredients; both firms are situated at the bottom of the value chain. Based on the findings from the research this distinction is important for the KILS because of two aspects, first, the nature of the technology (hard or soft) to boost the economic activity and second the focus of attention of the learning efforts (technology-push or demand-pull).

As explained in the cross-case analysis the emphasis placed by each firm on using certain learning schemes was partially explained by these two characteristics. Technological developments in the NSF, as suggested by the evidence, were mainly oriented towards the soft parts of the technology (know-how regarding the methods of propagation, which refers to techniques, procedures and timing in the sequence); and the focus of attention of the learning efforts was closely related to the sophistication of the technology according to what the managers considered the best for the production of plants for the fruit industry, rather than asking farmers what they needed. These characteristics made sense as the NSF considered itself an expert in the subject, with a mission of producing the best for the industry.

In contrast, the ISF focused its attention mainly on the hard parts of its technology (equipment and infrastructure, which refer to the mechanics of production to produce the mixes), at least over the first three stages of the firm's life cycle. Over the last stage the firm achieved a better balance between the development of the soft and hard parts of the technology. The firm's technological development, in terms of how it focused its attention on learning efforts, mainly responded to the needs of, and demand from, its clients (e.g. product development was the main learning scheme); in fact the firm managed to develop a system of communication between its clients and its engineering and design (E&D) area to get more inside information on what they wanted and to make sure that their requirements were met by a reliable technological response.

The research in this thesis considered these extrinsic conditions relevant to an explanation of how and why these firms' managers decided to approach in certain way the development of their KILS. So, taking into account the extrinsic and intrinsic conditions under which the evidence of the two cases was taken for the analysis, the following sections in this chapter aims to offer an overall discussion of the findings, and their contribution to the research of this field.

8.6 Implication for management and policy

The findings in this research suggest recommendations at three different levels of analysis. The understanding of knowledge integration and learning from an action approach define individuals and group attitudes and behaviours that emerge from the practices and knowledge they develop from the interaction with the operational routines. This action and practice –bottom-up- approach is defined at the micro-components of learning. The second group of implications are defined at the organizational level distinguishing the macro components of learning also recognised as strategic based approach. A third level of implications are identified out of the boundaries of the firm, centred on policy makers who are in charge in defining industrial policies to foster the building of learning capacities and the development of capabilities especially for those firms categorised as SMEs.

8.6.1 Practice based approach to learning

This research draws the attention to managers to the functional and micro aspects of learning which highlights again the importance of having a bottom-up approach to management rather than just a strategic and organizational one. So, autonomy, empowerment, individuals and group actions and participative process emerge as a key aspect to promote knowledge integration and learning for the strategic development of the firm.

The learning schemes became the means through which individuals and group actions are performed. Individuals within firms should be able to pursue these schemes in

order to transfer their cognitive knowledge – embrained knowledge- into the routines when required, as a response to a problem of production or market or to make the technological platform more sophisticated. So, having a full understanding of the routine in perspective with the strategic purposes of the firm (cognition), building a critical conception of its performance (interpretation) and developing a sufficient level of autonomy to perform changes along with a clear route of action (learning scheme) to make those changes are the challenges that firms' members must accomplish. These characteristics of firm members' behaviors describe then a relationship between their knowledge and the routine they perform. So, individuals within firms, as the evidence showed, in order to have effective KILS in which firms are able to efficiently reconfigure knowledge by using different sources and orientations, should move their behavioral capabilities towards this practice based approach to learning (cognition, interpretation and action).

By applying this approach, it is expected that individuals would avoid conformity regarding the performance of the routines and that they would search for satisfactory ways to get better results. So individuals are constantly searching ways to develop a better system of interpretation by interacting with others and exploiting their cognitive knowledge in a variety of ways.

For this approach to be fully applied by individuals, decision making systems must be expertise centered and highly concentrated in the functioning of the routine. Additionally, individuals must perceive that the system of incentives is open to failures under rationale conditions and promote, by any kind of social reward, the pursuing of these learning schemes. As a result, those engineers and technicians who stayed with the firm for a long time are the ones who are able to exercise their autonomy and responsibility by generating different means for the mobilization of knowledge. These sets of practices should be developed along the firm's life cycle, as firms should gain learning experience through the learning events that individuals perform. So, the evidence shows that the practice based approach emerges as a result of the learning dynamics of the firm.

Moreover, this practice based approach should be aligned with certain practices at the organizational level, and so, firms should create the conditions from which their personnel can put into practice their abilities to identify problems and push forward new ideas and solutions as is described in the managerial implications of the KILS.

8.6.2 Implications for management

How strategic firms can be, even if they are selecting the right knowledge and to what extent firms can appropriate that knowledge to gain competitive advantage? The efficiency of the technological transformation of any particular learning event depends on i) the way in which the knowledge was sourced, ii) the prior knowledge that managers have with regards to how to address the technological direction, and iii) the manner in which decisions were made.

To do so, this research proposes that managers should be able to **create alignments** between strategic decisions and individual actions in a way that the former increase the potential and assertiveness of the latter instead of blocking them. In this sense firms should be able to facilitate under certain order –i.e. through coordination capabilities for instance- the emergence of random and less planning actions, in other words, allow individuals to be proactive and develop their expertise over their routines. Nevertheless, for this bottom up approach to work properly socialization and coordination capabilities that promote more fluid and accurate communication and interaction practices should be pursued as well.

Therefore, from the learning dynamics to take place in organizations there should be a combination in between **clear procedures and autonomy of the staff members** to put in practice their own expertise at solving problems. Rather than economic incentives for instances staff member should be able to perceive that they are actors capable of carrying out changes. If the structure is too rigid it will be quite difficult to interfere in the functioning of the routine. So, clear procedures and flexible decision-making process on the routine bases favored learning to happen (mainly formative).

Managers should be able to **coordinate knowledge integration** from different sources in relation to a variety of factors: i) the nature of knowledge and transferability conditions: whether knowledge it is in its tacit, explicit or codified form, ii) The required effort to connect a variety of learning events through different schemes to create the cognitive and behavioural changes, iii) The level of cohesion that engineers have on their capabilities and the interpretation of the routines, iv) The level of understanding of the role of each learning scheme within a specific temporal and strategic context and how it fits their interpretative system ,v)The learning experience based on the intensity of learning events and use of appropriate learning schemes, vi) learning experience based on keeping the personnel within the organization by making their interaction with the routines satisfactory, vi) Combine intuitive with rational logics in the process of understanding the usefulness of new component knowledge with regards to the applicability of the routines and strategic possibilities., vii) The descriptions of the firms' learning events show that learning tends to be conceived in action and practice; therefore decisions are taken as part of the learning process.

In terms of motivations firms' managers should be able to analyse the benefits of knowledge integration and learning beyond economic benefits and short-term improvements. So, the evidence shows other driven motives that firms should consider as listed below:

- 1) Gaining perspective of the state of knowledge of the production system by exposing and contrasting the firm knowledge based.
- 2) Achieving technical satisfaction through market credibility.
- 3) Affording failures and understanding the conditions to overcome them instead of converting them into an obstacle.
- 4) Gaining a sense of opportunity of the technological and market possibilities
- 5) Gaining flexibility of the technological platform to be more focused on the strategic possibilities that firms can acquire.
- 6) Reducing the 'causal ambiguity' that key members of the firm have of the operational system.

This research also suggests that firm’s managers should be **fully aware** of the stage in the life cycle in which the firm is in relation to the learning capacities they have built and the conditions of their learning environment. Although having any learning experience is important what this research evidenced is that appropriability is in function of the state of knowledge of the firm and how it has been able to develop a sense of opportunity. Neglecting these two aspects could create not just misalignments (Leonard-Barton, 1988) in the knowledge integration process but bad experiences that could be related to spurious learning.

So, the more a firm is able to **systematically and formally learn from previous learning events** and to **make sense of the combinative efforts of a variety of learning schemes** in relation to its competitors, the greater the effectiveness of the technological transformation and so the firm’s absorptive capacity. In this sense firms’ managers should be capable to properly understand the scope of any learning scheme and which practices are better aligned to assure the effectiveness of knowledge integration and learning. Some of these practices were selected from each of the two cases (See table 8.4).

Table 8.4. Learning schemes and best practices for managers

Learning scheme	Best descriptor	Best practices for managers
Technical adjustments	This learning scheme is better used to develop a common ground in the interpretative system of the operational routine.	Autonomy of the staff members. Participatory decision-making to recognise everyone’s expertise.
	This learning scheme might be considered the foundation for knowledge reconfiguration.	Apply a problem-solving approach for the running of the production system.
Product development	This learning scheme is better used for supporting the diversification strategy	Versatility of the firm’s operational routines in which the same principles could be applied to a variety of market options.
	This scheme is one of the most relevant driving forces for the search for new capabilities	Develop a rational and routinized sequence form idea development to market entrance. Form a group for this purpose only – i.e. this was a formal participative system.
Hiring and	This scheme is better used for	Give time to new personnel to put

mobilization of key engineers	<p>incorporating new technical knowledge into the firm to develop better techniques with regards to the specific routines or support the product and product diversification.</p>	<p>into practice their abilities, to identify problems and push forward new ideas and solutions</p> <p>Create the conditions to push new personnel to exploiting their cognitive knowledge as much as possible.</p> <p>Develop a clear profile of the members by somehow standardizing the process to find personnel that fitted the firm's standards.</p>
Managerial and operational practices	<p>This scheme is better used to create the conditions to encode knowledge.</p> <p>Scheme developed to encourage the development of explicit and codified knowledge.</p> <p>This learning scheme allows the flow of information to be coordinated between areas of the firms. Through these events organizations managed to systematize and filter some useful information to record some of their experiences, as well as assess the performance of the operational routines.</p> <p>They could be considered as methods to create bridges within the KIL.</p>	<p>Learning events related to operational and managerial practices are better implemented after the firms had gained some understanding of their operational routines.</p> <p>Managerial support and the development of participative systems were decisive in making these practices work within the organizations.</p> <p>Implementation of standard procedures to make the flow of information from one area to another more assertive and commonly understood – i.e. this demonstrated system capabilities.</p>
Technical training	<p>This scheme served to mobilize knowledge throughout the learning process in those events in which there was a high cognitive distance between current and new knowledge.</p> <p>Technical training thus functioned as a bridge for assimilating new knowledge and reinforcing some adjustments that had previously been implemented.</p>	<p>A structured platform should be implemented for the purposes of consistently and formally addressing this technical training to fully align its purpose with the conditions of the component knowledge.</p> <p>The implementation of rules and procedures – i.e. system capabilities – generate the conditions under which these schemes are performed</p>
Technical experimentations	<p>This scheme is better used to reduce some technical asymmetries regarding technological opportunities.</p>	<p>Firms must identify and start using the cumulative cognitive experience of the most proficient engineers.</p> <p>Research activities should be</p>

Experimental research	This scheme is also used to improve the level of assertiveness at which technical adjustments were pursued.	conducted as part of well-established routines and not completely apart from the interpretative system.
	This scheme is used to keep exploring new technological and market alternatives to create the conditions that allow firms to move their interpretative system towards divergent technologies.	Embedding this knowledge through the formalization and routinizing of the procedures resulting from this technology.
	Engineering research was justified when advanced technologies were distant from the current technological platform in place. It helps to develop reputation and technological substitution	The firm should have research-oriented staff that start developing their research capabilities within the organization in relation to the technological requirements of the organization.

Source: the author

Clearly having effective operational routines is as important as having effective use of the learning schemes for achieving competitive advantage, as the seconds can actually be the source of the first ones. And so, organizations must be aware of the importance of devoting some efforts in constantly integrating new knowledge and lost their fear to carry on research. But, this it will possible if firms' managers understand also that processes and pace are two important aspects in the development of effective learning and technological trajectory. Therefore, developing a sense of opportunity goes hand in hand with creating a flexible technological platform.

8.6.3. Implications for policy: industrial policy

Policy makers and technological providers on the other hand should be able to recognise the conditions of the industries and firms in terms of their learning capacities to be assertive in the way that they look to promote technological transformations and the development of capabilities. This perspective might give some indications on how to place the efforts and resources in a coordinated way to facilitate the appropriability of new technologies into the firm's routines.

Another policy implication of this research refers then to the identification of the role that different technology intermediaries have in promoting the development of the firm's learning capacities depending on the transition in which firms and industries are engaged in. Which type of knowledge, which sources and which learning schemes are issues which should be pursued to improve technological flexibility and the sense of opportunities in the firm development should be the questions that industrial policy makers and technology intermediaries should be asking.

In more general terms, at the industrial level, policy makers and technological providers should align efforts to avoid redundancy, as well as inefficient and inconsistent support to SMEs in the development of their learning capacities and capabilities. First, policies should distinguish not just industrial asymmetries in the life cycle but also asymmetries in the level of the capacity of an SME to assess its competitive level and availability to move forward its technological platform according to market requirements. Second, support should be addressed through the specificities of the learning schemes and the expected outcome and scope for the KILS of each firm or requirements of the industry. Industrial policies in this sense should focus on developing learning capacities and not just capabilities.

Moreover, policies in science and technology should be oriented to create the conditions for knowledge providers to address scientific and technological knowledge consistently with the required standards. Technologies should be available for firms at the point to be ready for exploitation or for exploring their implications for the operational routines in a way that appropriability conditions could be easily identified. Scientific and technological knowledge developed by these organizations should not be ambiguous in nature. The more ambiguous the more the investment firms need to undertake for its integration.

8.7 Methodological limitations and scope for future research

The main purpose of this last section is to consider whether consistency of methods was assured throughout the research. Several authors who have addressed the specific methodology for case-study research (Platt, 1988; Eisenhard, 1989; Leonard-Barton,

1990; Yin, 1994; Lee, 1999; Armstrong, 2003) have expressed their concerns over how the quality of this type of endeavour should be judged. It is therefore important to consider to what extent the adopted research strategy has been consistent throughout the process and whether it offers valid arguments. This section aims to discuss the methodology in terms of the criteria used to judge the extent to which quality was achieved; however, so as to inform future research, the limitations of the approach taken are also acknowledged.

From all the criteria that have been discussed from the literature on case-study research, Yin's (1994) suggestions have been the most widely applied. He proposed four relevant categories to test the quality of a case study: construct validity, internal validity, external validity and reliability. Each of these categories is reviewed against the methodological decisions of this research.¹¹⁸

Construct validity refers to degree of objectivity to which the operational measures to collect the data are assured in terms of the intentions and theoretical framing of the research. The intentions of this research were focused on understanding the organization's learning dynamics from a process perspective in a way that the two selected components of knowledge were observable (i.e. the sources and their orientations). To do so, the analysis of the research has focused on the micro-components of learning that the literature has recognized as FLMs as well as the learning process. From these two concepts a construct defined as the learning schemes was elaborated. Although defined in a different vein, this construct includes, and intends to be consistent with, the intentions and foregoing theoretical arguments.

Three other features to test construct validity refer to the type of data, distance in the interpretation of the researcher in relation to informants, and the use of multiple sources. First, beyond perceptions, the data relates to historical events which are the representation of situations that each of the organizations faced over its lifetime. Second, key informants of the firms reviewed the interpretation of data from their organizations through to the elaboration of the final case reports at different times

¹¹⁸ Other aspects such as logical consistency, empirical validity, degrees of freedom (Lee, 1989; Leonard-Barton, 1990) are considered by the literature.

during the research process. And third, as described, multiple sources and interviews were used to accurately capture each of the events. Based on Yin's (ibid.) suggested tactics construct validity was actively sought.

Internal validity is far more problematic to justify using a case-study research strategy. Explanations and causal relations are questionable without a proper stochastic analysis of the extent to which (x) affects (y). Nonetheless, from the elaboration of building blocks and matching patterns within strategies in a historical reconstruction of events, well-supported inferences using theoretical arguments can be made to offer explanations and causalities.

This research has looked for different explanations: i.e. whether experiences within learning capacities and among them have an impact on the efficiency of the firm's knowledge integration and learning dynamics. In addition, explanations that relate the MLMs with the FLMs as well as the organizational features regarding the decision-making process and alternatives to growth were examined. To find these explanations building blocks were elaborated regarding learning capacities and transitions through the firms' life cycles. The patterns of the learning capacities were then matched with the other characteristics to understand their level of interdependency and interaction.

Another questionable aspect of the case-study research is related to **external validity**. This criterion prompts the question to what extent are the findings generally applicable to any other situation or context? Although discussions clearly argue that general findings are not the purpose of this research strategy, this problem is solved by offering clarity over how the research is bounded on theoretical grounds.

First, what matters the most in case-study research is the theoretical reasoning and contributions; so, despite the context-specific features, a strong theoretical argument should be given. In this sense this research has focused on a paradigmatic discussion related to the link between knowledge integration, learning capacities and capabilities regarding the interaction of knowledge sources and their orientation. In doing so, a variety of similar and contrasting literature such as on knowledge management, organizational learning, dynamic capabilities and absorptive capacity were discussed.

Second, departing from this literature the settings were explained, from the characteristics of the system, the industry and the organization, rather than only specifying the political and social distinctions of the context. The fact is that the country of choice for the research (Columbia –which has placed practical implications on the research) is not that relevant for the arguments within the thesis. Findings are limited or explained by the situations in which the technological opportunities are dispersed and discontinuous and where the industry is considered moderately dynamic. Regarding the organizations, the theoretical contributions of this research focus on SMEs with engineering knowledge bases that are embedded in an organizational form defined as a machinery bureaucracy, and they are moving forward from mature single technologies to emerging complex technologies.

Although these specifications were made, the research has lacked sufficient evidence to assure consistent replication logic, so external replication and **reliability** of the research are affected. This limitation has been acknowledged within the thesis: while it has reduced the strength of the findings, it has offered opportunities for developing a research agenda in this direction, which could be explored by searching for cases with similar but also contrasting conditions.

Reliability also includes aspects related to how protocols and sequences of the research process were clearly defined for others who may want to make use of these procedures; reliability has been sought through the efforts taken to systematize the whole process from case selection through to data analysis. Besides the detailed description of the process, databases and documents were constructed to keep track of how the data was treated for the elaboration of the cases.

This thesis proposes that future research in this field should challenge integrative frameworks to understand knowledge integration and learning from different angles. Therefore, process and historical case studies should be pursued to gain more insights into how the micro-components of knowledge integration and learning actually work and inform decisions of how the technological trajectories of firms should be oriented. However, because of the acknowledged limitations, future research could be oriented

towards understanding differences among other industries and technological and market contexts. It would also be beneficial get more insights from firms who might have developed these learning capacities without going through the four stages of the life cycle. With this additional research, some of the propositions in the research for this thesis could be challenged. Research should also be focused on larger samples of firms in which proxies to assess the evolution of the sense of opportunity and the technological flexibility could be conducted. Finally, an understanding of the role of knowledge producers such as universities, research centres and technological providers at each level of learning capacity could be useful to improve the understanding of how the external business environment could be oriented to accelerate the building capacity of firms.

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