FRIDO SMULDERS

GET SYNCHRONIZED!

Bridging the Gap Between Design & Volume Production

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To my father

Preface

This book is a PhD thesis. The subject is the interface between two distinct processes: product development and manufacturing. The product development process creates the design of a new product and manufacturing transforms this into a real tangible product. Sounds simple enough. However, in practice this often results in conflict among the people involved and/or time consuming problematic situations. How do actors bridge the gap between the design and the running production line?

The first time that I was brought into contact with this interface was a remark from my father, a shipbuilder, in the late 1960's. One day after work and during dinner I remember that he said something like: "I don't understand why the engineers [the people who developed the ship] spend so much time inking up their drawings after they made it in pencil? We can make the collotypes for production just as easy from penciled drawings. Production doesn't need ink, they just put the collotypes under the automatic cutting machine. This machine follows the lines from the drawing and cuts out the steel plates. And collotype of a pencil drawing is enough." In his efforts to make the (costly) engineering department more efficient, he wondered what caused the engineers to keep doing things that are unnecessary in eyes of the production people.

The second time that I encountered this interface, as I see it now, was when I started my studies in Aerospace Engineering at Delft University of Technology in the mid 1970's. My motivation for choosing this education was to acquire knowledge that I could use to develop (and test) racing cars. The knowledge on aerodynamics, lightweight constructions and advanced materials that is necessary to develop airplanes seemed to me to also be very useful for designing racing cars. It was completely clear to me that the knowledge of aerodynamics applied to the design of an airplane to get it and keep it in the air could also, in a reversed sense, be applied to prevent a car from doing the same. This and similar ideas made me think that the educational curriculum of Aerospace Engineering could help me to realize my objective. This seemed like a sure thing: a motivated student with a clear objective and an educational program that would provide the necessary knowledge to reach that objective. Unfortunately, my dream was shot to pieces in the first weeks of my education. When we received our first assignment, which was to copy a drawing of an airplane, I asked if I could copy a similar drawing of a racing car. This was not possible! Later, when we were asked to develop the space structure of a crop duster, I wanted to do the same for a racing car that, at that time, was built with similar constructions. Again, this was not allowed. They just said: "cars don't fly!" But what has this story to do with the interface between product development and manufacturing? Let's look at this situation a bit closer.

In a way, universities can be seen as knowledge companies; their task is to develop new knowledge in research programs, integrate it into existing knowledge and transfer it to society by means of scientific publications and educational programs. Their two main processes, research

and education, resemble in many ways the aforementioned processes of development and manufacturing. Scientific research programs at universities renew the content of the educational program in a similar way as the development activities renew the content of the manufacturing processes. On a more strategic level, and from the perspective of the university, scientific research and educational programs can be seen as explorative processes and exploitative processes respectively. Exploring with research to create new knowledge and exploit that new knowledge by transferring it to the students.

From this point of view, university research programs should be congruent with the educational curricula, that is, there should be a clear fit. The research program and the curriculum of the faculty of Aerospace Engineering were at that time, the mid 1970's, only focused on the associated objects: airplanes and spacecrafts. This object bounded research and education was not surprising since the Netherlands developed and produced aircrafts with Fokker and was heading two satellite programs for the European Space Agency (ESA), the ANS (1974) and IRAS (1983). This dominant object focus didn't leave much room for research and education aimed at additional objects like racing cars. Thus, what I experienced was that, at that time[1], there was no connection possible between my aims and their educational activities. In other words, the 'momentum' of their exploitative teaching routines did not leave any room for my explorative ideas about the application of aerospace knowledge for learning how to develop racing cars.

Needless to say, this 'misfit' caused some delays regarding my 'time-to-market'. It took some time and parallel 'excursions' in other fields like offshore engineering, house construction, and journalism before I found a new motivation to finish my studies. During those excursions I frequently encountered various manifestations of this interface. One of these is probably familiar to those of you who have refurbished a bathroom or kitchen: the interface between the architect and the builder. According to contractors, architects are all 'armchair generals' and don't understand anything about the building process. In their eyes architects just deliver drawings that are sometimes impossible to construct (or to follow). Architects in their turn believe that builders are ungovernable and don't even try to understand their carefully prepared and well thought-out designs.

During my activities as a freelance journalist of popular scientific articles I also met this interface. In one of my publications on the application of composite materials in airplanes I quoted a professor[2] who said: "… the problem is that the aeronautical industry thinks too much in aluminum, meaning that they mainly develop 'black-aluminum' airplanes". According to him, the industry was still using aluminum knowledge for designing (carbon) composite parts. What he really meant was that the engineers who were used to developing airplanes made of aluminum were not yet ready, in terms of knowledge and routines, to develop airplanes made from composite materials. This was the first time I realized that innovating was more than just having new ideas, or in this case having new materials available.

My final Master's assignment concentrated on a tough, unexplained problem regarding an important application of a new fatigue resistant material called Arall (the forerunner of Glare). The scientific staff[3] wondered what caused these problems. There were some tentative explanations, but

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[1] Now, 30 years later, the tide has turned. Fokker left the business arena and the faculty has realized that its knowledge is unique and can be applied to many other things, like LPG-tanks, beer barrels, prostheses, solar powered racing cars (the Nuna-series), rotor blades for wind turbines, etc.

[2] This quote was by W. van Dreumel in Smulders (1985).

[3] Prof. ir. L.B. Vogelesang, Prof. dr. ir. J. Schijve, dr. ir. G.H.J.J. Roebroeks

none of these led to technically and economically feasible solutions that would overcome the situation. I felt challenged by this 'knowledge vacuum', accepted the assignment and started an interesting exploration that would last for two years. At that time I didn't have any formal education in research methodologies so I just followed my intuition in the steps I undertook. I observed many, many samples under the electron microscope, we discussed what we saw, I used creativity techniques like personal analogy to try to understand what happened (How does it feel to be a fiber sitting in the adhesive under this kind of strain?), I formulated explanatory hypotheses that integrated new insights with existing knowledge, and finally I designed tests to check these hypotheses. Of course, in reality the process was not as linear as described here, I sort of oscillated between all these sub-processes with increasing amplitude, increasing in the sense of gaining a better understanding of the real problem and its' root causes. The interesting thing regarding this thesis is that when I gained more in-depth knowledge about research processes during this PhD project, I realized that the research process I had followed during my Master's thesis is very similar to the one that I follow in this book (as is described in Chapter 3). That is, searching for explanations of phenomena that can be observed in the empirical world.

The activities in my career as an innovation management consultant, first with the Innovation Consulting Group of The Netherlands Organization for Applied Scientific Research (TNO) and later as an independent consultant (part-time), can be divided into two streams: management consultancy and training. Over the last 15 years the nature of consultancy activities has changed from sparking innovation towards organizing innovation. The nature of the training programs also changed from teaching creativity techniques and innovation processes in abstract and remote settings towards more integrated programs on innovation and innovation management that also included organizational issues in real and concrete situations. In this way the interface between theory and practice was somewhat treated in the training itself.

In parallel to this, I felt the need to deepen my understanding of the phenomenon of innovation and to study some of the recurring problematic situations that I had encountered as a consultant. Therefore I chose to return to the Delft University of Technology (on a part-time basis), but now as an assistant professor at the faculty of Industrial Design Engineering (IDE). The management of product development processes that is being taught at IDE shows many similarities with the management of innovation. Also at IDE my colleagues and I try to synchronize theoretical courses with practical assignments, which sometimes include company representative role-plays in order to create a blend of knowledge and action structures in the minds of the students. The reason for mentioning this here is that the theory-practice interface exhibits more similarities to the Design-Manufacturing interface than one would expect.

I learned at IDE that design processes are, apart from the construction of prototypes, cognitive processes that lead to drawings, part lists, dimensions, and plans for production and assembly sequences. This output can be regarded as theory; they are theoretical conjectures about the future practice within Manufacturing. There are many books that clearly describe how things should be or how processes need to be followed and they read like blueprints. But putting these blueprints into practice is a lot more difficult for the participants than the theory itself seems to suggest. Therefore I decided to investigate the Design-Manufacturing interface on the level of the actors involved, et voilà, that is what this thesis is about.

This book describes the explorative journey I have taken to find my way within the complex phenomena of human interactions and social sciences that followed the prelude described above. It was a

challenging, interesting but also a strange journey because I know the field of design very well, from theory as well as from practice. But using grounded theory as an approach to investigate familiar territory brought me perspectives that I never had before. Maybe the expression by Johan Cruijff "You are going to see it when you see through it"[4] best illustrates what I have experienced.

The book is organized as follows.
In **Chapter 1** this interface will be introduced as an interface of frequent conflict among the actors and as an interface that has two manifestations: between explorative and exploitative processes and within the product innovation process going from design towards production. Meanwhile, it will be shown that the literature seems to have overlooked the interface concerning the interactions between representatives from both processes. It is assumed that knowing what happens among the actors and what they are trying to achieve might be of help.
In **Chapter 2** the present literature on New Product Development (NPD) is reviewed in search of possible foothold to use during the empirical enquiries. The chapter ends with defining research questions and the formulation of requirements for a possible research method.
With help of these requirements, in **Chapter 3** the research approach is selected and described. The chapter ends with reviewing the research questions and devising the research plan for this project.
Chapter 4 describes the first stage of this research process which aims at the creation of empirical awareness about the NPD-Manufacturing interface in its natural corporate environment and to identify some early categories.
The second stage, which is addressed in **Chapter 5**, describes a further concentration on the NPD-Manufacturing interactions and forms the central part of the empirical investigations. The chapter ends with what is called 'fledgling' categories.
Chapter 6 presents the main results of this project in the form of a theoretical concept that describes the social process of interactions between NPD and Manufacturing and the aim of these interactions.
Finally, **Chapter 7** summarizes the whole project by presenting some contributions to the existing literature and by speculating about some future research projects. This chapter ends with a reflection on the research approach that was chosen.

Now that you know about the 'fuzzy front end' of this research project and have an overview of the book you can choose your own reading path. If you are just interested in the problem statement and the results: read the abstract. If you want to know about the specifics of the problem, the approach and the results: read Ch 1, Ch 3, § 5.5, Ch 6, Ch 7. If you are interested in knowing more about the NPD-Manufacturing interface: read Ch 1, Ch 2, Ch 5, Ch 6, Ch 7. If you want to know about a research process using grounded theory: read Ch 3, Ch 4, Ch 5, Ch 6 and § 7.5. If you want to understand fully the results of this study and how one could report a grounded theory investigation: read it all.

But whatever you choose to read, I challenge you to translate what you read in this book to situations that you are involved in which are similar to those described here. I wish you an inspirational time as you read about my scientific journey. But it is important that the reader realizes that I would never ever have been able to make this journey without the support of many people. You will find the expressible part of my gratitude in the acknowledgements.

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[4] Translation of: "Je gaat het pas zien als je het door hebt." (quote from Johan Cruijff)

Contents

1 *New Product Development and Manufacturing: 'Living apart together'*

*The aim of this research project is to get a better understanding of the **interface** between **New Product Development** (NPD) processes and **Manufacturing** processes. In this way I hope to contribute to the theory and practice of product development.*

Section 1.1 illustrates that NPD processes and Manufacturing processes are each part of different business strategies, the first being an explorative strategy and the other an exploitative strategy. Exploration strategies focus on the renewal of business processes through innovation and exploitative strategies utilize current business processes by gradually improving them. I hope to make clear that execution of both strategies in parallel is necessary to stay competitive, however difficult this may prove to be. The interface between NPD and Manufacturing is one of the places where explorative processes within a company converge with exploitative processes. Section 1.2 shows that this particular interface produces a lot of tension among the actors involved. That NPD and Manufacturing have a sort of love-hate relationship is discussed in Section 1.3. Each of the two processes has its own and very different environment but for successful product innovation they need to cooperate somehow. It is strange that this critical area seems to be overlooked by researchers. In Section 1.4 I will discuss this lack of attention in innovation studies and try to understand some of the reasons behind it. In Section 1.5 the R&D-Marketing interface will be discussed as being a related and well-researched interface. In the final section (1.6) the research aim and main research questions will be described.

1.1 NPD & Manufacturing => Exploration & Exploitation

Consider the following conversation (Clark and Fujimoto 1991, p. 205):

Manager: *"Is this your work?"*
Developer: *"Yes."*
Manager: *"Why did you do this?"*
Developer: *"Based on my calculations, I thought it would work."*
Manager: *"Anyone in the factory could have told you it wouldn't! Did you ask anyone in the factory?"*
Developer: *"No, I did not."*

Unfortunately, this and similar situations still illustrate incidents and conflicts within many companies as they adapt their business to the changing competitive environment by developing new products. Why is it that the people who develop new products hesitate or forget to contact the people who have to produce those new products (Susman & Dean 1992)? Is it because they think they know all the answers or that they speak different 'languages'? Or are there more fundamental reasons?

I felt challenged by these issues and decided to start a PhD-study that concentrates on examining the interface between New Product Development (NPD) and Manufacturing on the level of interactions between the people involved. This book reports on the empirical journey that was initiated by this challenge. This chapter provides the empirical and theoretical context of this interface.

Let us consider the NPD-Manufacturing interface in its organizational context. Physical products are the outcome of the primary processes of a company. Companies buy raw materials that are transformed by manufacturing processes into products which are sold to customers. The outer appearance and the physical properties of the products, including the plans for the manufacturing processes, are the result of development. The development processes aim at creating the best possible offer regarding the needs of customers, clients and consumers balanced with the economics of the company. This allows companies to generate financial flows that can be reinvested in development processes for new products. These new products are necessary because the qualities representing the 'best possible offer' in the marketplace erode over time. This erosion process is the result of technological advancements, competitor movements, changing customer needs and many other changes in society (Rumult 1984). Companies that follow a strategy like 'cost leadership' (Porter 1980) which focus on incremental improvements to lower costs, must constantly be aware of market erosion and begin the development of new innovative products in time to avoid backing themselves into a corner. Or as March puts it:

> *"[a] system that specializes in exploitation will discover itself becoming better and better at an increasingly obsolescent technology." (March 1995, p. 432)*

By developing new products and services and introducing these to the market, companies are able to renew themselves strategically and to sustain and strengthen their competitive advantage which prevents them from being swallowed up by competitors or even going bankrupt. The process of renewing their current business offerings by searching, experimenting, risk taking, and developing new and innovative products and services could be considered to form the 'explor-

ative' side of the company. Creating quality & reliability through refinement, efficiency of production and focused attention through incremental innovation of existing business output forms the 'exploitative' side (Levinthal & March 1993).

This conceptual distinction could be regarded as a fundamental fissure that has been under investigation for a long period of time. According to Galbraith (1982) companies that want to innovate need two organizational arrangements because the process of innovating uses a fundamentally opposing logic than the process of manufacturing. He illustrates this aptly by remarking that:

> *"…an organization that is designed to do something well for the millionth time is not good at doing something for the first time" (Galbraith 1982, p. 6).*

Academics have not only concentrated on this distinction in the past decades (e.g. Burns & Stalker 1961, Perrow 1967, Hage & Aiken 1969, Miles & Snow 1978, Galbraith 1982), but this subject has more recently drawn the attention of a later generation of researchers (e.g. March 1991, Levinthal & March 1993, March 1995, Tushman & O'Reilly 1996, Zack 1999, Sutcliffe et al. 2000, Boer 2001, Holmqvist 2004, He & Wong 2004).

Sutcliffe et al. (2000) present an interesting model with three perspectives regarding the distinction between exploration and exploitation: a singular, a binary, and a dual perspective. The singular perspective views this difference on the level of a total company, in other words companies dominated by either exploration or exploitation. In the binary perspective companies use both strategies in an orthogonal way meaning that they are not directly related to, nor directly dependant on each other. This resembles what Tushman & O'Reilly (1996) call 'Ambidextrous Organizations', which balance incremental and revolutionary innovation in parallel but within different organizational subunits. Strategic integration of exploration and exploitation in the ambidextrous organization takes place at a senior team level which functions across the organizational subunits (Tushman et al. 2004). The dual perspective on exploration and exploitation views both processes to be integrated within the boundaries of one organizational unit. This perspective makes it possible to investigate the interactions between New Product Development (NPD) and Manufacturing as being interactions across the interface between exploration and exploitation.

In most companies the NPD processes are undertaken separately from the Manufacturing processes (in different departments for instance) until the design phase is finalized and the product is ready for production. This separation is not surprising since exploration capabilities like the development of new abilities by long-term research & 'out of the box' thinking and/or innovative & flexible behavior are, more or less, the opposite of exploitation capabilities like the efficient and effective operation of present abilities by adaptive and routine behavior. This is what Galbraith (1982) means by the fundamentally opposing reasoning of exploration & exploitation. In the dual perspective companies must concentrate on both 'logics' that, to some extent, are incompatible and typically occur in different departments within an organization. Companies need to balance the efforts spent on exploration and exploitation while at the same time managing the interplay between the two processes in order to prevent thorny situations. Unfortunately, finding the right balance between exploration and exploitation is still found to be problematic. Overcoming this puzzle is seen as a major academic challenge:

> *"…there is an urgent need for industry and academia to jointly develop actionable models combining exploitation and exploration…" (Boer 2001, p. 14).*

According to Boer (2001) most theories provide organizational building blocks like decentralization, empowerment and teamwork as a 'blue-print', but they fall short when it comes to actionable knowledge around these constructs. This is the consequence of a lack of insight into the interaction between the exploration and exploitation processes. To optimally balance and manage these two contradictory processes we need to know how they relate to each other and how the interplay between them can be organized. We know that these processes can exist concurrently during a period of time but are likely to interweave with ongoing operations (Schroeder et al. 1986) to take advantages of new insights (March 1995) or to change the course of the company (Andreassen & Hein 1985). A company cannot persist in exploration without exploitating what has been discovered or developed. For an efficient transition from one process to the other it is necessary to know how this can be organized. However, according to Holmqvist:

> *"…little effort has been devoted, […] to examining how transformations occur between exploitation and exploration that would illuminate how they are interlaced"*
> *(Holmqvist 2004, p. 70, italics in original).*

The issue that is addressed here by Holmqvist supports the academic challenge that was formulated by Boer (2001) and indicates that our level of knowledge is not sufficiently detailed regarding the interplay between these two very different but inseparable processes. Thus, one could say that it is especially important to investigate the connections and interactions between exploration and exploitation at a higher level of detail in order to better understand the barriers and facilitators regarding the necessary and inevitable interaction between the two processes. The interface between New Product Development and Manufacturing is where the explorative processes must engage with exploitative processes. It is this interface that forms the subject of this book.

1.2 NPD-Manufacturing interface – a source of conflict

The interface between NPD and Manufacturing plays an important role in the total product innovation process because all newly developed products must pass through it on their way to Manufacturing. An effective and smooth transfer from the explorative process to the exploitative process will have a positive impact on the time-to-market and the subsequent commencement of new cash flow. However, according to Ginn & Rubenstein (1986) this interface forms a locus of frequent interpersonal conflict. Pelled & Adler (1994) mention two types of conflict, task conflict and emotional conflict. The first is a good-natured disagreement that remains functional regarding the task. The emotional conflict comes into being if the "disagreement evokes feelings of dislike or hostility" and tends to be dysfunctional (Pelled & Adler 1994, p. 22). Although these observations were made longer ago, the following Figure (1.1) presented by Joseph Dowling from Bausch & Lomb in June 2004 at the EAISM International Product Development Management Conference illustrates that these conflict issues are still very much alive.

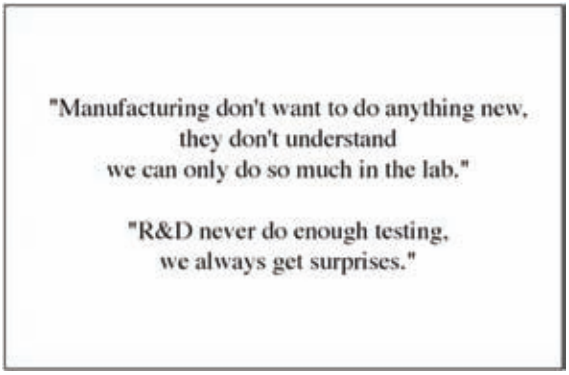

Figure 1.1 *Slide that describes the two different perspectives from NPD and manufacturing (Dowling 2004).*

This illustrates the differing perspectives of people from each side of the interface between NPD and Manufacturing. The first remark clearly represents the explorative colored NPD viewpoint regarding the attitude of the people on the exploitative Manufacturing side. The second remark shows the exploitative view of the activities of R&D and the unexpected problems they cause. These unwelcome surprises often lead to all kinds of additional testing and development work. Smith & Reinertsen (1998) even talk about redesigning the new product after it has been implemented in the Manufacturing processes. But often less dramatic changes and adjustments are necessary.

For instance, consider the transition from NPD to Manufacturing of a new car. Walton (1997) followed the development project of the 1996 Ford Taurus over a period of three years from the concept phase until the first sales. Once the car was in production and introduced onto the market, car journalists started writing about the new car. People who have been involved in earlier car projects seem to know the story of what the situation between NPD and Manufacturing is like at that moment.

> *"The designers would be in their air-conditioned studios giving interviews to awed car writers about the beauty of their creation, and the [manufacturing] engineers from Detroit would be in Atlanta assembly plant hell, in hundred-degree temperatures with cars rolling off the line that had A-margins, V-margins, tenting, ratholes, kinks, the whole sheet-metal schemer, while grizzled tobacco-chewing, profanity-spewing plant bosses bounded them with a kind of good-ole-boy joy, as if the guys from Dearborn [NPD] had purposefully designed parts that diemakers couldn't make dies for, the stamping plants couldn't stamp, and the assembly plants couldn't assemble." (Walton 1997, p. 36)*

From this quote it becomes clear that the NPD deliverables as input for Manufacturing are not sufficient enough to just press the 'start production button' and walk away, at least from the Manufacturing point of view. Designers, on the other hand, seem to think otherwise and believe that their output is good enough for Manufacturing to get on with. It is not just the negative remarks but also the context of such remarks, which point towards inefficiencies in the total product innovation process. Surprises, complex designs, late changes, quality or tolerance problems often lead to delay, additional testing and extra costs, even when the new product has already gone into production (e.g. Adler 1992, Coughlan 1992, Mukhopadhyay & Gupta 1998). Or even worse, it has already been introduced onto the market and sold to customers.

Could this be related to the output of NPD? According to Roozenburg & Eekels (1995, p. 20) "the designs for the product and its production grow in successive cycles from vague ideas to concrete plans". As in most product development literature, the output of NPD is considered to be a design of the product and the plans to manufacture it and introduce it onto the market. One should expect that these plans that have purposely been developed for production are some kind of 'blueprint' that contains all the necessary information to ensure a smooth transition to Manufacturing. But from these illustrations there seems to be something in between the 'plans' that form the output of NPD and the start of the Manufacturing process. What could that be? Or, must NPD make better plans, plans that provide a better transition to Manufacturing?

It is my conviction that people who develop or create something new, including the plans for implementation, are not intentionally overlooking the necessary adaptations that must be accomplished on the other side of the interface. They would not deliberately disturb a process that contains their own creation. But the people on the operational side of the interface are the ones who will receive the new creation in the form of the plans developed by NPD. Why would they overlook these necessary adaptations during the pre-implementation interactions that they have with people from NPD while the product or process is still under development? Why would they, to some extent, 'screw up' that implementation within their own process? Somehow the individuals who participate in the innovation process and who intend to achieve a smooth transition and implementation are not sufficiently addressing all the possible adaptive issues that are necessary to realize their common goal. This perspective seems to call for shifting the focus of analysis to the level of interactions between the respective participants over the process from early product concept to manufacturing of the new product.

It is strange that surprises and conflict during the product innovation processes still occur after all these years of academic research, journal publications, management attention, and education about integrated product development. One would expect the unpredictable, iterative and renewable character of innovation processes to be general knowledge by now. Why is it that each side of the interface perceives the same subject so differently? Why are people from NPD not communicating with Manufacturing? Do product developers accidentally forget, deliberately postpone or simply assume that it is not necessary to consult Manufacturing? Why are the 'brilliant' ideas of NPD often received with so much 'skepticism' by Manufacturing? Why does Manufacturing often hesitate to embrace something new? And what are the 'surprises' that Manufacturing talks about?

These observations about conflicts and troubles between NPD and Manufacturing seem to call for a research project that looks more specifically into the interactions between the people who work within NPD & Manufacturing and try to reveal why they still have these complaints.

1.3 NPD & Manufacturing: 'living apart together'

In this section I will illustrate that NPD and Manufacturing are connected to each other considering the process of innovation over time, but are largely separated from each other and working on different things during the innovation process itself.

We will adopt Roozenburg & Eekels' definition of product development to describe the NPD process: "Product development comprises the development of the design of a new product in coherence with the plans for its production, distribution, and sales" (1995, p. 9). In this definition the

NPD process stops after the plans have been fully developed. Operational processes that include production, distribution, and sales then transform these plans into physical products and deliver them onto the marketplace. The NPD processes and operational processes together, i.e. the creation of new products and the realization of new products in the market, will be referred to as the **product innovation process** (Figure 1.2).

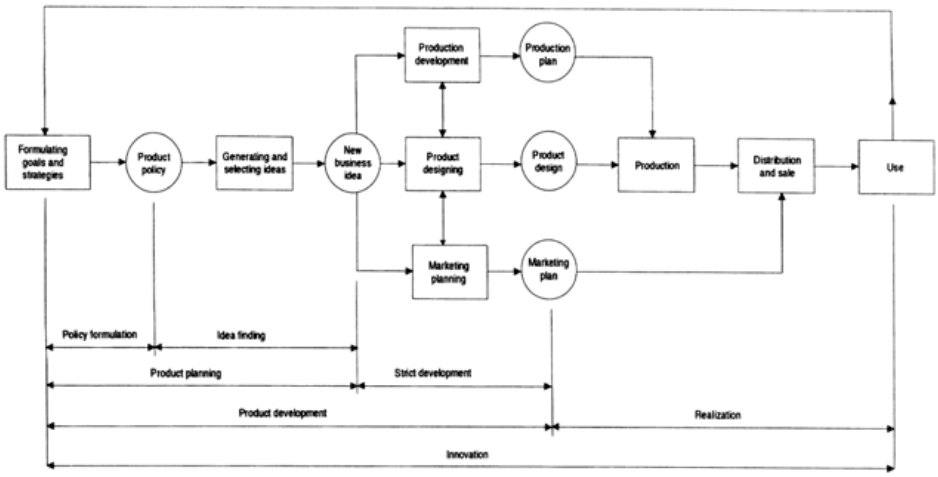

Figure 1.2 *The relation between product development and product innovation (Roozenburg & Eekels 1995, p. 13). The product innovation process is from the "Formulation of goals and strategies" until the first "use" in the market. The development phase ("strict development") is part of that. This figure also illustrates that the transition from NPD ('strict development') to Manufacturing (production) is made up by the 'Production plan' and the 'Product design'. These two elements form the input of Production.*

Because the people engaged in the manufacturing process cannot start without the results (plans) of the NPD process, the two processes on each side of the interface are sequentially dependent (Thompson 1967). This dependency exacts the need for cooperation between NPD and Manufacturing. However, it is a strange kind of dependency since the people in Manufacturing are not so dependent that they wait for NPD to finish the design for the new product **n+1**. In their day-to-day activities they are engaged with the manufacturing processes of current products **n**. Figure 1.3 shows this schematically. During this part of the product innovation process the new and the old product are embedded in two parallel streams of activities (Schroeder et al. 1986).

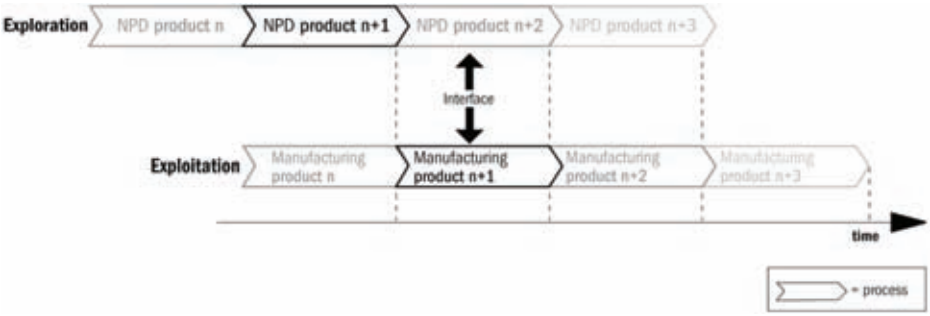

Figure 1.3 *The focus of this research is the interface between NPD & Manufacturing. At a more abstract perspective this is an interface between Exploration and Exploitation.*

During the development of product **n+1** actors in the explorative NPD process must interact with actors in exploitative Manufacturing process that are still producing product **n**. These preliminary interactions are necessary to secure a smooth transition from the development stage to the manufacturing stage. Apart from coordinating interactions, the day-to-day activities of each process, NPD and Manufacturing, are largely autonomous until NPD has finished the plans and production preparation of the new product **n+1** begins. During this process of 'integrated product development' (Andreasen & Hein 1985, Buijs & Valkenburg 1996) individuals that are based in the explorative side, like R&D and NPD, often work together in multifunctional teams with individuals that are based in the exploitative side of the interface, like production and assembly.

Troublesome situations between NPD and Manufacturing would be less problematic if companies would only develop and introduce new products occasionally. At the present time, this is not the case since companies are forced to respond quickly to all external pressure by adapting their products and exploitative activities to address changing circumstances. Developing new products is necessary to stay competitive. The pace of innovation activities has increased enormously over the past two decades and has reached a state of continuous innovation (Boer 2001) or continuous product innovation (Corso 2002). This implies a continuous stream of new product innovation projects to renew, change, replace, improve, and add diversity to the existing product portfolio. With the birth of all these new products and services the interface between the daily operational processes and NPD becomes especially important. In order to be efficient and effective in their innovative efforts companies need to have a clear process, organization and understanding of all the interactions between NPD and operations including a smooth transition from NPD to operations for the new product. Unfortunately this is not always the case. Rice et al. (2002) found that 8 out of 12 innovation projects with a 'breakthrough' character experienced a surprisingly difficult transition from R&D to operations. They identified technical, market, organizational and resource uncertainties related to managing the transition process to operations, including the manufacturing processes. They conclude,

> *"….it was clear that the companies in our study all had inadequate organizational structures and processes for driving the transition to completion quickly and efficiently."*
> *(Rice et al. 2002, p. 336).*

However, not only breakthrough innovations experience these transitional problems. Boer & During (2001) have found that companies have the tendency to overlook the necessary organizational adaptations that must take place during the implementation phase of the object of innovation, that is, adaptations on the exploitation side of the interface. The early identification of these adaptations is enhanced by interdepartmental integration (Jassawalla & Sashittal 1998, Kahn 2001) that is, by involving actors from downstream processes in development. We know that the plans for implementation are no longer developed in isolation by NPD and then thrown over the wall, but are shaped in cooperation with important stakeholders. But are these plans sufficient to assure a smooth transition and thereupon the start-up of the Manufacturing process as theory seems to suggest? Olson et al. (2001), who looked at the patterns of functional cooperation, suggest that the importance of cooperation between R&D and operations changes from the early to the late stages of the NPD process and by the level of innovativeness of the product under development (Olson et al. 2001). At the same time these authors conclude that revealing the nature or behavioral dimension of that cooperation still needs to be done. For instance, questions remain like: What problems frequently occur during these interactions? Is there any change in the nature of the interactions during the course of the NPD process, that is when NPD is still separated from

Manufacturing in comparison to when they start to interweave during the ramp-up period? And what exactly happens during the interactions between participants from NPD and Manufacturing? What is this process of interactions like? Is there any possible way to streamline these interactions?

We need more insight and understanding about this interface to guide us toward the answers to these and other associated questions. In fact, it seems that we need to put the interface between NPD and Manufacturing under a microscope.

In the next chapter the literature on the NPD-Manufacturing interface will be examined in more detail. Here I will continue by addressing academic research in the field of product innovation.

1.4 NPD-Manufacturing interface: part of product innovation

Before we discuss the NPD-Manufacturing interface as being an important interface within the product innovation process it is worthwhile to define what is meant by the word **interface**. According to the dictionary an interface is a common boundary between two objects, regions, phases, and substances (Oxford Dictionary). The previous section illustrated that NPD and Manufacturing to a large extent work separately in their daily operations which constitutes two dissimilar processes. But it is clear that they must interact in order to create a smooth transition from the development phase to the manufacture of a newly developed product. Because of the necessary interactions, NPD and Manufacturing create a common boundary and therefore, an interface.

Song, Montoya-Weiss & Schmidt (1997) note that the communication between R&D and parties other than the marketing group, like manufacturing (production) or purchasing has received little attention. These authors observe that:

> *"…internal facilitating mechanisms are the primary determinants of cross-functional cooperation and new product performance…" (Song et al. 1997).*

Although we believe that Song et al. address a potentially important subject, they provide no further details about these facilitating mechanisms. More recently, Olson et al. (2001) observed more or less the same regarding the limited attention paid to the interface between NPD and Manufacturing and add that most studies are on overly abstracted levels of analysis. Meaning that most studies look at levels of interaction between entire functional departments.

It is surprising that academic NPD researchers have never really focused on this interface on the level of the actors involved, whereas during the last thirty years the R&D-Marketing interface has received lots of attention as can be seen in the literature overview of Griffin & Hauser (1996). The NPD-Manufacturing interface, or more generally the NPD-Operations interface, was somehow not perceived to be part of the innovation process. I feel strengthened in this observation by a reality check pertaining to the fundamental principles of NPD by Calantone et al. (1995). They made a list of forty principles they found in the NPD literature and classified them in five broad categories (see table 1.1). They then conducted a survey among practitioners from marketing and technical disciplines to identify their relevance. The results showed that most research topics pursued by the academic world are relevant to the practitioners. This sounds good regarding the specified principles that they mentioned and the research done in the past.

Product Innovation
Tasks in New Product Development and Launch
Product Diffusion
Marketing-R&D Interface
Organizational Issues

Table 1.1 *Broad categories covering the forty NPD-principles (Calantone et al. 1995)*

However, none of the forty fundamental NPD principles focus on the interface between NPD and Manufacturing! Only two of these forty principles mention the word 'manufacturing' but they do not explicitly address the NPD-Manufacturing interface.

> *"Later entrants can do better than pioneers in the long run if they have advantages of either lower costs, superior manufacturing techniques, or improved product design." (Calantone et al. 1995, p. 237)*

> *"A product that has manufacturing or technology advantage but does not fulfill a need in the marketplace is likely to fail." (Calantone et al. 1995, p. 237-238)*

The first principle refers to the learning that takes place over the period of time that a new and innovative product has been on the market. The learning, according to this principle, either results in lower costs or in superior designs. The second principle refers to the possible negative consequences of product innovation that is dominated by a technology push. Another thing that I observed is that the formulation of these two principles is stated in general terms and this is no exception to most of the other 38 principles. This is in accordance with the findings of Olsen et al. (2001) concerning the overly aggregated level of analysis of NPD-studies. From this, one could conclude that the NPD-Manufacturing interface does not cause any problems and therefore doesn't need any extra consideration. However, this is obviously not the case (Voss 1988, Pelled & Adler 1994, Walton 1997, Boer & During 2001, Riek 2001, Rice et al. 2002). A better conclusion could be that serious problems do occur, but these problems are seen as inevitable so are accepted as being normal. Could it be that this unavoidable, troublesome but accepted situation in corporate life didn't reach the notice of the academic community which caused researchers in the field of innovation to overlook the NPD-Manufacturing interface? Of course there is literature addressing the NPD-Manufacturing interface as we will see in Chapter 2, but this literature doesn't describe this interface as a **process of interactions** between actors from explorative and exploitative processes.

NPD-Manufacturing interface: between the cracks

Twenty years ago Voss (1985) pleaded for a new research field that would focus on innovation implementation and, by doing so, this new research field could build a bridge between two separated research streams. One stream being studies which focused on the process of innovation while the other focused on the diffusion of innovations in the marketplace. According to Voss, the process studies stopped after successful development while the diffusion studies started after the first adoption in order to examine the subsequent spread throughout the market. Using this distinction one could say that one stream focused on exploration and the other on exploitation. Consequently, neither stream really focused on the implementation of the innovation within the daily operational and exploitative processes like Manufacturing. At that time, it seems there was no

serious research focus on how to move from a successful design to the first unit sold in the market, including the transition to the operational processes.

In the following years, both streams of research have broadened their area of attention. The innovation process studies began to focus on time-to-market, extending the process until the first unit was sold (see Figure 1.4). One would expect that these time-to-market studies include the NPD-Manufacturing interface. But the problem is that time-to-market studies do not reach far enough into the product innovation process to fully include all the interactions between NPD and Manufacturing (Terwiesch et al. 1999) in relation to a complete product innovation project.

Time-to-market studies usually end as the first unit is sold and this could be shortly after the production line has started. Therefore, studies that focus on time-to-market do not include the whole ramp-up phase, which is the period from zero up to volume production. Figure 1.4 shows this ramp-up phase, the market introduction, and the sales process as an addition to Figure 1.3. You can see that studies which only focus on the time-to-market do not necessarily include the interactions between NPD and Manufacturing during the ramp-up phase. I have tried to indicate schematically that the sales process of product **n+1** can begin before the ramp-up phase is concluded.

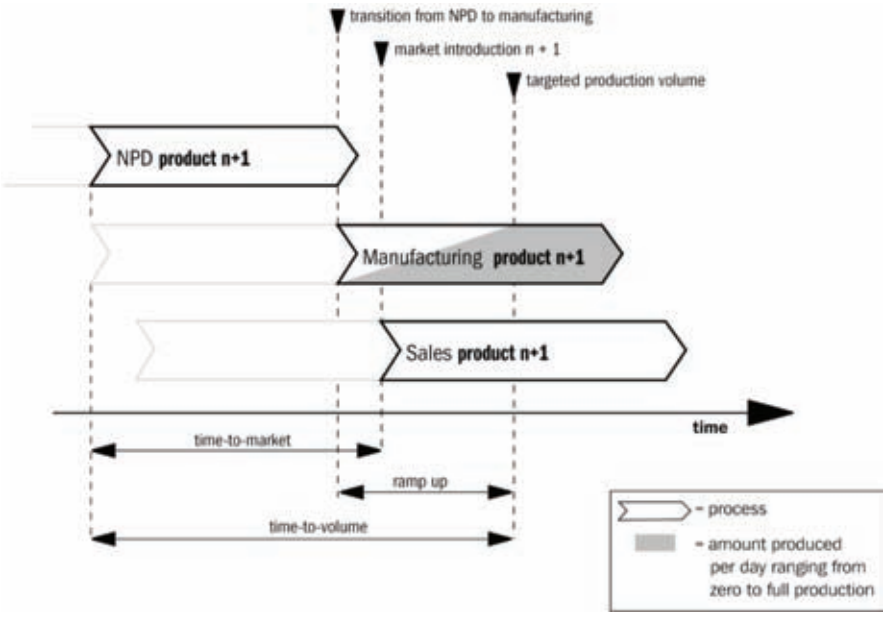

Figure 1.4 *Difference between Time-to-market and Time-to-volume. The time-to-market ends when the first products are sold to the customer and doesn't necessarily cover the full ramp-up period.*

Complex products like cars that contain many parts and subassemblies require relatively long ramp-up periods (Clark & Fujimoto 1991). The people in Manufacturing have to learn how to produce and assemble the parts into the new product. During this ramp-up period redesign and engineering changes often occur (see Smith & Reinertsen 1998) and these must bring about frequent interactions between individuals from both sides of the NPD & Manufacturing interface. The ramp-up phase where the explorative NPD process is transformed into the exploitative volume production seems to combine these two usually separate processes, i.e. explorative processes in relation to the engineering changes and exploitative processes which focus on reaching the required volume.

Then there appears to be an increased interest in research that focuses on Design-Manufacturing Integration (DMI) over the last decade. Their main aim is to bring Manufacturing knowledge into the NPD process by way of integration mechanisms, like cross-functional teams, co-location, individual integrators, group based design reviews and formalization in order to achieve a better design and a smooth transition to Manufacturing (Vasconcellos 1994, Adler 1995, Rusinko 1999, Liker et al. 1999, Nihitilä 1999, Vandervelde & Van Dierdonck 2003). As such, these studies concentrate on the explorative product development in an integrated way but don't explicitly address the actual transition from explorative NPD to exploitative Manufacturing and the interactions among the actors from these processes. But some elements might be helpful for this study and will be discussed in Chapter 2.

On the exploitative side the diffusion studies worked their way upstream by, for instance, including the Launch strategies of new products (Hultink 1997) and the behavior of sales representatives related to their adoption of and adaptation to the new product (Hultink & Atuahene-Gima 2000, Hultink & Lebbink 1999). But do the downstream extensions and the upstream inclusions meet each other to cover the total process of product innovation? No, say Terwiesch, Chea & Bohn (1999) since, to their knowledge, there is no previous academic work that provides a detailed description of the ramp-up period. To somehow bridge this gap, in 1999 they began an exploratory study explicitly focusing on the ramp-up phase (Terwiesch et al. 1999). In this study they focused on capacity utilization, yields, and process improvement regarding the ramp-up phase of a computer hard disk (Terwiesch & Bohn 2001). Unfortunately, they didn't include the interface between NPD and Manufacturing either. But there still seems to be a necessity to address this oversight if we want to be able to improve product innovation capabilities.

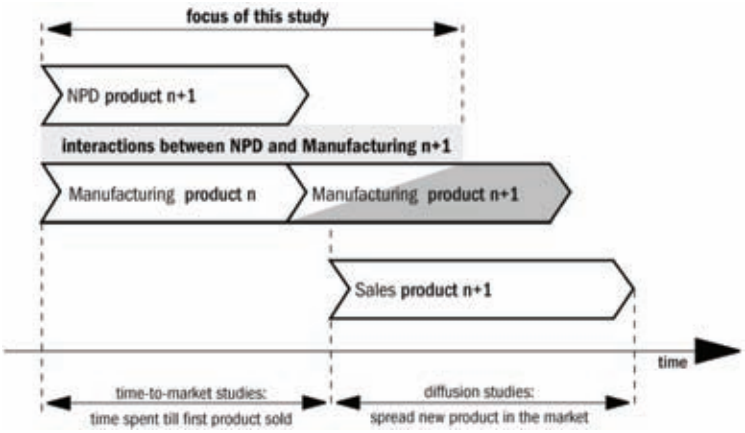

Figure 1.5 *The focus of this study: the interface between NPD and Manufacturing in between Time-to-market studies and Diffusion studies.*

In conclusion one might say that for a long time researchers have focused mainly on the explorative side of the process, as being the actual heart of innovation. Most of them consider the innovation process as having a mostly ill-defined beginning that ends with the introduction of a new product in the market. The research stream that focused on the diffusion of innovations throughout the market implicitly limits their focus to the exploitative side of the interface, i.e. sales and market diffusion. Figure 1.5 (which is an extension of Figure 1.4) illustrates that the manufacturing process falls in between these two strands of research.

1.5 R&D-Marketing interface

It is surprising that the R&D-Marketing interface has received so much attention in comparison with other interfaces like NPD-Manufacturing or NPD-Purchasing. It has only been in the last decade or so that the interface between NPD and Manufacturing is also receiving research attention as was made clear earlier. But can't we simply use the insights gained from research on the R&D-Marketing interface to improve our understanding of the NPD-Manufacturing interface?

There is, in fact, a simple reason why we can't use the insights from the R&D-Marketing interface. As discussed in this chapter, I have chosen to investigate the NPD-Manufacturing interface because of the tensions between the two. The perspective from which this will be done is one where explorative and exploitative processes meet and have to interact. This is not the case at the R&D-Marketing interface. Marketing is involved at the beginning of the product innovation process because they are responsible for identifying the changing needs of consumers. This is an explorative activity. Therefore the interface between R&D and Marketing is mainly[5] an exploration-exploration interface. This makes the insights that have been discovered about the R&D-Marketing interface inapplicable to the NPD-Manufacturing interface from the viewpoint that is chosen for this project.

1.6 Research aim

In this introductory chapter I have shown that the interplay between the explorative development process and the exploitative manufacturing process is necessary for a smooth transition from NPD to Manufacturing. However, the interactions between the participants do not seem to be free of conflict and misunderstandings which result in delays and troublesome situations downstream. At the same time, there is little academic research that concentrates on these issues on the level of those involved.

To sum up, it may be said that there are five observations that inform the starting point of this research project:

1. The NPD-Manufacturing interface seems to cause conflicting and contradictory situations for the respective participants (Section 1.2).
2. On a more abstract level the interface between NPD and Manufacturing is an area of transition and interaction between explorative and exploitative processes. It is difficult for companies to have efficient and effective interplay between the explorative and exploitative processes and to create smooth transitions from the explorative process to the exploitative process (Section 1.1).
3. The NPD-Manufacturing interface has a dual nature: an interface within the sequential process of product innovation that makes the transition from exploration to exploitation and an interface between explorative NPD and exploitative Manufacturing before that transition is made (Section 1.3).
4. Most studies in the field of product innovation either concentrate on the explorative time-to-market or on the exploitative diffusion of products once they are on the market. The NPD-

[5] In some organizational settings marketing has a dual role: explorative for identification of needs and an exploitative for doing the marketing and sales, i.e. one department for both activities. In such settings marketing at some point in time most probably need to switch from exploration to exploitation. This might result in confusing interactions between the Marketing and R&D.

Manufacturing interface falls in between the cracks and is not investigated as a process of individual interactions which lead to volume production (Section 1.4).

5. Insights gained on the R&D-Marketing interface are related to an exploration-exploration interface and are therefore not directly applicable in this study (Section 1.5).

These observations provide opportunities for further research. Based on the first observation and supported by the other four observations it was decided to start an explorative study to investigate the NPD-Manufacturing interface as a process of interactions between the respective participants from concept until volume production.

While discussing the context of this interface open-ended questions were formulated around the following themes:

- What is the nature of the interactions?
- What influences the nature of the interactions?
- What is the influence of the dual nature of the interface on the interactions?
- What provokes misunderstanding and misinterpretation during interactions?
- What is the relationship between production plans, interactions and ramp-up?

Answering these and related questions might help to realize the main purpose of this research project which aims at **exploring the process of interactions among actors from explorative NPD and exploitative Manufacturing during the development of a new product until volume production of that product is reached.**

Gaining insight into this interaction process during the course of a product innovation might help to understand the persistent occurrence of misinterpretations and conflict between actors from NPD and Manufacturing. This insight might help to improve the quality of the interactions between NPD & Manufacturing. Some preliminary research questions are:

1. *What influences the quality[6] (effectiveness + efficiency) of interactions between actors from New Product Development and Manufacturing?*

To answer the first question a framework of theoretical components is needed that allows a description to be made.

2. *What are elements of a conceptual framework that make a description of the interactions between NPD and Manufacturing possible?*

In the next chapter the existing research and literature that focuses on the interface between NPD and Manufacturing will be discussed and analyzed. I will examine these bodies of literature for three things. First, I will search the literature for theoretical elements that might be used to construct the conceptual framework later in this study. Second, discussing the literature creates a better understanding of the NPD process with its successive stages and activities. Third, based on the insights gained from the literature and the theoretical elements that were found, I will review the initial research questions.

[6] According to Moenaert et al. (2000) quality depends on the efficiency and the effectiveness of the interaction. Effective communication is defined in terms of the result in relation to the intention of the communication. The efficiency then is the costs made (or time spent) in relation to these intended results. Note that quality in communication is different from what generally is understood by total quality within TQM.

2 *Exploring past research to provide a foothold*

We have seen that there has been very little research looking at the NPD-Manufacturing interface that focuses on the interface itself and on interactions between the participants from the two processes. In this chapter I will explore the research and literature that does focus on this interface. We will be investigating the literature to create a better understanding of the NPD process and to look for theoretical elements that will help us to build a conceptual framework that makes it possible to describe the two processes on the level of interactions between each other. Based on these insights, a set of requirements regarding this research approach can be determined.

Following the introduction, Section 2.2 describes the process perspective on NPD that includes the interface between NPD and Manufacturing. A discussion of an information perspective (2.3) on the interface is then followed by a similar discussion of a structural perspective (2.4). In Section (2.5) these observations from literature are shortly summarized. The last section (2.6) reviews the research questions and derives some requirements of the research approach.

2.1 Introduction

The aim of this study is to explore the interactions among actors from NPD and Manufacturing, because the NPD-Manufacturing interface seems to be an area of tension (Chapter 1). To describe these interactions a framework is needed consisting of conceptual building blocks as constituent elements. In this chapter descriptions of the NPD-Manufacturing interface as found in the scientific literature will be discussed in order to identify potential building blocks for such a framework. This chapter ends with reviewing the initial research questions from Chapter 1.

As we have mentioned in Chapter 1 there is no literature that directly describes the interface between NPD and Manufacturing on the level of individual interactions between those who are involved in the product innovation process. Nor is their any literature that treats the dual character of the NPD-Manufacturing interface. There are no theoretical models and no empirical studies that directly deal with this subject. But, that doesn't mean that there is no literature that addresses the interface that we can learn from. In the literature one could detect three bodies of work that each discuss the interface between NPD and Manufacturing from a different perspective:

- Process perspective (2.2)
- Information perspective (2.3)
- Structural perspective (2.4)

The literature on the process perspective describes the stages of the total product innovation process from idea to market and therefore includes the transition from NPD to Manufacturing. A better understanding of the stages and activities within the development process could be helpful in our further exploration for three reasons. First it provides an overview of what might be encountered within companies regarding the successive stages of their development processes. Secondly it provides an understanding of the activities within these stages. This will be of use during the investigations because one could expect that the interactions between NPD and Manufacturing might be different during the various stages of the development process, because of the changing nature of the interface over these stages. Finally, we will examine these models to find out what they mention about the transition from NPD to Manufacturing.

The second body of literature discusses the interface with respect to the information that has to cross the interface. I will describe the sorts of information that goes from one side of the interface to the other and the mechanisms that are described in literature for transferring the information. This section ends by looking at the output of NPD that forms the input for the manufacturing processes.

The third body of literature discusses structural and organizational measures that are related to the NPD-Manufacturing interface.

This chapter ends with a summary of the possible theoretical elements that could serve as footholds during this research project (2.5).

2.2 NPD-Manufacturing interface: A process perspective

In this section NPD models which include the interface between NPD and Manufacturing in their description will be discussed. First we will look at the general phases of the product innovation process and zoom in on the stages of the actual development phase (2.2.1). A further detailing of the activities within the development stages that are linked to the NPD-Manufacturing interface follows in Section 2.2.2. Then, we will focus on the transition of the design from NPD to Manufacturing and the following ramp-up of production (2.2.3). Section 2.2.4 analyzes these observations in the light of the aim of this study. Finally, the findings regarding this process perspective will be summarized (2.2.5).

2.2.1 Phases of product innovation and stages of product development

There are many models available that describe the separate steps of the product innovation process. Some have different divisions between the steps and others are more detailed. But overall there are many resemblances.

The model of Buijs (1984, 2003) shows five phases of the total product innovation process (Figure 2.1) as well as a detailed description of the development phase. His first two strategic phases are to identify ideas for new products that lead to the formulation of a design brief. These phases are followed by a phase that covers the development processes. The final phase of the model, Implementation, is concerned with the introduction of the newly developed product into the market. According to Buijs, this product innovation process is a learning process, because:

> *"…coming up with new products and services is the answer (learning) of a company reacting to its changing environment." (Buijs 2003, p. 81)*

Although the description of this model fits a rational-analytic way of thinking, Buijs & Valkenburg stress a more social-interactive approach for managing these processes in reality (Buijs & Valkenburg 2005).

With the social-interactive approach they mean that humans are emotional creatures that show ambiguous behavior and that the reality of product innovation is not at all like the rational-analytic description that one can find in the literature.

Since we are interested in the interface between NPD and Manufacturing, we will focus on the last two phases (Figure 2.1): Development and Implementation. An interesting element of the development phase as described by Buijs is the three parallel development processes: market development, product development, and production development. According to Roozenburg & Eekels (1995), who describe similar parallel development processes, these three development processes are generally divided into four stages: clarification of the task, conceptual design, embodiment design and detail design. The first stage, clarification of the task, leads through an analysis of the design problem to specifications of the new product. These specifications, also called 'program of requirements', form the basis of the conceptual design in which the designer generates a broad range of solutions for the design problem. During the third stage, a chosen concept is further expanded into a more definitive form that can be evaluated in detail using functionality, usability, or manufacturability considerations that were listed in the specifications. In the final stage the design is refined further and the tolerances, materials, surface properties, etc. are fully speci-

fied in assembly drawings, detailed drawings, and part lists. The latter is sometimes referred to as the Bill of Materials (BOM). Besides these drawings and lists the plans and instructions for production, assembly, testing, transport, use and the like must be worked out (Roozenburg & Eekels 1995). Notice that the terms used by Roozenburg & Eekels to describe the respective stages mainly refer to the development stages of the product and not to stages that relate to the development of production or market.

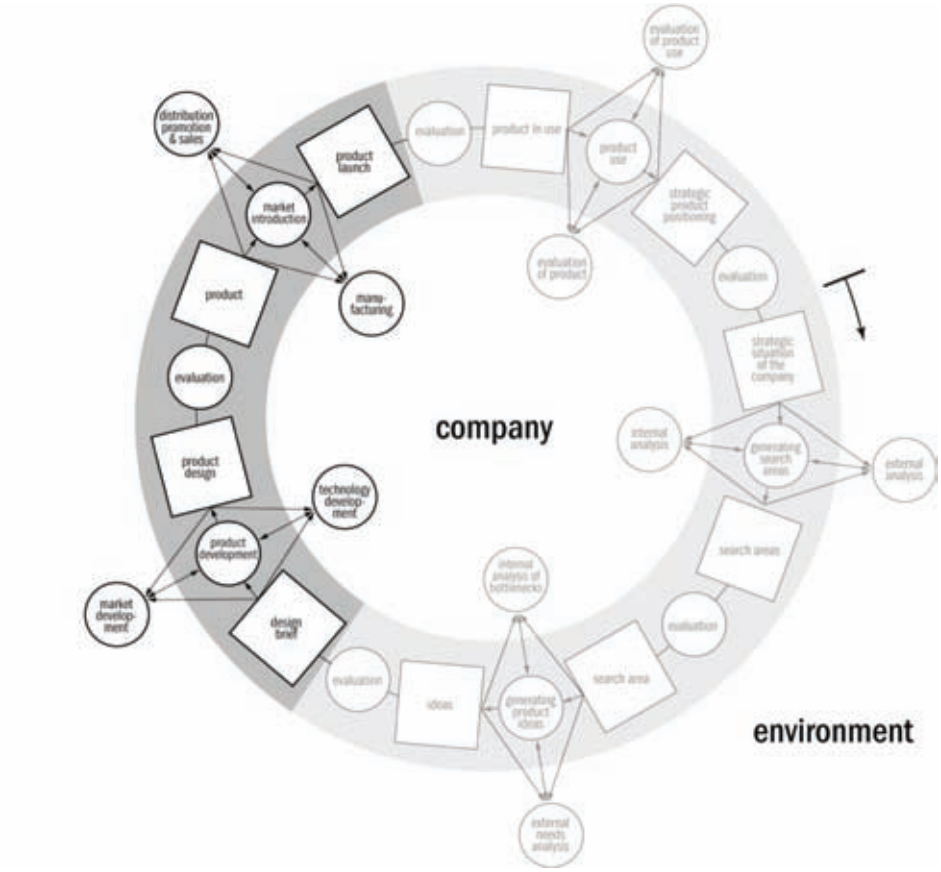

Figure 2.1 *The five main phases of the product innovation process according to Buijs (2003) and the two phases this research concentrates on.*

There are many models that also elaborate on the activities within the parallel market and production development processes using more or less the same stages (Andreasen & Hein 1985, Ulrich & Eppinger 1995, Buijs & Valkenburg 2005). Most of these so-called Integrated Product Development models describe the creation of market, product, and production as one cross-functional and integrated process.

2.2.2 Activities within development stages

The integrated model of Ulrich & Eppinger (1995) assigns the various development activities to these respective functions: Marketing, Design, and Manufacturing (Figure 2.2). I have high-

lighted the activities from the two functions that are relevant to this research: Design (NPD) and Manufacturing.

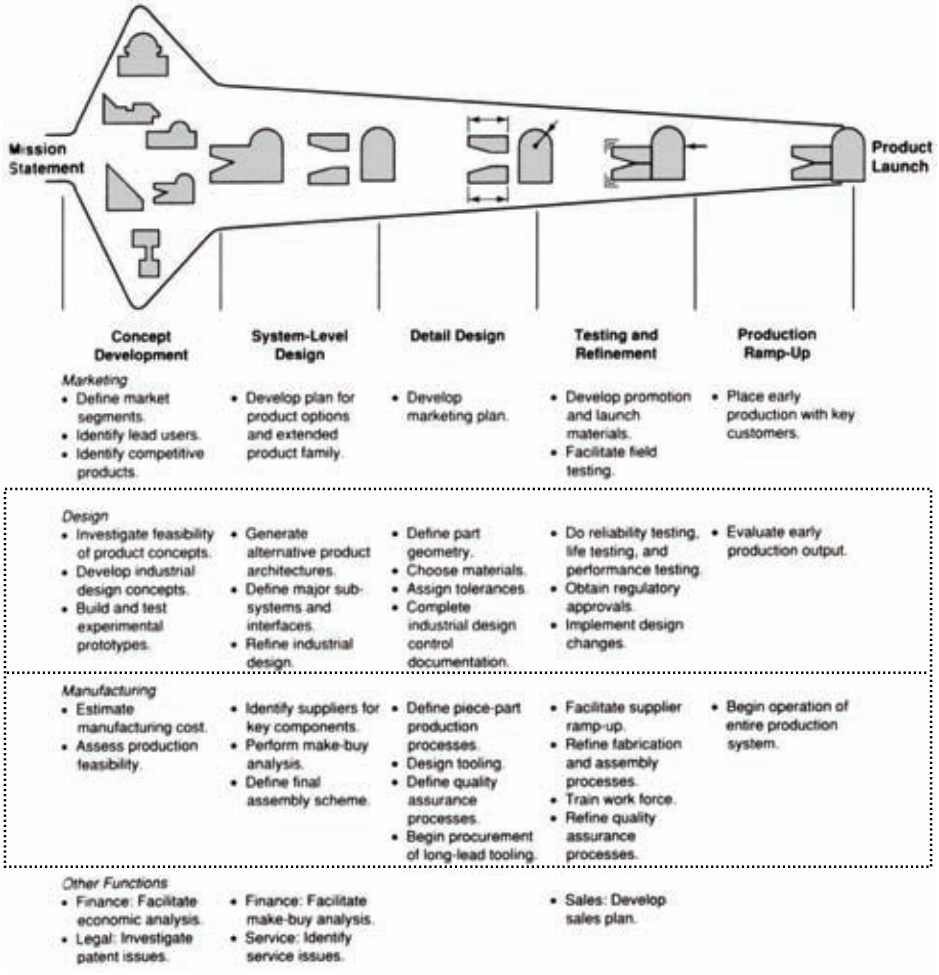

Figure 2.2 *Generic model of product innovation by Ulrich & Eppinger (1995, p. 15)*

It is clear from those activities that most of them cannot be performed without having interactions between the two functions. How would Manufacturing be able to estimate 'manufacturing costs' in the conceptual stage without knowing about the concepts that are generated by NPD? Is this done sequentially? Does this mean that NPD first finishes the concept stage and then Manufacturing looks at their ideas? Is NPD somehow involved? Are they waiting until Manufacturing has finished or do they continue on to the next phase? For most of these activities Manufacturing needs information about the design. These separate activities and their results need to be well connected somehow. According to Clark & Fujimoto (1991) this can be done in several ways. They discuss the integration of the parallel streams of development or problem solving cycles[7] between product engineering and (manufacturing) process engineering. They show various forms of

[7] Integrated problem-solving cycles, as Clark & Fujimoto (1991) call them, are in fact parallel development processes and resemble or are similar to what other scholars call Concurrent Engineering.

overlap related to these two processes (fig 2.3) which represents their findings in the worldwide auto industry during the 1980's.

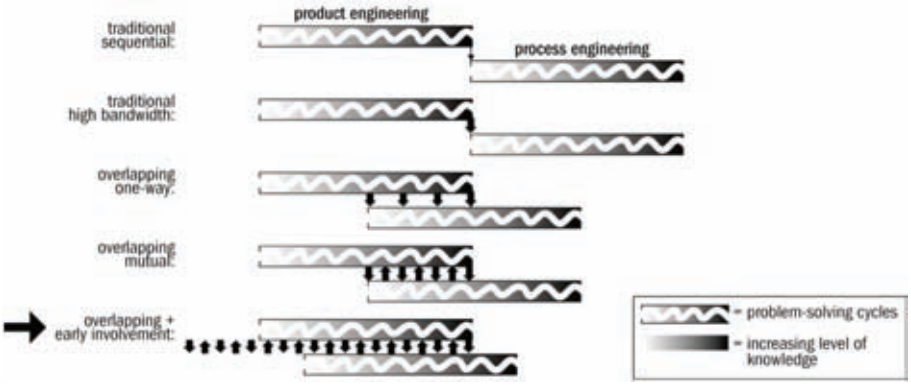

Figure 2.3 *Decreasing lead-time of engineering activities by increasing integration of problem-solving cycles (based on Clark & Fujimoto 1991). Pre-project interactions (arrow) result in shortest lead-time.*

It is clear that the reduction of engineering lead-time increases as the forms and intensity of information and the simultaneity of the two processes increases. The top panel of Figure 2.3 illustrates clearly the traditional sequentially 'over-the-wall' behavior. The bottom panel illustrates maximum integration and overlap of the two engineering processes in which the exchange of relevant information and insight between upstream and downstream parties occurs even before the actual problem-solving cycles start (see arrow in Figure 2.3). These are informal pre-project interactions. In between those two extremes are differing levels of integrated problem solving. Smith & Reinertsen (1991) go one level deeper into detail and provide a description of the separate functional activities as mentioned earlier with a maximum possible overlap. They tie the activities of both functions together using a so-called truss diagram (see Figure 2.4). In this diagram one sees linkages between activities of the same function and diagonal information exchanges with the other function.

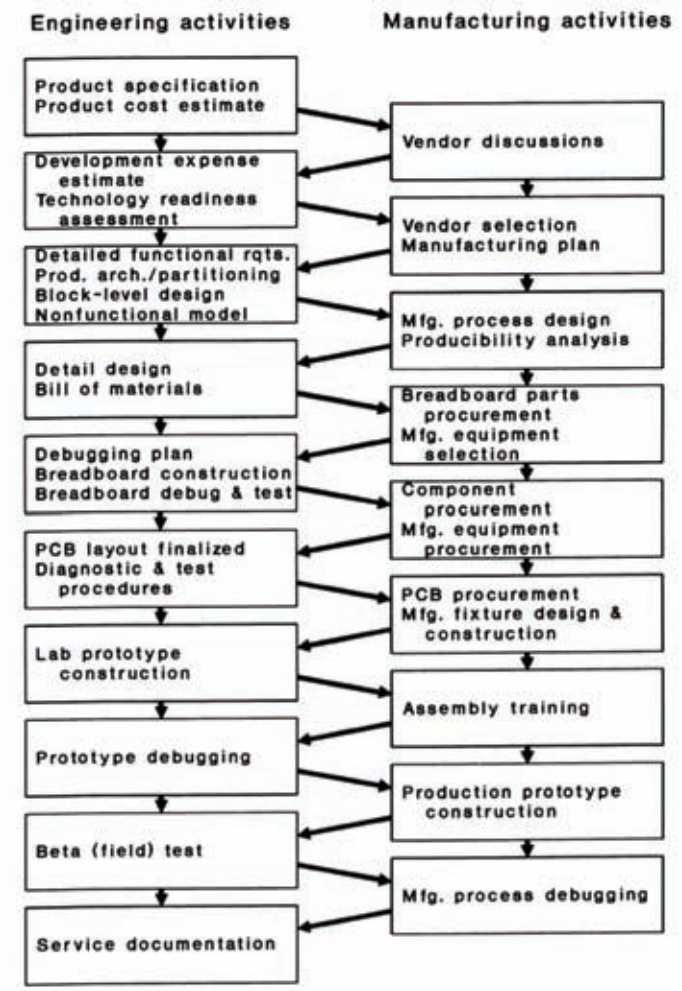

Figure 2.4 *Detailed division of activities between NPD and Manufacturing using a truss diagram (Smith & Reinertsen 1991, p. 157)*

To achieve this kind of overlapping participants must be able to release partial information and discuss it with each other. Partial information is incomplete but provides a possibility for the other function to get started or to proceed and after a while to give information back about their own progress and discuss that in the light of advancements regarding the original partial information. The literature advises the participants not to wait for NPD to finish concept development, but to transfer some early ideas about possible concepts to Manufacturing. By weaving back and forth between the two functions, the information about the new design increases until all the plans for the operational processes are completed.

To describe these various levels of integration or overlap, Clark & Fujimoto use five dimensions of an interface (Figure 2.5). The top dimension is related to the moment in time when downstream and upstream development activities start and ranges from sequential to stage overlapping. The second dimension describes the richness of the media that is used to transfer information and ranges from documents sent by (internal) mail to face-to-face communications. The third dimen-

sion refers to the frequency of information transfer: from only transferring when things are finished which results in a low frequency or frequent transfer with fragmented or incomplete information. The fourth dimension is formed by the direction of information flow: unilateral or bilateral[8]. The last dimension relates to the attitude of information release: late or early in the development process.

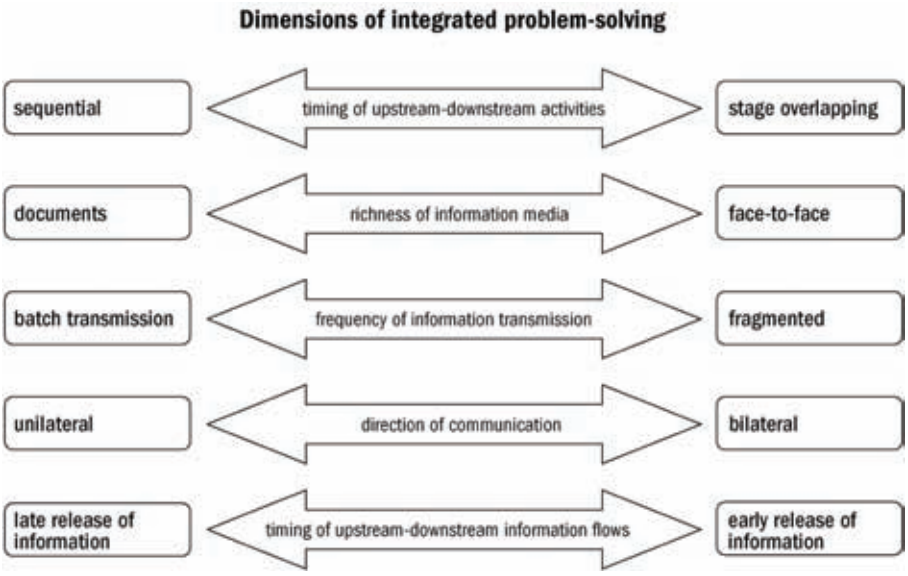

Figure 2.5 *Five dimensions of integrated problem-solving (Clark & Fujimoto 1991)*

According to Clark & Fujimoto integration requires the NPD process to be organized utilizing the right side of the spectrum of each dimension.

> *"integrated problem solving is achieved only when two conditions exist: a high degree of simultaneous activity, which we call stage overlapping; and rich, frequent, bi-directional information flows, which we henceforward refer to as intensive communication"*
> *(Clark & Fujimoto 1991, p. 216).*

However, according to the authors this is not easy to achieve, because companies need to balance "hard, analytical capabilities with the appropriate soft, intuitive attitudes and philosophies" (Clark & Fujimoto 1991, p. 245). According to these authors the hard and analytical capabilities usually suit the characteristics of engineers whereas this is less true of the softer attitudes.

> *"Engineers, tending to be perfectionists, are often reluctant to release work that is incomplete. The upstream group will even be less willing to release information early if the environment is hostile, with design changes triggering accusations of sloth and incompetence. If the attitude of product engineers is "I won't give you anything now because I know that I'll have to changes it later and I know that I'll take the blame for it," management may have to effect a fundamental change of attitude throughout the engineering organization, both upstream and downstream, a very difficult task." (Clark & Fujimoto 1991, p. 213).*

[8] Unilateral communication stands for one-way communication, whereas bilateral stands for two-way communication.

Regarding the soft side of this balance, the right cooperative attitude of both upstream and downstream personnel forms an important facilitator. According to them, this attitude is built on a certain degree of mutual trust and joint responsibility. Smith & Reinertsen (1991) have similar conclusions that point towards making changes in the attitude of the actors involved. They observe that it is difficult to work with partial information which is a necessary aptitude to increase the overlap between the two development processes. Their advice is to train the participants on both sides of the interface in special skills:

> *"The recipients of the information in particular must develop a sense of just how far they can go with the information they are given without going too astray. It must be recognized that they will go astray occasionally because if they don't they aren't pushing – or rather pulling- hard enough. The recipients of [partial] information must constantly be projecting what its likely outcome will be and what some alternatives are." (Smith & Reinertsen 1991, p. 166).*

Because communication is a two-way process, the information providers also need to take responsibility and act accordingly.

> *"The providers of the information also have an obligation to try to appreciate where it may lead the recipients. They need to be aware of how information will be used and be sensitive to the impact on downstream activities of any changes they may make. They also need to keep in touch constantly with those working with their partial information."*
> *(Smith & Reinertsen 1991, p. 166).*

According to Smith & Reinertsen the recipients of information need to have some *projecting capability*, i.e. a capability to imagine future outcomes. The providers need to be aware of the *impact* of their information on the other side of the interface. The interesting thing about this view is that by discussing the individual skills that are necessary for effective interaction, Clark & Fujimoto and Smith & Reinertsen bring us to the level of the participants, the level that I want to focus on for this thesis as was discussed in chapter one. What we learn from this is that we have to be aware of the skills and behavior of the actors in relation to the interactions among them. It is interesting to find out what kind of skills and behavior are associated with the interactions. For example, how do receivers of partial information elaborate on this information to predict its future outcome?

Let us go back to the activities within the development stages. Two of the activities that belong to Manufacturing and that we have seen in Figure 2.2 and Figure 2.4 attracted notice. In Figure 2.2 'Facilitate supplier ramp-up' and 'Train work force', and in Figure 2.4 'vendor selection' and 'assembly training'. Similar activities are also mentioned by Buijs & Valkenburg (2005). Nowadays, it is the rule rather than the exception to have suppliers participate in the product innovation process. They either participate as the developer and manufacturer of parts and subassemblies or only as the manufacturer of parts that are developed by the outsourcing company. In both situations there exist interfaces between NPD and Manufacturing, but now these interfaces are spread over different legal entities. This research will not include this additional complexity.

The second activity that is interesting is 'train the work force' (fig. 2.2), or 'assembly training' (fig. 2.4). Although both sources don't go into much detail, it can be assumed that this is connected to

the ramp-up of the production line including assembly. We will come back to this issue in the next section (2.2.3).

A final remark regarding these IPD models is their correspondence to Concurrent Engineering (CE). By developing the product, the market, and the production processes in parallel with each other in a cross-functional integrated way, the IPD models seem similar to the ideas behind Concurrent Engineering. The broad concept of CE focuses on doing the engineering work, that is, the product engineering and the process (manufacturing) engineering, in parallel or simultaneously as opposed to doing the work sequentially. In other words, CE integrates upstream and downstream engineering stages and brings as many downstream considerations as possible into early stage decision making (Clark, Chew & Fujimoto, 1992). CE is therefore about two parallel explorative processes and not about the interface between exploration and exploitation. A difference between IPD and CE might be that IPD also describes the market development stream that in most CE definitions and descriptions (e.g. Linton et al. 1991, Paashuis & Boer 1997, Gardoni et al. 2000) is not mentioned explicitly.

After the design is finished in detail together with the plans for the operational processes, the implementation will take place. In the next section we will focus on this transition to Manufacturing.

2.2.3 Activities during implementation and Ramp-up

We have seen in the first chapter that there is very little focus in the NPD literature on the actual implementation activities of the newly developed products into Manufacturing processes. There are many models on product innovation that do include the transition to Manufacturing but don't describe this transition on the level of interactions between the various actors from NPD and Manufacturing. Most of them mention 'plans' or 'recipes' as the main input for the ramp-up. But these models could still help in providing an idea about possible activities and the nature of these activities during implementation and ramp-up, that is, the period that begins with the implementation in the Manufacturing process of the plans that are made by the NPD process and ends when volume production is reached.

The early model of Archer (1971) that has been an inspiration to many NPD academics, describes the product innovation process in 10 stages. In Figure 2.6 we have listed these stages and focus on the activities within the last four stages because these relate to the upcoming and actual transition to Manufacturing.

Figure 2.6 *The ten steps of product innovation and the activities of the last four stages. (based on Archer 1971)*

In this model the product development and production development streams are sequentially described. The market development activities seem to be integrated in the successive stages. Looking at the stages, the transition from NPD to Manufacturing seems to take place in stage 9, 'Tooling and Market preparation'. Stage 10, 'Production and Sales', must contain the ramp-up of the production line. The activities in stage 9 'Construct trial batch' and 'test trial batch' are activities that are linked to the transition from NPD to Manufacturing. We can imagine that during those activities actors from both processes are involved to discuss the results and decide on design or manufacturing changes. Ulrich & Eppinger (1995) (Figure 2.2) have a similar stage, 'Testing and refinement'. This stage involves the construction and evaluation of multiple pre-production versions of the product. Early pre-production products might be called prototypes as we will discuss in Section 2.3.2. The later pre-production products, sometimes called Field Evaluation Unit (FEU), are the result of pilot runs or zero-series (Walton 1997). Clark & Fujimoto formulate the transition between NPD and Manufacturing as follows:

> *"When engineering has signed off on the design, when prototypes have been built and tested and the production tools and dies are produced, all that remains is to bring everything together to see of it works as planned." (Clark & Fujimoto 1991, p. 188).*

This sign off and transition to the operational stage of Manufacturing will in most cases be followed by a pilot run that could be seen as a full-scale rehearsal using all the commercial tooling (tooling that will be used for commercial production) and real parts (Clark & Fujimoto 1991). It is hard to determine in the literature if such a pilot run is part of the development period or of the ramp-up period.

Getting familiar with the new product forms an important part of the activities during implementation and ramp-up. The people on the Manufacturing side of the interface must become familiar with the new product and how it will be produced and assembled in other words, they must go through a learning process. We assume that most of the learning that the work force in Manufacturing must achieve takes place during the ramp-up and is aimed at understanding the new product and learning how to produce and assemble it. Terwiesch & Bohn (2001) define the ramp-up of production as the period between the end of product development (see also Figure 1.4) and the moment the full capacity utilization in production is reached (volume production). Ramp-up begins with perhaps one unit the first day and is then accelerated to volume production a couple of months later. According to them there are two conflicting factors during this period: high demand by customers and low production output. The low production output during this ramp-up is particularly interesting for this research.

> *"Yet output is low due to low production rates and low yields. The production process is still poorly understood and, inevitably, much of what is made does not work properly the first time. Machines break down, setups are slow, special operations are needed to correct product and process oversights, and other factors impede output." (Terwiesch & Bohn 2001, p. 1)*

Their phrase 'The production process is still poorly understood' implies that Manufacturing is not fully aware of the variables within the production process that influence the output. In their research the authors focus on capacity utilization, yields, and yield improvement by learning. Regarding the latter, they discuss the importance of deliberate learning by controlled experimentation in addition to the learning by (cumulative) experience that is often referred to as the learning curve of production processes. This curve, also termed the experience curve, provides a prediction of the decline of the costs related to the various production processes. The decline of costs is mainly based on the decrease of the time spent by the workers during the manufacturing and assembling of parts and components and the end product. The decrease in time in its turn is the result of the learning by the actors in production.

But learning can also be recognized on other levels of abstraction. Buijs (1984, 2003) considers the whole process of product innovation at the company level as a learning process. During all phases of innovation new knowledge is either developed or transferred to other people in the process, as we will discuss in section 2.4. He also suggests using individual learning capabilities as a selection criterion for the composition of innovation teams. Where Buijs describes the product innovation process (see Figure 2.1) as a learning cycle on the company level, Terwiesch & Bohn (2001) discuss learning on a lower level of aggregation in the form of deliberate experiments by small groups of engineering and manufacturing individuals. At an even higher level of detail and on the NPD side of our interface, Dorst (1997) has been able to describe design as series of experimental actions and reflections by one designer. It might be interesting to find out how these levels and forms of learning relate to each other because they are part of one product innovation process. According to the literature learning takes place on both sides of the interface and across the interface on an individual level as well as on the group level.

And how is the learning of the participants on both sides of the interface accommodated within this process? Is there a difference in their learning? As we will see in section 2.4, NPD has to learn about manufacturing and assembly possibilities and constraints. Manufacturing in its turn has to learn about the new product. How is information transferred between the two processes in

order to start or facilitate the learning that has to take place? Looking at the ramp-up, what is it that people are learning during this phase and what is the involvement of NPD?

From this discussion we can see that theories on individual as well as joint learning might play an important role in shaping a conceptual framework regarding the interface interactions between NPD and Manufacturing.

2.2.4 Analyzing the observations: process perspective for this project

In this section I will highlight the insights that have been obtained by studying the literature that describes the process perspective of product innovation.

As we have seen in Chapter 1, during development and before the ramp-up phase, NPD and Manufacturing are at a certain moment in time working on different products: development of product **n+1** versus manufacturing product **n** (Figure 1.3). We assume that when the ramp-up begins and during the early part of the ramp-up phase, NPD and Manufacturing are both working on the same product **n+1**. We also assume that at some point during or after the ramp-up NPD will start on a new development project **n+2** (see Figure 2.7). This implies that there is only a relatively short period of time when both NPD and Manufacturing are working on the same product **n+1**. Figure 2.7 illustrates that in the other two periods, 'preramp-up' and 'post ramp-up', both parties are working on different products. This results in three periods of interactions between NPD and Manufacturing which are associated with one product innovation process **n+1**.

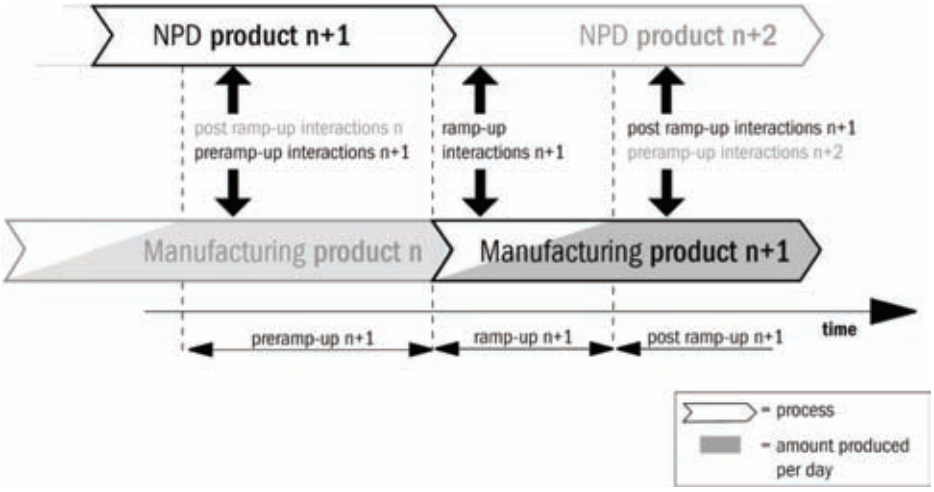

Figure 2.7 *Three periods of interactions between NPD and Manufacturing*

In all three periods the relationship between NPD and Manufacturing might be different because of the shifting attention within NPD and Manufacturing. Because of this changing focus we can expect to find differences in the pattern of interactions during these three periods. It is important to realize that these three periods of interaction are concerned with the same product innovation process **n+1**. From the perspective of the interface interactions and the relationship between NPD and Manufacturing, the 'post ramp-up' period of product **n+1** is equal in structure regarding the interface interactions to the 'preramp-up' period of the same product **n+1**. However, on the

content level there will be differences, because both parties are actually working on other products, **n+2** and **n+1** respectively. As we see it now, there are only two periods of interaction that are relevant to this study: preramp-up and ramp-up.

2.2.5 Concluding on the process perspective

In conclusion regarding the phases, stages and activities we can say that there seems to be a broad consensus in the literature with respect to the various stages of the NPD process. We have seen that during the NPD process which begins with the design brief, there are generally three parallel development processes: product development, market development, and manufacturing development. From the design brief onwards we have found four stages within the actual development phase: clarification of the task, conceptual design, embodiment design and detail design. From this **two periods of interaction** seem to be relevant to this study: preramp-up and ramp-up.

Within the preramp-up stages and within each of the three development processes the literature identifies various activities. Regarding the interactions between those parallel activities and their actors, some authors mention important attitudes like mutual trust, joined responsibility, and the **ability to work with partial information**. And interactions during the development process are, by definition, about the exchange of partial information. We understand from the literature that providers and recipients of partial information need to have empathic and projecting/imaging capabilities respectively. Because of the possible involvement of these kinds of capabilities I feel that it would be wise to keep an eye on the more attitudinal and behavioral side of these early interactions between NPD and Manufacturing. The activities during the ramp-up are very much concerned with refinement of production, assembly and quality processes, as well as with design changes and testing activities.

Finally I have identified various **forms and levels of learning** that are all related to the product innovation process.

- Product innovation is learning on the company level (Buijs 1984, 2003)
- Individual learning capabilities are important in team composition (Buijs 1984)
- NPD processes are made up of various problem solving cycles which is also a form of learning (Clark & Fujimoto 1991)
- The actual development activities of designers are learning cycles (Dorst 1997)
- Deliberate experiments during ramp-up are learning cycles (Terwiesch & Bohn 2001)
- The system behind the ramp-up is governed by learning curves

These various levels and forms of learning might become an important theoretical element for our conceptual model of the interface interactions.

2.3 NPD-Manufacturing interface: An information perspective

In essence, the task of the NPD process is to close the gap between the present knowledge about the current products and manufacturing processes and the desired situation which leads to knowledge about a new product and its manufacturing processes. This is achieved by processing information from a large variety of sources as well as applying this information in a new and creative way. Buijs (1998, p. 18) presents the following list of information blocks.

Information about the:

- *The customer*
- *Competitor and its products*
- *Manufacturing processes*
- *Logistics*
- *After-sales service*
- *Maintenance*
- *Safety regulations*
- *Legal standards*
- *Quality*
- *Distribution system*
- *Social-cultural context in which the customers want to use the new product*

All this and more knowledge needs to be taken into account somehow while developing new products. New products, per definition, require new knowledge (Souder & Moenaert 1992) that will be implemented in the manufacturing processes. There is new knowledge in terms of novel combinations of existing knowledge that make up the new product and its production processes. In this section we will review the literature that focuses on the various classes of information that are related to Manufacturing and on mechanisms that enhance the transfer of information between Manufacturing and NPD. An important body of knowledge discusses the availability and use of downstream information regarding possibilities and constraints in upstream development processes. This information is mostly categorized in areas of specific attention and is labeled 'Design for'. After that we will discuss Prototyping as an important means of information transfer between NPD and Manufacturing. We will end this section with discussing the output of NPD as being the input for Manufacturing.

2.3.1 Information transfer: DFM, DFA, and DFX

Design for Manufacturing (DFM) became popular in the mid-1980s. DFM principles, techniques, and guidelines mainly focus on minimizing component and manufacturing costs:

> *"DFM includes any step, method, or system that provides a product design that eases the task of manufacturing and lowers the manufacturing costs. […] DFM is primarily a knowledge-based technique that invokes a series of guidelines, principles, recommendations, or rules-of-thumb for designing a product so that it is easy to make." (Bralla 1999, p. 9.30).*

Other authors like Pugh (1991) and Ulrich & Eppinger (1995), focus on DFM to secure on easy transition from NPD to production. According to Pugh (1991) the main aims of DFM are to minimize the component and assembly costs, to minimize development cycles and to enable higher quality products to be made. Design for assembly, DFA, was developed later but has now been largely incorporated into the DFM methodology[9], causing DFM to move "from a relatively narrow definition of specific design rules to a much broader concept of producibility" (Wheelwright & Clark 1992, p. 239). DFA itself focuses on reducing the assembly costs by reducing the complexity of the design and the number of parts. DFM and DFA are just two of many "design for's". These came into being because,

> *"Historically, designers have tended to underemphasize or overlook the preceding factors and have concentrated their efforts on only three factors: the function (performance), features, and appearance of the product that they develop. They have tended to neglect the "downstream" considerations…" (Bralla 1999, p. 9.25).*

[9] DFM and DFA together are also called Design for Manufacturing and Assembly (DFMA).

Consequently there are many more focuses in design that together are called 'Design for X'. 'X' stands for any of the quality criteria that feeds the product design specification. Other examples are, design for piece-part producibility, design for serviceability (DFS), design for packaging, maintenance, etc. All these various aspects (X) of a product must be in balance with the whole and not be applied in isolation. Cross talk between the 'design for' disciplines and specialisms is necessary to prevent an imbalance in the characteristics of the newly developed product (Pugh, 1991). These DFX theories provide no further details about the interface interactions between NPD and Manufacturing. For instance there is no focus on the actual ramp-up phase of the manufacturing process, like Design for rapid Ramp-Up (DFRU).

But there is something else that is interesting. All the DFX theories aim to bridge a upstream-downstream interface. They do so by incorporating information in terms of possibilities and constraints about the present downstream situation into the upstream development process. The trouble is, however, that the task of NPD is to create a new and competitive product that will result in a future state involving the downstream processes that is different from the present circumstances. This results in a dilemma for both parties. How much does NPD have to take the present downstream constraints into account? If they try to accommodate every new product into the present manufacturing system, then the company might loose competitive advantage because of a lower pace of renewal as compared to its competitors. Audi would never have been able to develop new cars made out of aluminum if they had stayed within the constraints of production processes dominated by the use of steel plates. This new aluminum frame even resulted in building a new factory, because it is better not to treat aluminum and steel within one environment. A less drastic example is the side panel of the 1995 Ford Taurus. Because of stiffness reasons the designers decided to make the side panel of the model out of one plate. This required the Manufacturing plants to redesign the layout of the plants and invest in much larger stamping machines (Walton 1997).

A way that could settle this dilemma is the involvement of suppliers who can deliver such new production possibilities. However, involving specialized suppliers is not really a satisfactory solution because it leaves the company's own production unused. But outsourcing can be an effective strategy for short or even longer periods of time. Clark & Fujimoto have formulated this accommodation dilemma as follows:

> *"Ignorance of downstream constraints hampers integrated problem solving, but for product engineers [=NPD] to over-adapt to manufacturing conditions by making excessive compromises in key features of design quality and performance can be equally harmful. […..] Manufacturability must not dominate design decisions; rather, it must be carefully balanced with design quality issues in order to maximize total product quality. Thus product engineers must be capable of making subtle trade-offs between product performance, design and manufacturing quality, and costs." (Clark & Fujimoto 1991, p. 240).*

This not only requires a continuous exchange of partial information between NPD and Manufacturing, but also an open and creative environment to discuss this vulnerable information. Vulnerable, since new and innovative ideas that are still in a conceptual state can easily be killed by existing constraints in downstream processes that are seemingly unchangeable. We are interested in how the actors on both sides of the interface handle this subtle dilemma. How much partial information is needed for the receiving party to understand its future state? A future state that might result in yet unknown changes of the production and assembly processes. How can people from

Manufacturing handle such complex tasks? These kinds of questions bring us back to the earlier point regarding the necessary attitudes of the actors to achieve effective interactions while using partial information.

2.3.2 Prototyping

Prototypes come in different versions and therefore may serve a large variety of testing goals, like functioning, reliability or manufacturability. According to Ulrich & Eppinger (1995, p. 230), "a prototype is an approximation of the product on one or more dimensions of interest". Every version of a prototype renders a close approach of the product regarding future processes that are related to that product, like for example the manufacturability. Prototypes are built in advance of the real product to reduce the risk of expensive changes late in the process. Because of this orientation on the future prototyping can be seen as an interface bridging activity to other phases and stages of the product innovation process. Highly concentrated technical tests using prototypes can serve to identify and solve problems early in the development process that are associated to very complex technical issues (Reinertsen 1997). Wheelwright & Clark (1992) describe a traditional approach to prototyping that is managed by different functions in different phases, is mainly technically driven, and is aimed primarily at design evaluation and verification. Together these make up a string of successive design-build-test cycles throughout the NPD process that have, according to Wheelwright & Clark (1992), important strengths regarding the transition to manufacturing. They see the shift of responsibility and the subsequent limiting communications and understanding across functions as shortcomings of this traditional approach.

> *"When design engineers are responsible for a prototype build and test cycle, their focus is primarily on design feasibility (and the ability of the product to meet customer requirements, usually as stated by marketing). When manufacturing is responsible for the cycle, their focus is on resource utilization and manufacturability." (Wheelwright & Clark 1992, p. 272).*

Ulrich & Eppinger indicate that prototypes can be used for four purposes: learning, communication, (product) integration, and milestones. These authors describe alpha and beta prototypes. The testing of the alpha prototypes considers the functioning and fulfillment of consumer needs. Beta prototypes, which come later in the process and use all the final parts and subassemblies, are tested on reliability and performance. The relevant point for the research presented here is Ulrich & Eppinger's purpose of communication. They mention communication with top management, vendors, partners, extended team members, customers and sources of financing (Ulrich & Eppinger 1995). However, communication with Manufacturing is not explicitly stated. It could be that Manufacturing somehow fits into what they term 'extended team members'. According to Wheelwright & Clark (1992), successive prototyping or successive design-build-test cycles with the involvement of other functions will support the integration and communication across these various functions because prototypes can serve as a platform to discuss important issues from these different functional perspectives.

> *"The physical object represented by the prototype becomes the vehicle by which different contributors can focus and articulate their concerns and issues, and reach agreement on the best ways to resolve conflicts and solve problems. Because even simple prototypes can convey substantial amounts of information, they serve as a bridge between individuals and groups with very different backgrounds, experiences, and interests. Thus management can use prototypes*

to gauge, share, and extend organizational knowledge."
(Wheelwright & Clark 1992, p. 273-274).

The authors propose 'periodic prototyping'[10] throughout the length of the product development process with the involvement of all functions that play key roles at some point in the product innovation process. Periodic prototyping can serve as the communication vehicle between functions in a much better way than drawings and renderings can. Drawings and renderings always need to be studied and translated into some kind of inner representation in order to fully understand the consequences of the new product. Not every involved individual is good at these kinds of translation processes.

"Too often we delude ourselves into thinking that we can visualize things accurately from a blueprint. Not everyone can. For example, a VP of marketing at a telecommunications equipment company saw the first physical prototype of a new product and said, "You know, I really thought that it was going to be smaller than that!" Blue-prints and artists' renderings never communicate as much as a full-scale physical model." (Reinertsen 1997, p. 192)

Thus, prototypes convey lots of information that is useful in interactions between NPD and Manufacturing and can, according to Clark & Fujimoto (1991), serve as 'early problem detectors'[11]. These interactions will probably have the nature of discussions about certain parts or issues related to the future behavior of the product in the manufacturing process. It is not clear from the literature how these discussions between the respective individuals who represent the various functions are structured. From an organizational point of view, periodic prototyping requires 'heavyweight' NPD teams because of the inherent need for cross-functional involvement. We will discuss heavyweight teams under the structural perspective in Section 2.4.

What we learn from prototyping regarding this research topic is that prototyping seems a good tool to bridge the interface between the various actors involved in the development process, including interactions between NPD and Manufacturing. The discussions about the prototypes take place with the involvement of actors representing the other functions. They have to discuss the properties of the version of the prototype at hand in relation to the final state of the product that is envisioned. This way a prototype provides a starting point to discover important information about the gap between the present situation and the remaining NPD activities.

2.3.3 NPD process output = Manufacturing process input

In the previous two sections we have discussed DFX theories and prototypes as ways to bridge the interface between NPD and Manufacturing during development and before the ramp-up phase begins. In this section we will concentrate on what literature says about the information that forms the output of NPD and the subsequent input to Manufacturing. Earlier I used Roozenburg & Eekels (1995) to define NPD as the process that leads to the design of a new product and the plans for its production, distribution and sales.

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[10] Prototypes are expensive and periodic prototyping will increase costs of the development process, but may reduce the time-to-market and amount of the engineering design changes. Finding the right balance between costs and these other factors is necessary.

[11] Another form of detecting possible downstream problems early in the process is what Thomke & Fujimoto (2000) call 'front loading'.

> *"A product design is ready for production if all design properties have been specified definitively and in all required detail." (Roozenburg & Eekels 1995, p. 101)*

The design properties cover each part's (Hubka & Eder 1988, op cit. Roozenburg & Eekels 1995, p. 100):

- *Shape*
- *Dimensions*
- *Material*
- *Surface quality and texture*
- *Tolerances*
- *Manufacturing method*

This information is usually laid down in technical drawings, production plans and a Bill of Materials (BOM). The BOM provides a short description of every individual component in the product. According to Roozenburg & Eekels the production plan contains the design of the manufacturing processes and sometimes a new production organization or even a completely new factory. The design of the manufacturing processes must somehow describe the production of the raw materials by primary production processes like stamping and forging, the production of finished materials by secondary production processes like milling, and the final assembly (Andreasen et al. 1988) (see Figure 2.8). The secondary production processes also cover possible subassemblies. For complex products with many components there can be more assembly stages following each other, each stage adding parts or subassemblies.

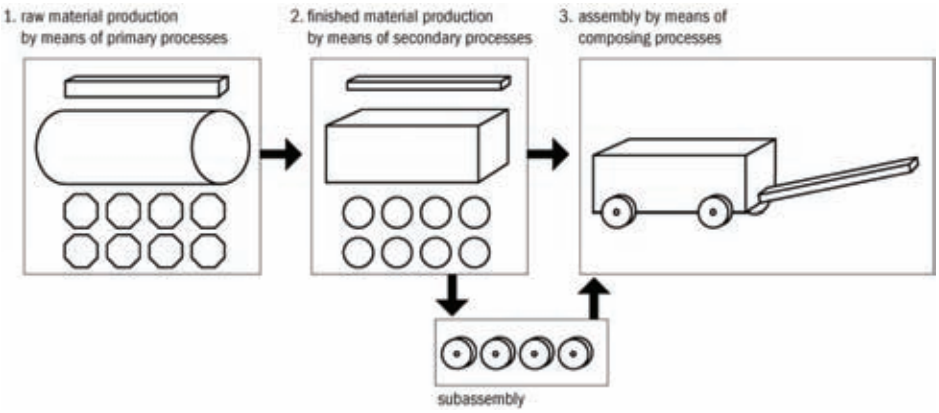

Figure 2.8 *Three stages of industrial production (Based on Andreasen et al. 1988)*

As an example, let's take the wheels in Figure 2.8. In the primary processes a steel plate is stamped out of sheet material. This is followed by a shaping process to create two three dimensional forms that can be welded together to get the steel wheel. Adding a tire and mounting a subassembly consisting of the roller bearings follow this. At this point the wheel, including tire and bearings, is still a subassembly in relation to the complete trolley. Production plans must contain such a sequence of production stages which include assembly instructions that describe how the parts, components and subassemblies are fixed together. All this requires a detailed insight and understanding of the possible production and assembly methods. Therefore, NPD and Manufacturing need to be in very close contact to exchange and discuss possible solutions. But how does NPD keep itself up-to-date regarding these possibilities? Do they understand at a detailed level

the present and new manufacturing options enough to incorporate them in their future designs? How does Manufacturing inform NPD about relevant new circumstances and changes in production and assembly? What is relevant for NPD? And how does NPD consult Manufacturing while they are in the middle of the product development processes? We can imagine that NPD sometimes needs advice regarding the assembly of a part in choosing one option or another. How do they interact in such cases?

Before the ramp-up of the production line can start, the NPD process must have finished these detailed production and assembly plans including all the drawings and the Bill Of Materials. This sounds like a large amount of detailed information. Perhaps some information regarding the production activities and assembly plans might not come from NPD but is acquired during the learning activities that take place in the ramp-up. If this is the case then development continues during ramp-up phase, at least during the first part of the ramp-up phase. Therefore it might be good to refer back to this at the end of this study.

2.3.4 Concluding on the information perspective

We have already discussed in this section possible information streams between NPD and Manufacturing. The DFX methodologies focus on bringing downstream production and assembly information to upstream NPD processes. This is done in a static form by handbooks that contain guidelines, principles, etc. and in a dynamic form by frequently exchanging partial information during interactions. Part of this dynamic form is the use of prototyping as a means to trigger discussions among the various downstream and upstream functions. However, bringing downstream information to upstream processes might increase the smoothness of the transition from one process to the other (fewer iterations, for instance) but it doesn't change the nature of the interface itself.

What we have learned is that the amount of information, including the level of detail, that has to be transferred between NPD and Manufacturing is enormous. I can imagine that some information doesn't need to be transferred because this information is developed during the zero-series (also referred to as: 0-series) or ramp-up phase. Other information might not need to be transferred because the people on the other side already have that information or are believed to have it. Regarding the prototypes, we have understood that they convey lots of information, much more than can transferred by drawings only. Because NPD tries to approach a future state of the new product through prototypes, they seem to act as interface 'bridgers'. This could be an interface between stages of the development process but also an interface with the future manufacturing processes. In this empirical study, I must keep an eye on the **role of prototypes** in the interactions between NPD and Manufacturing.

2.4 NPD-Manufacturing Interface: A structural perspective

From what we have seen in the literature thus far it is clear that NPD needs downstream Manufacturing information during the development processes. The dynamic way of providing that information is the involvement in the NPD process of individuals who have their home base in Manufacturing. The various organizational measures and structures that surround the NPD process might influence the interactions between the individuals. In this section we will discuss some organizational structures and their system of interactions between NPD and Manufacturing.

Besides the integration of the three parallel processes, the models of Integrated Product Development that we discussed in Section 2.2 also include the integration of the people involved (Andreassen & Hein 1985, Buijs & Valkenburg 2005). This is accomplished by establishing integrated teams that consist of people from various disciplines and functions. These multidisciplinary and cross-functional teams are, according to the research of Clark & Fujimoto (1991), the rule rather than the exception. Cross-functional teams consist of people that come from and represent different downstream operational functions like purchasing, manufacturing, assembly, marketing and sales. This way the detailed information about the downstream processes is brought into the NPD team. Besides the involvement of these downstream functions other specialized engineering disciplines, like electronics, mechanics, software or ergonomics often take part in the development process. These disciplines mostly come from the same functional department like Product Development or R&D and deliver specialized technological knowledge to the development process in the form of modules, designs, parts or programs. These disciplines, together with the functional representatives, have to create an integrated and balanced design for the new product. Doing the NPD work in cross-functional and multidisciplinary teams is an organizational structure that should enable the use of downstream Manufacturing information in the NPD process.

An important element of teams is their composition and the organizational embedding. Wheelwright & Clark (1992) have identified four dominant modes of organizing such development teams (see Figure 2.9). The traditional functional structure (Figure 2.9, upper left) is where the work is divided over the respective functions with clear procedures for coordination and detailed specifications to make it all fit together.

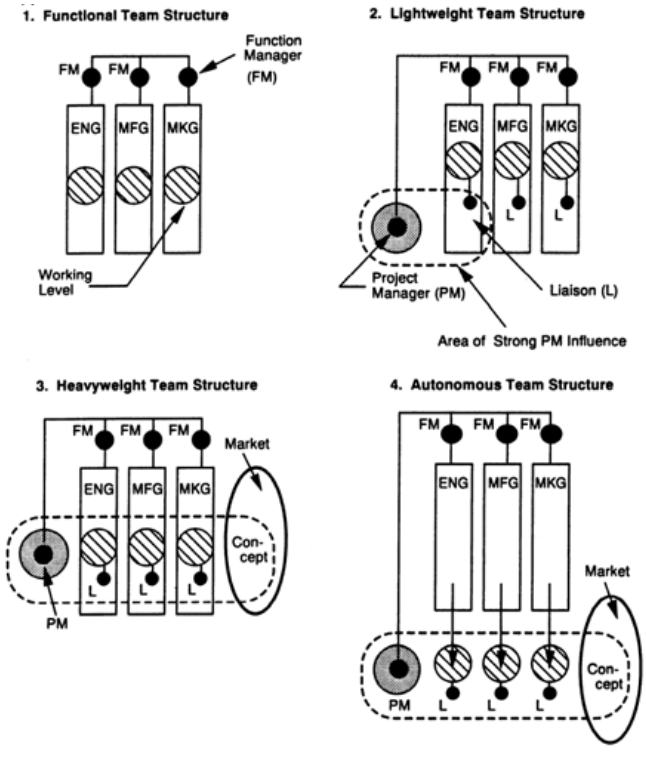

Figure 2.9 *Four modes of organizing NPD (Wheelwright & Clark 1992, p. 191)*

Then (upper right) there is a lightweight team composition with a project manager, who coordinates development activities through a liaison person from each function. The main purpose of the project manager in this organizational setting is to keep track of the project's status to aim at the overall project objectives and to help functional groups solve conflicts. The people assigned to the team reside physically in their functional areas, as is also the case with the functional team structure.

The heavyweight project managers (lower left of Figure 2.9) are mostly senior employees who are responsible for internal coordination, product planning and concept development. They act as a sort of general manager of the new product and have responsibility for all the work done by the team members. Finally there is the autonomous team structure, also called 'tiger team', with a heavyweight project manager who works with a team of people that work full time on one project and are co-located. Team members leave their functional base, accept more responsibilities than within their day-to-day functional life, and report directly to the project manager.

According to Clark & Fujimoto (1991), face-to-face communication is an enabling factor regarding the integration between NPD and Manufacturing. For face-to-face communication to happen coincidentally, their desks or offices must not be too far apart (Allen 1977). This spontaneously meeting of upstream and downstream people seems to enhance the transfer and discussion of preliminary information, which are necessary conditions for integrating problem-solving cycles, as we have seen in Figure 2.3 (Clark & Fujimoto 1991). Co-location of the cross-functional NPD team, for instance placing people's primary offices and workstations in physical proximity to each other (Van den Bulte & Moenaert 1998), has been proven to increase the communication among team members (Allen 1977, Becker & Steel 1995).

On a higher level of abstraction Kahn (1996) discusses integration by introducing an interesting model of interdepartmental integration. He describes integration as a "multidimensional process that comprises two distinct processes of interaction and collaboration" (Kahn 1996, p. 139). In his definition interaction relates to formally coordinated activities between departments, like routine meetings & telephone calls, memoranda & reports and the flow of standard documentation. Collaboration has a more affective nature and is defined as a shared process with characteristics like a common vision and collective goals with determined actors. In the research presented here interaction is seen as a dynamic social process between individuals, a process that causes the actors to adapt their actions and reactions as a result of the actions of their interaction partner. Formulated as such, interactions could be, and most likely are, part of both distinct processes. In Chapter 7 I will reflect on the results of this study in relation to the distinction introduced by Kahn.

It is clear that the level of integration between the functions involved increases over these four organizational structures from Figure 2.9. But how does this integration influence the interface between NPD and Manufacturing? In the first two situations, the traditional and lightweight teams the functional participants are not co-located and remain in their functional units. Manufacturing people will do the explorative NPD work among their colleagues who have their day-to-day exploitative work. If they are only involved part-time, they have to switch between the two types of work: explorative and exploitative. Is such a switch easy to accomplish?

The heavyweight teams seem to encapsulate the interface between Manufacturing and NPD within a team by including team members who have their base in Manufacturing. However, what happens inside the development team in terms of cross-functional interactions has only been researched and addressed in literature in a limited way (Valkenburg 2000, Vissers & Dankbaar 2002). As well

as what is happening within the team, one could say that the NPD team in fact creates a new interface between the team itself and the respective exploitative functional bases by doing their development work more or less in separation. And this new interface still falls within the scope of this study since it is also an interface between explorative and exploitative activities.

What we learn from these four organizational structures about cross-functional teams is that there can be major differences in **the way the NPD team is organized**. If people are not co-located we will have to keep an eye on the interface between that team member and his/her own department. On the other hand, if team members are only involved part-time in the development work, then they have to switch back and forth from explorative activities to exploitative activities. In the case of co-location, we need to be aware of the extra interface between the cross-functional NPD team and the functional departments.

2.5 Footholds for future research

In this section the lessons from the literature on NPD interfaces will be summarized by recapitulating the issues that could be important during the research and by naming some theoretical constructs that could be of use in my conceptual framework. This will be used as input to review the research questions.

In this chapter we have discussed the literature that addresses the interface between NPD and Manufacturing from three perspectives:

- Process perspective
- Information perspective
- Structural perspective

From these perspectives we have seen that we can divide the interactions between NPD and Manufacturing in the product innovation process over **two periods: preramp-up and ramp-up**. The preramp-up period covers the actual NPD process and can be sub divided into **four stages**: clarification of the task, conceptual design, embodiment design and detail design. Of course, I am aware of the fact that in reality there will be iterations, loops, and jumps between those stages but we also know that at the end of the NPD process these four stages have somehow been addressed. Over the course of the NPD process interactions with other functions like Manufacturing are necessary to create a design that is easily implemented in the downstream processes. However, the information shared during these interactions is, per definition, incomplete since the design is not ready yet. From literature we understand that **working with incomplete information** requires special attitudes and behavior of the participants since they are the providers and recipients of that incomplete information. Therefore, we will pay extra attention to the issues concerning the exchange of information.

Some social-cultural elements in what we have discussed in this chapter have to do with the **various forms of learning**. The people within NPD learn by creating new knowledge about the product and its production plans. Then during the ramp-up phase the people in Manufacturing learn to produce and assemble the new product and learn to understand the ins and outs of the production and assembly processes. A special form of learning that we have also seen is by deliberate experimentation. And **prototyping** also seems to be an important learning and interface bridging activity.

The **definition of NPD** that I use in this book includes the plans for production, distribution and sales (Roozenburg & Eekels 1991). In Section 2.3.3, which discusses the output of NPD, we have seen that these plans must contain large amounts of information if they describe all the necessary knowledge/information for the downstream processes including Manufacturing. We expect that some of this information is not really transferred from NPD to Manufacturing and maybe not even developed within the NPD process. It might be that parts of the procedural information related to production and assembly is already available in Manufacturing from earlier products or is developed during the zero-series or ramp-up within Manufacturing itself.

Another element to keep in mind during our research is the **amount of involvement and the location** of the functional team members that take part in the NPD process. We expect that these will also influence the interface interactions between NPD and Manufacturing. Part-time involvement means that team members have to switch from one process to the other. And co-location means that an extra interface is created between the team and the functional departments.

2.6 Research questions and research requirements

In Chapter 1 the main purpose of this study was formulated as: exploring the process of interactions among actors from explorative NPD and exploitative Manufacturing during the development of a new product until volume production of that product is reached.

The reason for undertaking this study is that the NPD-Manufacturing interface is a locus of conflict on the level of the participants (Chapter 1). According to the literature there are misinterpretations, task & emotional conflicts, hostile situations, unwelcome surprises and various other problems. These circumstances must have a negative influence on the effectiveness and efficiency of the interactions. Literature proposes all kinds of integration mechanisms that mostly aim at enhancing the communication among the departments involved. However, these mechanisms as such do not provide insight into the actual interactions that seem to create these contentious situations. We do not know the influence of, for instance, the dual character of the interface. Based on these observations two preliminary research questions were formulated.

1. *What influences the quality (effectiveness + efficiency) of interactions between actors from New Product Development and Manufacturing?*

2. *What are elements of a conceptual framework that make a description of the interactions between NPD and Manufacturing possible?*

In this chapter I have searched the NPD literature for such theoretical elements, that is, the footholds for further research. The elements that were detected as being possibly related to the quality of the interface interactions are:

- The notion of working with incomplete information during interactions
- The various forms of learning that are related to this interface
- Prototyping as an interface bridging activity
- The organizational and spatial influences

As mentioned earlier, I intend to use these elements to create a framework if they prove to be relevant. However, for a coherent framework these elements need to have clear relationships

with each other. This is not yet the case. Of course, building and testing a prototype can be seen as a learning process. So some of these seem to be related, but how do the relationships become apparent during interface interactions? Answering this would be highly speculative. This implies that a third research question is needed to direct the empirical investigations.

3. What are relationships between the elements that constitute the framework?

Based on these questions it is possible to formulate some requirements that will help in the selection of an appropriate research approach.

In this chapter some potential elements were found in the scientific literature, but we lack the insight into the relationships among them. I also don't know if all possible elements have been identified. Therefore, I need to explore this interface in practice and look for elements and relationships among them to build a theoretical construct of interactions that is relevant to the NPD-Manufacturing interface. This singles out the Empirical Sciences as the main approach for this research. Within the Empirical Sciences, the inductive approach is directed **from empirical data to theoretical conceptualization** (Swamidass 1991, Locke 2001) (Figure 2.10). This inductive direction could fulfill our need to build a theoretical construct out of theoretical elements incorporating their interrelation.

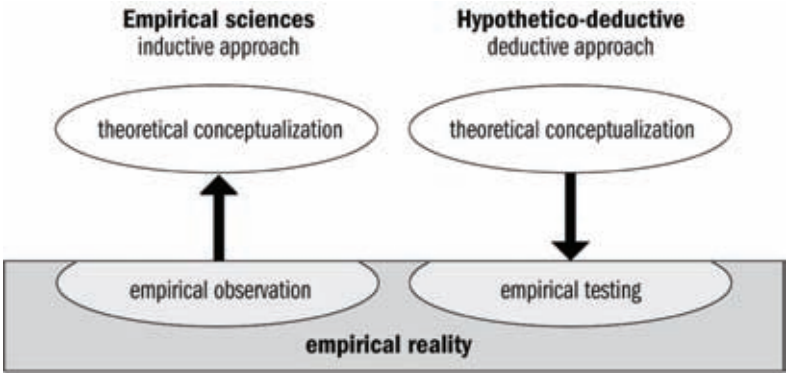

Figure 2.10 *Different directions of investigation between Hypothetico-deductive Sciences and the Empirical Sciences (Based on Locke 2001, Swamidass 1991).*

Within the inductive approach the rhetoric tends to follow the sequence 'method, data, findings, theory', and the hypothetico-deductive rhetoric tends to follow 'theory, method, data, findings' (Daft 1985). The Hypthetico-deductive approach would not suit the purpose of this research project (Figure 2.10). One first conceptualizes theoretical concepts, by generating logical assumptions and speculations that are then empirically tested in the real world. From what we have seen in the last two chapters, there is no foundation to generate such assumptions other than guessing. There are no theoretical constructs to test.

To study the interface properly I must first find out what happens between the two parties, NPD and Manufacturing. This implies that it is necessary to include the **actors from both sides of the interface** who are involved in the product innovation process, that is, the process that runs from concept to volume production and this includes the interface between NPD and Manufacturing.

What do these actors tell us about their working situation and their interactions with the others? To be able to 'weigh' their experiences as objectively as possible it would also be nice if we could take a **neutral standpoint**. Meaning, that it is better to not be affiliated with either side, for instance as a colleague to one of the two parties.

In the next chapter I will discuss the research approach that satisfies these three requirements: empirical data collection on the level of the actors, being in a neutral position during data collection and the ability to identify theoretical constructs.

3 *Research approach*

This chapter describes the research structure. In the first section I will motivate the preference for case studies as a research approach for this project. Section 3.2 describes a grounded approach as a form of case study research and explains the meaning of pursuing theories as a research goal. Section 3.3 explains the terminology and activities within the grounded approach. In section 3.4 the different views on and developments around the grounded approach will be discussed. Section 3.5 gives an overview of the expected stages of the research process for this study.

3.1 Moving towards a research approach

In the first chapter I made four observations regarding the context and the present status of the knowledge concerning the interface between NPD and Manufacturing:

1. Effective and efficient interplay between NPD and Manufacturing is difficult for companies
2. The NPD-Manufacturing interface is where exploration and exploitation must interact
3. The NPD-Manufacturing interface has a dual nature: a transitional nature within the product innovation process and the give-and-take between explorative NPD and exploitative Manufacturing
4. The NPD-manufacturing interface falls in between time-to-market and diffusion studies. The NPD-Manufacturing interface is not sufficiently researched on the level of the actors.

Based on these observations it was decided to start a research project that aims to explore the Design-Manufacturing interface on the level of the actors who are involved in a product innovation process from concept to volume production. In Chapter 2 the existing literature on NPD interfaces was investigated for two reasons: first to create a better understanding of the NPD process with its stages and activities. Second, to explore this literature for theoretical elements and areas of attention that could be useful later on in creating a conceptual framework that describes what is happening within Design-Manufacturing interface. The elements identified appear to be relevant but lack relationships among each other that are necessary to create a such theoretical framework. This led to the formulation of an additional research question. The three questions are:

1. *What influences the quality (effectiveness + efficiency) of interactions between actors from New Product Development and Manufacturing?*

2. *What are elements of a conceptual framework that make a description of the interactions between NPD and Manufacturing possible?*

3. *What are relationships between the elements that constitute the framework?*

At this point, to be able to proceed with the investigations a research approach needs to be selected. In Chapter 2 three requirements were formulated that a potential research approach would have to meet. The research approach must make it feasible to:

- Discover elements of a conceptual framework out of empirical information, that is, an inductive approach
- Collect empirical data on the level of the participants on both sides of the interface
- Keep a neutral and value free position regarding the two sides of the interface during data collection.

In this section these requirements will be applied to select the research approach. According to Den Hertog & Van Sluijs (1995) there are five main routes to study an organization:

- Experiment
- Survey
- Case study
- Action research
- Ethnography

We will discuss these methods using definitions Den Hertog & Van Sluijs (1995) use and compare them to the requirements. Figure 3.1 shows how these five main routes fulfill the three requirements.

The first two, *experiment* and *survey* are disqualified because of their predominantly deductive direction of research. The purposes of an *experiment* can be, among other things, the testing of theory and the identification of causality among variables. A *survey* is mainly for creating statistical insights between factors at a certain moment. Although both research approaches fulfill the other two requirements, both need theories or variables as a starting point and are therefore not suitable for identifying unknown contextual factors or discovering theoretical constructs.

Case studies can serve many purposes, but testing theories, theory development and organizational problem solving are the most relevant purposes for the research presented here. It fulfills all three criteria and seems applicable to the research issue so I will return to case studies later.

	'Discovering' Theories	Actor Level	Neutral Position
Experiment	No	Yes	Yes
Survey	No	Yes	Yes
Case study	Yes	Yes	Yes
Action research	No/Yes	Yes	Yes/No
Ethnography	Yes	Yes	Yes/No

Figure 3.1 *The five main routes for studying organizations in relation to the criteria for this study*

In *action research* the researcher actively participates in the organization that is the subject of the study which makes it possible to investigate on the level of the individual. *Action research* typically contributes to the organization by helping them solve a certain problematic situation as well as to the academic community by advancing knowledge and understanding of certain phenomena. Therefore, one of the goals of *action research* is to bridge the gap between theory and practice by concentrating on a specific problem within the organization. However, action research is not preeminently a method for explorative research which aims to identify new theories or conceptual theoretical frameworks. Therefore, this method does not seem to be an optimal choice in relation to my research issue. Action researchers actively participate in the area that is under investigation. However, acting from one of the two sides of the interface would contradict the requirement of retaining a neutral position. The role of project leader or external consultant as an action researcher could be a neutral one. That is, not directly tied to either of the two parties by having, for instance, a managing or bridging role regarding the two processes. This could be done by using the method of *reflective action research* as described by Boonstra (2004) which could lead to the development of theories by means of repetitive cycles of action and reflection. But action researchers need to fulfill an action-oriented role, meaning that they need to perform actions in this substantive field of research which requires an existing theoretical framework to act from. However, such a framework seems to be missing, at least in the scientific NPD literature. All in all, *action research* is not a logical choice at this juncture in the project. It could be that after this first exploration of the Design-Manufacturing interface the method of *action research* is more advantageous.

The last of these main routes for conducting research within an organization is formed by *ethnography*. In *ethnographic* studies the researcher becomes the main research instrument, by taking a participative and/or observational role in the organization. *Ethnographic* research focuses on the culture of the organization and aims to reveal the underlying meaning of overt behavior. Ethnographic studies can have a longitudinal character. The researcher needs to spend a considerable amount of time in the organization in order to be able to discover the deeper, mostly unwritten cultural rules within that organization (e.g. Goulding 2002). This way it is possible to develop theories and do so on the level of the actors. To explore the NPD-Manufacturing interface an ethnographic approach is possible. This would require a long-term presence in an organization either as a neutral observer or by taking a participating role on one side of the interface. The observing role could work regarding my research aim, but to collect data from more than one case would require spending long periods of time in several organizations which makes the observation role rather unpractical. Being a participant within an organization would require a choice to participate on one side of the interface or the other. For an investigation of interactions between NPD and Manufacturing it is not appropriate to take a position on only one side of the interface. Based on these considerations, I conclude that a participative ethnography is not in accordance with the third research requirement and that an observatory ethnographic study is impractical.

A case study approach fulfills the three requirements and so has been chosen as a suitable and practical method for this research project. The next section will elaborate on case studies as a research method.

3.2 From case study to grounded theory

In this section I will discuss the aim of this research in the context of case studies. I will concentrate on one particular approach within case study research: grounded theory. Explaining what is generally understood by a 'theory' follows this.

3.2.1 On a grounded approach

Case studies have a long history and are still widely in use. Collecting and analyzing empirical information taken from real life situations is what is generally understood by a case study. The empirical data can serve as a basis for an inductive reasoning process, a reasoning process that moves from a particular instance observed in the data to a more general theory. In my situation this inductive process will aim to identify elements and relationships among these elements that might become a theoretical framework to help understand the interplay between NPD and Manufacturing. The elements that I am looking for will underpin a description of the social process in terms of the interactions, or aspects of the interactions, between NPD and Manufacturing and hopefully will also provide an insight into the efficiency and effectiveness of those interactions.

A way to use case studies to explore social processes in an under-researched area is called 'Grounded Theory' (Glaser & Strauss 1967, Glaser 1998). Grounded theory is an approach that aims at the generation of "theories of process, sequence, and change pertaining to organizations, positions, and social interaction" (Glaser & Strauss 1967, p. 114). These theories are 'grounded' in empirical observations and are abstracted from these observations by using a process of inductive reasoning. The research approach of grounded theory originated in the domain of sociology and is claimed to be the most widely used qualitative interpretive framework in the field of social

sciences (Denzin 1994 in Locke 2001, p. 1). But over the past decades it has been applied in many other fields including the field of management and organization studies (Locke 2001). Grounded theory gives the researcher the possibility to create theories that encompass the level of individuals who are involved in activities or interactions with other individuals. This feature of grounded theory perfectly fits the requirement of doing research on the level of the actors.

> *"Grounded theories are very much oriented towards micro level processes reflected in action and interaction. The researcher focuses on the study of patterns of behaviour and meaning which account for variation in interaction around a substantive problem in order to arrive at conceptually based explanations for the processes operating within the substantive problem area". (Locke 2001, p. 41)*

The interface between NPD and Manufacturing forms the substantive problem area that I want to explore at the micro level of interactions between the two processes. Finding out what is going on between the respective participants or determining what drives their social processes is what grounded theory calls the Basic Social Process (BSP) (Glaser 1978). According to Glaser (1978, p. 93) "the goal of grounded theory is to generate a theory that accounts for a pattern of behavior which is relevant and problematic for those involved." Relevant and problematic behavior is what we are looking for. Issues that I wondered about in Chapter 1, for instance the persistent delivery of 'surprises' from NPD to Manufacturing is one of the symptoms of problematic behavior. The same is true of the seeming unwillingness of Manufacturing to try new things. The pattern of behavior that underpins or accounts for these symptoms is what I want to discover. Not just the behavior of one person, or groups of people on one side of the interface will be investigated, such as the many studies that concentrate on designers, but the social behavior across the interface between NPD and Manufacturing.

These observations support the idea of choosing a grounded approach for exploring the interface between NPD and Manufacturing. Before I describe the research process within a grounded approach I will first explain what is generally understood by 'theory' as a concept.

3.2.2 Theories as a research goal

In this research project I want to discover a theory, but what is meant by a theory? Strauss & Corbin (1998) define a theory as a set of relationships that offer a plausible explanation of the phenomenon under study. Collins (1987, p. 1515) has a very compact definition of a theory: 'an idea or set of ideas that is intended to explain something'. Both definitions use the verb 'explain' as what should be achieved by a theory. Before one is able to explain a phenomenon, that phenomenon needs to be described and understood, in other words the phenomenon must be made intelligible (Miles & Huberman 1994). The phenomenon under consideration here is the interactions between actors from NPD and Manufacturing. Describing the various interactions between NPD and Manufacturing at a level of detail that allows a clear view of what is happening requires a framework that is constructed by variables or conceptual categories and their interrelations (Glaser & Strauss 1967, Strauss & Corbin 1998). In the next section (3.3) the process of category development will be described. In this section I will continue the discussion on theory.

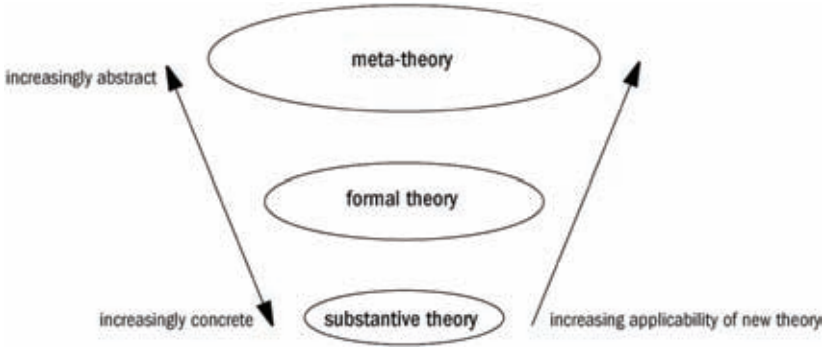

Figure 3.2 *Three common levels of theory*

There are three common levels of theory, each of them at a different level of abstraction: meta-theory, formal theory and substantive theory (See Figure 3.2). Grounded theory starts with a substantive theory, a theory that emerges from a substantive area. Grover & Glazier (1986) define a substantive theory as "A set of propositions that furnish an explanation for an applied area of inquiry" (Grover & Glazier 1986, p. 233-234). The interface between NPD and Manufacturing is just such an 'area of inquiry'. Also in the research process of grounded theory it is advised that first a 'substantive' theory is created that is grounded in the empirical data which has been collected in the area that is being investigated. Later this substantive theory can serve as a springboard to a formal theory that covers multiple substantive areas (Glaser & Strauss 1967) within one discipline or even a meta-theory which is applicable across many disciplines. This generalization process is accomplished by successive verification cycles of the newly developed theory in other substantive areas. This is a gradual process of verification in other settings with an increasing number of differences with respect to the substantive area that served as the theory's origin. First verification can be done within the same discipline but must be confirmed in other settings to arrive at a formal theory. In this case, it could be other interfaces between NPD and parties within the operational chain, like Sales, Logistics, or Quality Control. To arrive at a meta-theory the verification should take place in other disciplines, for instance the interface between an architect and the builder. Figure 3.2 shows the respective levels of theory. Meta-theories are the most abstract and least changeable. Substantive theories are specific theories that are applicable to certain areas of inquiry and might need to be modified as the area itself undergoes change. However, these changing substantive theories will still fall under the umbrella of the covering formal and meta-theories.

The next section will continue to describe the research process within the grounded theory approach and explain how, according to that process, a substantive theory is developed by the emergence of categories.

3.3 Research process within grounded theory

In this section I will describe and explain the various stages, elements, and terms that are used within the process of grounded theory. Although Glaser & Strauss grew apart from each other, as we will discuss later, the main elements of grounded theory has remained undisputed. In the following description I will lean heavily on the original work of Glaser & Strauss (1967), the more re-

cent work of Glaser (1978 & 1998), and on the work of Locke (2001) who explicitly discusses the use of grounded theory in organizational research.

3.3.1 Theoretical sampling

According to its founders, Glaser & Strauss (1967), the research process of the grounded theory method is in fact one integrated process:

> *"whereby the analyst [researcher] jointly collects, codes, and analyses his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges" (Glaser & Strauss 1967, p. 45).*

This is called 'theoretical sampling'. During theoretical sampling the researcher oscillates between two main activities: the collection of empirical data and the interpretation of that data, including deciding what data to collect next. One of the ideas behind grounded theory is to analyze segments of the data immediately after it has been collected and then adjust the plan for the next stage of data collecting activities. Even within stages or during interviews the remarks of the interviewees can lead to micro adjustments within the interview protocol.

> *"The rationale of theoretical sampling … is to direct all data gathering efforts towards gathering information that will best support the development of the theoretical framework" (Locke 2001, p. 55).*

This induces a funnel-like research process which has one clear focus: the development of a theoretical framework that explains what occurs in the area of investigation. All subsequent data collection activities are therefore theoretically driven, that is they are based on emerging theoretical categories and the researcher decides the manner in which the next data collection will take place. This dual track research path in which data collection and data analysis frequently overlap is 'a striking feature of research to build theory' (Eisenhardt 1989, p. 538). The ultimate goal of theoretical sampling is to collect data to a point of theoretical saturation of the emerging theoretical concepts. According to Charmaz (2000) the point of saturation is reached if new data fits into already existing categories and no new categories are needed to incorporate the data.

3.3.2 Process of theory emergence

In the process of theory emergence one could detect three states of growth with an increasing amount of theoretical substance.

The **first** state is the generation of conceptual categories by analyzing the empirical data. According to Glaser & Strauss (1967) there are lower level (preliminary) categories that emerge rather quickly during the early stages of data collection and higher level categories that are more integrated and which tend to come later in the research process. Regarding the categories, Glaser & Strauss (1967) recommend not using categories from existing theory, because in doing so the researcher merely tries to maneuver the data into those categories. This could easily lead to "forcing 'round data' into 'square categories'" (Glaser & Strauss 1967, p. 37) and tends to hinder the generation of new categories. This advice is consistent with the approach in Chapter 2 where I only explored the existing research and literature in order to provide footholds that might be useful during data analysis.

To identify the properties of these categories forms the **second** state of growth. Properties are attributes of a category that describe their variations. For instance in the discussion about learning in Chapter 2, the individual problem solving activities of designers, the deliberate experiments during a ramp-up phase, and learning curves are all properties related to learning. Some of the categories from this second stadium might become what Glaser later calls sub-core categories (Glaser 1978) to indicate that they could play in important role in the emergence of the final core category. Because these sub-core categories are detected earlier in the process than the core category itself I would like to call them 'fledgling' categories to indicate their potential to grow further towards the core category.

The **third** and final state of growth is reached when generalized relationships among the fledgling categories and their properties are generated. In the beginning these categories might be unrelated, but the accumulation of interrelations between these categories and their properties as well as the gradual shift to higher abstraction levels of these categories stimulates the gradually integration into a substantive theory. Discovering the connections between categories and their properties may result in the generation of propositions[12]. Of course these early propositions are only suggestions so there is no need for "an excessive piling up of evidence to establish a proof" (Glaser & Strauss 1967, p. 39-40). However, during the course of the research the links among categories and their properties need to be constantly verified by the empirical data (Glaser & Strauss 1967). Like the categories and their properties, these propositions merely function as stepping-stones towards a more integrated central theoretical framework, the core category, which is what I am aiming to achieve. The core category serves as the essential foundation to describe the basic social process among the people acting in the substantive area. It is this basic social process that "accounts for a pattern of behavior which is relevant and problematic for those involved" (Glaser 1978, p. 93). The 'problematic' issue here refers to behavior that requires effort from the actors in order to get it resolved.

Within this theory emergence process, Glaser & Strauss identify four activities that must support the interpretation of the empirical data. These four data processing activities are called the constant comparative method and span the entire study. They do not run in parallel, but the researcher alternates from one activity to the other. These four activities are (Locke 2001):

- Comparing incidents
- Integrating categories and their properties
- Delimitate the theory
- Writing the theory

These four activities will now be briefly discussed. During the first analytic activity the researcher aims to assign a common meaning to multiple data observations (Locke 2001). This is done by two sub-activities: naming data incidents and comparing data incidents and their names[13] (Locke

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[12] Glaser & Strauss use the word hypotheses. But Whetten (1989) introduced the word 'propositions', because propositions involve conceptual relationships whereas hypotheses require measurable relationships. GT produces conceptual relationships that intend to explain something which are not measurable relationships. However, these propositions can eventually lead to hypotheses.

[13] Glaser & Strauss (1967) use the word coding. But, Locke (2001) argues: "The word coding also has various other uses, and as a term it becomes increasingly unclear over time." I agree with Locke and therefore I decided to use the word 'naming' which in fact better fits the actual activity. This shows similarities with the term 'naming' that is used by Schön (1983). According to him, naming is the process of assigning names to a phenomenon. Later, in conversation with Glaser (July 2005), I found out that he also uses the addition 'substantive' to this coding process; substantive coding. But I still am of the opinion that the word 'naming' better conveys the actual analysis process and have decided to use that term.

2001). Names represent the researcher's interpretation of what that incident signifies. This forms the first step towards a conceptual category.

> *"In naming, researchers attempt to conceptualize and develop abstract meaning for the observations or incidents in their data by articulating what they perceive is happening or is being expressed in those incidents." Locke (2001, p. 47)*

This naming activity could be done in as many different ways as the researcher finds necessary. It is more a brainstorming method to gather possible interpretations and helps in thinking broadly about possible meanings (Locke 2001). In fact, keeping an open mind during the analysis and not too prematurely deciding on the ultimate category facilitates the robustness of the emerging new theory. Locke indicates that:

> *"Its 'ultimate' meaning will be settled over the course of the analysis through comparison with other data observations." (Locke 2001, p. 47).*

Data incidents and names are compared by identifying what is similar and dissimilar about them and must lead to a set of categories and related properties that form the conceptual elements of the 'in-process' theory (Locke 2001), the theory that slowly emerges during the research process. This is a process of inductive reasoning and successive abstraction.

One of the ideas behind this successive abstraction is that the various symptoms, i.e. the incidents or problematic interactions between NPD and Manufacturing, are compared with each other in order to discover possible theoretical explanations that together may have caused these symptomatic events. For this 'climbing' process the researcher needs a certain 'theoretical sensitivity', which means that the researcher must be informed about existing theories to a certain extent because not knowing anything about the field in question might result in redeveloping existing theories. Unfortunately, the grounded theory literature is not precise about this issue.

Rearranging the conceptual categories until clear relationships among them can be seen making it possible to integrate the categories, forms the second activity of data analysis: 'integrating categories and their properties'. Considering the properties and dimensions that compose the conceptual categories and visualizing possible relationships with simple diagrams facilitates this creative search to integrate the categories. The aim is to find the right level of abstraction that allows the conceptual categories and their properties to consolidate into variables.

The third form of analysis, 'delimitate the theory', is the process of bounding and bringing the analysis to a close. Locke formulates this as follows:

> *"The aim here is to settle on the framework's theoretical components and to clarify the story they have to tell about the phenomenon or social situation that was studied," (Locke 2001, p. 52).*

According to Glaser & Strauss (1967) this delimiting takes place on two levels: on the level of the framework and on the level of the conceptual categories that are composed from the data incidents. This is, in fact, a further integration towards the formulation of a conceptual whole, towards a theoretical framework consisting of variables that account for the incidents as observed in the data.

Statement of the problem
Conceptual framework
Research questions
Methodology
Data analysis
Conclusions
Discussion

Figure 3.3 *Possible format of quantitative study publications*

The last activity Glaser & Strauss have identified is 'writing the theory'. According to Glaser & Strauss the written document should only be considered as a pause in the "never-ending process of generating theory" (Glaser & Strauss 1967, p. 40). Writing then becomes part of the research process and is therefore discussed here. However, to write up the results of qualitative research there is no general format. The format that is used often within the quantitative studies (Figure 3.3) is according to Miles & Huberman (1994), too schematic and too constraining. For instance, most qualitative studies like this one aim to develop a conceptual theoretical framework instead of starting with one. The absence of a accepted format has caused many qualitative researchers to struggle with the problem of transforming their large amounts of data into journal articles (Golden-Biddle & Locke 1997). Generally speaking, we write to present our newly developed theoretical framework to our readers. According to Locke (2001) qualitative researchers need to write in such a way that they are taken as authoritative regarding the theory they present. She identifies three subjects that could create that authority: 1) authors must show the 'groundedness' of their theory, 2) they must be able to indicate what their contribution is to the existing theory in the field, and 3) the description of the analytic operations must demonstrate good practice. With the last issue she refers to the interpretative and discerning operations with the empirical data.

The groundedness of the theory can be shown by moving back and forth from theoretical treatises to illustrative excerpts of the data. Regarding the contribution the new theory makes to the field, Golden-Biddle & Locke (1997) discuss an interesting distinction between two 'stories' related to the process of grounded theory: the field-based story and the theoretical story (Golden-Biddle & Locke 1997). The field-based story is formed by the grounded theoretical framework that the authors have developed in interaction with their data. The theoretical story links the new theory to existing theories in the field. It is possible to integrate these two into one description as demonstrated by Hargadon & Sutton (1997). They have been investigating the social processes within a large design agency[14] and identified the activity of technology brokering as a Basic Social Process. This way they were able to describe what was happening within the design agency and at the same time contribute to the existing theory on technology transfer. But sometimes the development of the grounded theory needs to be well advanced in order to substantiate the contribution to the existing literature. In such occasions the two stories can be brought separately to the readers.

Showing good practice regarding the analytic operations is only possible to a certain extent. Inherent to the four modes of constant comparison are the oscillations among these modes. The process of moving back and forth from data to categories while trying to achieve integration and robustness of the theory is hard to describe accurately. Furthermore, the inductive process is considered to be highly creative. One does not know when a new insight will appear, nor what triggered the occurrence of this new insight. Describing such an event is not really possible because

[14] IDEO Product Development of Palo Alto

one is never certain where the hunch or new idea came from. Showing the reader the contours of the theoretical sampling process that the researcher has followed is more important: a description of the key stages the research has been through and an illustration of how these stages are related to each other. It is also advised to discuss the emergence of major categories and the relation of the research questions to the analyzing process (Locke 2001).

3.3.3 Need for creativity

Glaser & Strauss (1967) and other authors use words like 'generating', 'emerging', 'creating', 'discovering', 'getting insights', and 'new perspectives' to indicate that the researcher will not be able to plan the moment that new insights and perspectives pop up during the inductive process. Roozenburg & Eekels (1995) even speak about an 'inductive leap' to indicate that it is not clear at all how the inductive process proceeds. Of course, it is not a problem to create early categories from the data incidents, but the problem, or creative challenge, lies in the integration of these categories on a more abstract level without losing relevancy to the field of investigation. However, following the guidance about grounded theory will not provide any guarantee regarding the discovery of a new substantive theory that will have the potential to evolve into a formal theory. The researcher must have a certain theoretical awareness in order to accomplish this. Or as Glaser & Strauss emphasize: "the root sources of all significant theorizing is the sensitive insights of the observer himself" (Glaser & Strauss 1967, p. 252)[15]. This theoretical sensitivity could be built up by occupational training, commitment to a particular school of thought or a particular paradigm of inquiry. Triggers for new insights might come from anywhere even from sources outside the researcher's disciplinary domain or outside the field of inquiry. Glaser & Strauss indicate that getting those new insights may occur during the whole process and can very well happen even on the final day of study, if there is any final day.

> *"The root sources of all significant theorizing is the sensitive insights of the observer himself. As everyone knows, these can come in the morning or at night, suddenly or with slow dawning, while at work or at play (even when asleep); furthermore, they can be derived directly from theory (one's own or someone else's) or occur without theory; and they can strike the observer while he is watching himself react as well as when he is observing others in action. Also, his insights may appear just as fruitfully near the end of a long inquiry or as near the outset." Glaser & Strauss 1967, p. 251).*

According to Glaser & Strauss this perspective on the emergence of theoretical insights has some corollaries. The first thing they mention is that the researcher can get crucial insights from his own personal experiences prior to his investigation or outside the research process in parallel with it. A second corollary is that the insight may come from the experiences of others, for instance other researchers. The researcher then needs to internalize these experiences and relate them back to the substantive field of study. A third source of insights might come from existing theory. Of course, it is not possible to enter the research area as a Tabula Rasa. One cannot erase from the mind the things that are already known. The use of such insights during the data analysis will almost automatically occur. The researcher may cultivate such sources of ideas but not at the expense of obtaining new or even conflicting insights that are identified in the data itself. "He must have a perspective that will help him see relevant and abstract significant categories"

[15] This is why Glaser & Strauss see grounded theory as a difficult but exciting adventure.

(Glaser & Strauss 1967, p. 3). Because there seems to be a great need for creativity I wonder where and how creativity techniques could be applied to catalyze the inductive process.

What must be prevented at all costs is making the data unnaturally fit the existing categories. Investigating retrospectively where the spark came from, or what triggered the imagination of the researcher which led to the new insight is not really necessary. The insight is there and the theoretical concepts that are derived from it must be able to explain, to some extend, the behavior as detected in the data. It is the robustness and relevancy of the new theory in relation to the empirical data from the field of inquiry that is important. This line of thought leads us towards the verification issue within the grounded theory approach.

3.3.4 Verification of theoretical concepts

During theory generation, the focus must be on reaching theoretical saturation by making the theory dense and it is preferable to give this new theory more conceptual generality as opposed to focusing on testing and verification. According to Glaser & Strauss (1967, p. 27) too much emphasis on testing and verification may lead to "well-tested theory fragments, which can only partially account for what is happening in the researched situation". What is meant here is that the inductive process of climbing up to a level that is more abstract must dominate. Glaser mentions recently (Glaser 2002) that theories must be able to sensitize people with an instant 'grasp'. Theories should 'ring true with credibility' and form exciting means of understanding (Glaser 2002). Scholars don't make the theory any stronger by making it clear that there are heaps of time spent and mountains of evidence created (Glaser & Strauss 1967, p. 28). They continue:

> *"Of course, verifying as much as possible with as accurate evidence as possible is a requisite while one generates his theory –but* not *to the point where verification becomes so paramount as to curb generation" (Glaser & Strauss 1967, p. 28).*

It is the generation of new insights that help to describe the basic social process that must be the main focus of a grounded study. More accurate evidence and testing can be done after the initial creative processes of analysis and abstracting a conceptual framework from the data. Within the study itself the oscillation between data and emerging theory are more or less verification steps regarding the substantive theory, that is, the theory relevant to the area under investigation. For verification outside that area, say towards a formal theory, the theory needs to be verified in other substantive areas. However, here it is too early to go any deeper into such verification studies.

3.4 Different views on grounded theory

Before I can present the plan for this research process we need to discuss some developments within and about grounded theory. The original work of Glaser & Strauss from 1967 formed a reaction to the dominant research paradigm of quantitatively testing existing and seemingly unchangeable 'grand' social theories that were discovered by 'geniuses' like Merton. Glaser & Strauss thought there was an imbalance in the verification of these existing grand theories and the generation of new theories. They advocated that researchers do not need to be geniuses to generate useful theory and that there are guidelines and rules of procedure that can help in

his/her qualitative research process. After publishing their original book, Glaser & Strauss both kept developing the grounded theory approach but grew apart from each other. The main differences between the two authors are related to the use of theory during the research process and the description of procedures to use during the process. Especially the work of Strauss with Corbin (1990) made Glaser (1992) furious. He even asked them to withdraw the book or to present it as a different method, not grounded theory. One of the main points of contention is that Strauss & Corbin introduce more rigidity into the research and analysis processes. Although this rigidity provides some guidance and security (Goulding 2002) it is at odds with the necessary flexibility that is required by the creative aspect of the theory development process. The assumed guidance and security might be the reason why Strauss & Corbin say that their techniques and procedures for analyzing data are also applicable to research that does not aim at building theory but works with qualitative data. The recent PhD thesis of Vermeulen (2001) provides an example. He writes:

> *"This study has no intention to develop a 'new' theory, but it uses the grounded theory procedures as a means to collect and analyze qualitative empirical materials by using "a systematic set of procedures" (Strauss & Corbin 1990, p. 24) (Vermeulen 2001, p. 22)*

Vermeulen clearly choose the approach of Strauss & Corbin to supply him with detailed techniques and procedures for his qualitative analysis.

> *"The main reason for proceeding with Strauss and Corbin's work is their extensive treatment of coding procedures required for the analysis of empirical material…" (Vermeulen 2001, p. 23)*

However, this is not the case for this research project. In this study I aim to create and develop a conceptual theoretical framework that enables me to describe the interactions between NPD and Manufacturing. I expect that a too rigid form of step-by-step data analysis will hamper creativity. I suspect that I will need this creativity during the interpretation of the data and therefore I want to stay flexible during this first exploration of the interface between NPD and Manufacturing. Because of these observations, I have decided to stay close to the original work of Glaser & Strauss (1967). In the next section I will discuss the approach of this study.

3.5 Research plan for this project

Now that I have opted for a research approach based on grounded theory I think that it is necessary to make some minor adjustments to the research questions. There are two things that need to be mentioned here. First, the method of grounded theory aims at the identification and subsequent description of the social behavior among the actors in a substantive field of research. Let us look again at the main research question:

> *What influences the quality (effectiveness + efficiency) of interactions between New Product Development and Manufacturing?*

We see that there is a quality issue involved. The discovery of influential factors which impact the quality of interactions does not seem to be in accordance with the particular class of results that the method of grounded theory brings the researcher. Grounded theory helps to describe the interactions but doesn't necessarily provide an assessment on the quality (effectiveness + effi-

ciency) of those interactions. This would require an additional research step after the application of grounded theory using another research approach.

Second, the method of grounded theory requires an open-minded and a flexible approach towards the field of research in order to find out what is happening among its actors. In the words of Glaser, the researcher could start his study "with the abstract wonderment of what is going on" (Glaser 1992, p. 22). This reflects my approach to the Design-Manufacturing situation. At the same time there is not a single obvious research problem as was illustrated by the array of open questions that were formulated in Chapter 1. This implies that the research questions should be open enough to allow the investigation of the phenomenon under study from those perspectives that seem relevant to the researcher and that are empirically based on the emerging concepts. For this study I intend to formulate guiding research questions for each stage. As the research unfolds and categories show the possibility to undergo integration this could lead to a narrowing of the focus and the formulation of more precise and concrete questions towards the end of this research project (Charmaz 2000).

Therefore, based on these considerations I have adjusted the first research question into:

What happens during the interactions between the actors from NPD and Manufacturing?

This question will be regarded as the main research question to steer this study. At the end of this project I will again address the issue concerning the quality of the interactions between NPD & Manufacturing and determine what further research steps would be sensible to take. The other questions that were formulated in Chapter 1 and 2 seem to adapt well regarding grounded theory, but it would be better to use grounded theory terminology.

1. *What fledgling categories with what properties make a description of the interactions between NPD and Manufacturing possible?*

2. *How are the categories and properties related?*

These questions are to be seen as sub-questions the main research question. In the successive stages these and possible additional guiding questions will act as stepping-stones to answer the main research question.

I am aware of the fact that the necessity for creativity and flexibility throughout the research process has repercussions on my ability to devise an attainable plan at the beginning of this research project. The essence of a grounded approach is to adapt the plan for the next stage based on the findings of the preceding stage. Therefore, this section gives an overview of the possible stages that I expect. The findings within each stage could result in adjustments to the earlier plan and will form the starting point for the development of a more detailed plan for the next stage.

At this moment I think that there will be four successive stages. The first three stages will show similarities to the three states that Glaser & Strauss have mentioned in relation to the growth of the theoretical substance. The aim of the **first stage** is to build some awareness by scanning the empirical field. We know that the interface between NPD and Manufacturing is deeply nested in the organization and is surrounded by many other operational processes like sales, purchasing or logistics. The objective of this 'scanning' stage will be to become informed about the issues that

are relevant regarding NPD interfaces in general. In Chapter 4 the detailed approach of this scanning stage will be described including a report on the findings. Besides the creation of some insight regarding the NPD interfaces it might be possible to identify some preliminary categories that could be of help in devising the plan for the second stage. The **second stage**, as I see it now, could be a more focused sampling activity to identify new names which could result in some additional tentative categories. Elaborating on these categories and their properties might provide some answers to the two sub-research questions as formulated above. Ideas about possible fledgling categories, their properties and their relationships might be such an answer. I will report on this second stage in Chapter 5.

The **third stage** could be an integrating and theorizing stage with a detailed investigation of these fledgling categories. The integration of these into a core category will be the major aim of the third stage. The core category would then form a theoretical description for relevant and problematic patterns of behavior regarding the participants in NPD and Manufacturing. At the same time it is important to keep an eye on the level of saturation, that is that the core category should account for a large portion of the behavior in the substantive area. Chapter 6 will contain the results of this integrating and theorizing stage.

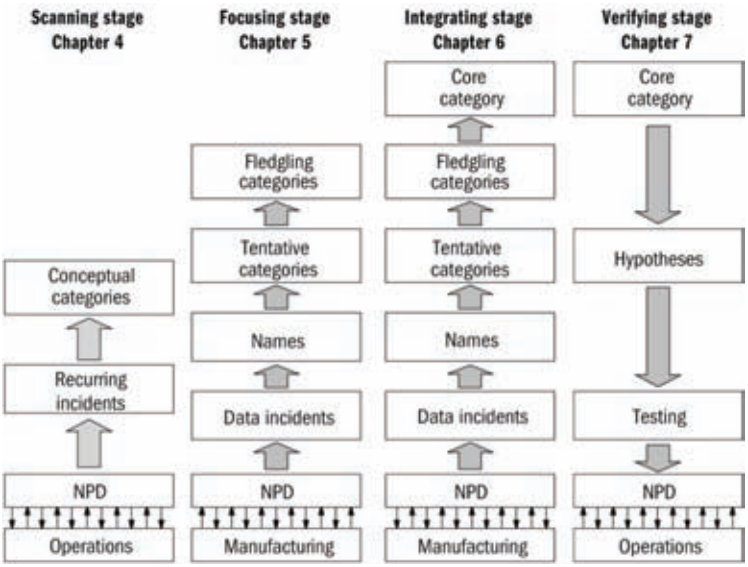


Figure 3.4 *Four successive stages of this research project*

Although within grounded theory verification is not the usual procedure, I have the idea that in order to arrive at 'actionable knowledge' later on, some sort of verification would be in order. Therefore the **last stage** could be a verification step. But it could also be a generalization step that focuses on the verification of the results in other related substantive fields in order to arrive at a formal theory. For both options this could be done by the formulation of hypotheses based on the core category and testing these empirically.

However, in either situation reaching a level of 'actionable knowledge' is, as was mentioned in Chapter 1, too ambitious for the scope of this PhD-study. In Chapter 7 I will report on this final stage and

bring the research project to an end, at least regarding this thesis, by evaluating the research approach, its stages and the inductive and creative processes within these stages.

In the next chapter I will describe in detail the approach that was taken for the scanning stage and the results that were reached. Based on these results I will formulate the plan for the second, focusing stage.

4 *The scanning stage: Exploring the NPD-Manufacturing environment*

This chapter presents the results of the scanning stage of this explorative study. Section 4.1 provides a description of the research setup of this stage. The data collection method that was developed and used during three case studies is described (4.2). Section 4.3 presents the case study subjects together with the obstructing events that were mentioned by the interviewees. Based on this data a first inductive step leads to the emergence of five tentative categories (4.4). A second inductive step brings us in contact with a specific body of literature that helps to make a rational reconstruction of the processes that could have resulted in the obstructing events that were mentioned by the interviewees (4.5). Section 4.6 finalizes this scanning stage.

4.1 Scanning stage research setup

As we have discussed in the Chapter 3, I decided to follow the method of grounded theory to explore the interface between NPD and Manufacturing. To do this I devised four stages. This chapter contains the description and results of the first stage of this project, the scanning stage.

The aim of this first stage is to create empirical awareness about the features of an embedded NPD process within organizations and to identify possible tentative categories that could be used, together with the theoretical elements from Chapter 2, as stepping-stones for the following stages (Figure 4.1). To create this awareness it was decided to enlarge the scope of this first stage to also include other exploitative operational processes.

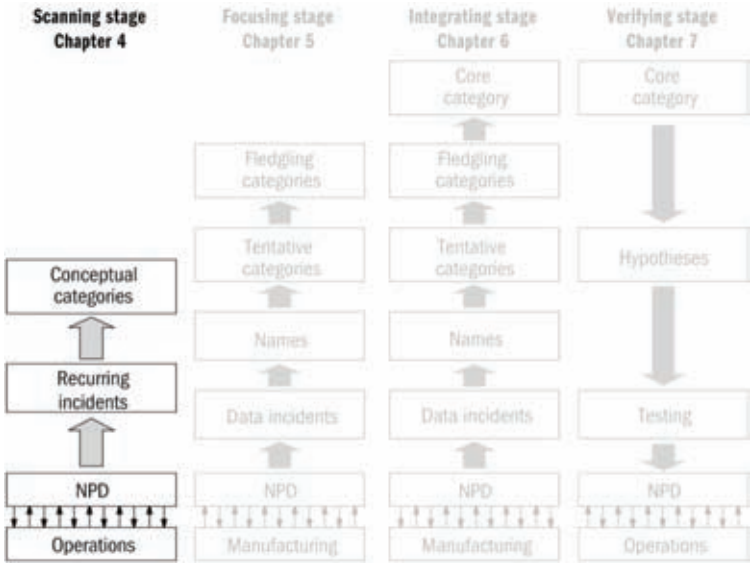


Figure 4.1 *Overview of the research stages (equivalent to Figure 3.4)*

As mentioned in Chapter 3, I will formulate guiding research questions for each stage of the investigation. The grounded approach strives to uncover the behavior of actors that is aimed at resolving their main concern. Therefore I want to know the recurring critical interactions or incidents according to the people who are participating in these processes. By recording these incidents it is possible to develop some awareness about what is important to the participants. The reason to ask about **recurring** events[16] was to identify structural problematic events, not just incidents that occurred only once in a specific project. In fact, asking for recurring obstructing or critical events is the same approach that grounded theory takes during the first interpretation of the data: comparing incidents and naming incidents. Doing this a second time by comparing these issues over the companies that will be investigated could possibly result in the emergence of some early tentative categories.

[16] Because we asked for recurring events these can also be regarded as 'issues' as will become clear later.

At the same time I would develop some awareness of relevant interface issues and I would create some sensitivity that is necessary for the identification of theoretical concepts later in this project. The following questions acted as a guide during this stage.

1. *What are recurring obstructing issues from the perspective of the participants between explorative NPD and exploitative operational processes?*

2. *What preliminary categories can be detected from these issues?*

To answer these questions three companies were selected with a range of organizational characteristics to achieve a wider perspective. The three different companies were:

- The centralized research department (Netherlands) of a large European telecom company, business-to-business and consumer market.
- The decentralized research departments (European branch) of a global and US-based (Fortune 500) business-to-business company that converts adhesives into adhering products.
- The Dutch branch that develops and produces escalators; part of a large German based industrial conglomerate.

All three companies can be considered as major players within their market segment (their parent companies are all part of the Forbes 2000). This should imply that their NPD processes are proficient enough to sustain their competitive position in their respective business arenas. The possible differences in 'clockspeed', that is the pace of innovation, among the respective businesses might provide some extra contrast (Fine 1998). The settings of the interviews depended on the organizational structure of each organization. In total, 65 people were interviewed and most of them were in groups.

4.2 Research procedure

I wanted to reveal incidents that individual participants had experienced more than once, but at the same time I had to be sure that these were not tied to individual persons. I also didn't want to hold two rounds of interviews in which the second round would serve as conformation of the first and to filter out the incidents that are exclusively linked to one individual. Therefore it was decided to interview groups of people. According to Fontana and Frey (2000), group interviews are less time-consuming and often result in rich data that is constructive for further investigations. But group interviews have some adverse consequences: groupthink and the influence of dominant group members. In developing the interview protocol I thought this could be prevented by not allowing discussion among the interviewees. For this it would be necessary to use a directive approach with pre-formulated questions. One of the possibilities regarding these requirements is the Nominal Group Technique (VanGundy 1992).

The Nominal Group Technique seems to be suitable for situations where the experts might have disparate and conflicting opinions and makes it possible to interview experts without the social interactive behavior that often appears during group discussions. Such behavior can have 'coloring' influences on the forming of opinions. Especially the dominance of powerful opinionated leaders is prevented as well as the possibility of groupthink. Since there is no discussion individual opinions are more respected and can be rated at their true value.

I consider the participants in product innovation processes to be experts regarding this research project because it concerns their daily work. At the same time, our field of investigation may be loaded with disparate and perhaps even conflicting opinions since the participants reside at opposite sides of the interface. This is why I decided to use the Nominal Group Technique for the group interviews.

The following interview protocol is based on the steps that VanGundy (1992) describes (see also Figure 4.2):

1. Each individual had to write down approximately 10 events that he/she experienced that had a negative influence on the progress of the product innovation process.
2. Each individual had to prioritize his/her chosen events in terms of being the most obstructive to the product innovation process.
3. Then an inventory was made of all the number 1 events on each individual list, followed by the number 2, and so on, until all events were collected on a Metaplan board. Each participant then had to describe the experience in order to make it clear to the others and to give them the chance to erase any duplication. It was not allowed to go into discussion other than explaining what was meant by the event. This resulted in a long list of obstructing events.
4. From all these events the participants had to individually[17] choose three events that had the most negative influence on the fluidity of the NPD process. This lead to the top three of that particular session (see left column of Table 1-3 in the Appendix I).

During the interviews we also asked about things that generally went well in the NPD process. This was done to create some balance between obstructing and stimulating issues.

The schematic representation in Figure 4.2 shows the theoretical maximum of obstructing issues. In most cases there are many duplicates among the individual lists of events from the interviewees. Also, most interviewees were not able to identify 10 recurring obstructing events. All in all, the real amount of events was considerably less than the theoretical group maximum.

[17] To prevent 'groupthink' this was done without discussion and without sharing any information before all participants had made their choice.

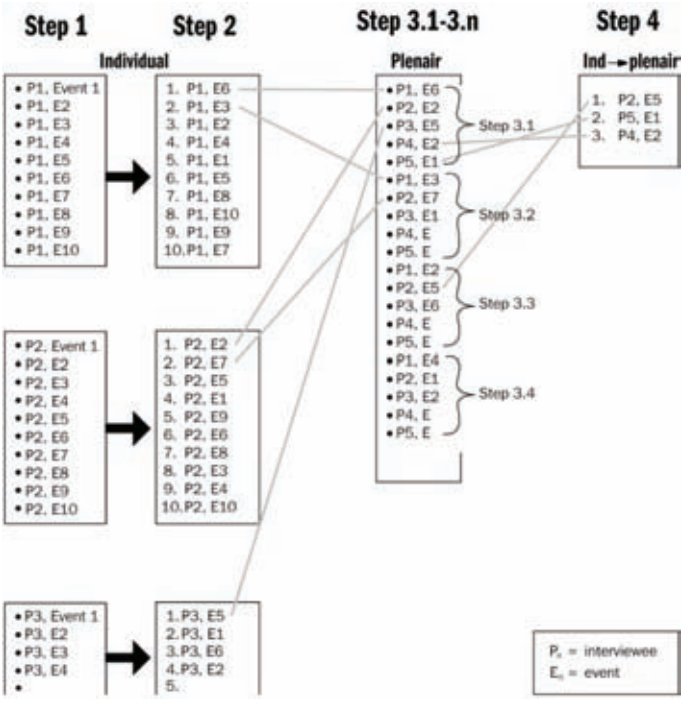


Figure 4.2 *Schematic and theoretical representation of group interview protocol.*

From a focus group interview method I know that by putting something in writing people take a position and commit themselves to that position (Saxton et al. 1980). On a personal level this implies that the interviewee must be able to articulate the motivation behind that position, or in our case, the importance of that specific recurring event. From each interview I would get a list of recurring issues that are more or less structural in the eyes of each group of interviewees. This method prevents (recurring) personal conflicts surfacing as obstructing events, because other interviewees from the same group would not rate these as important. The data collection procedure was similar for all three companies.

During the interviews they were not asked to name only those problems that particularly had to do with other parties outside the NPD project or with interactions across the project interface. The interviewees were just asked to name the recurring events that somehow obstructed the product innovation process. There was no restriction on the parties that were involved in those events. This general approach was chosen because of the fact that problems that occurred within the teams could very well be symptoms that are associated with interactions with outside parties. The identification of the possible involvement of peripheral parties was done after the interviews by the researcher and two other independent researchers. Although we were able to identify these interface incidents, it was not possible to distinguish unambiguously the specific party or function on the other side of the interface that could be jointly responsible for the recurring situation. At this stage of the research this was not regarded as problematic since the categories that emerged only serve as stepping-stones for the research activities of the next stage.

The research procedure was similar for all three cases, but there was some variation in the parties that were interviewed. At the first company we only interviewed participants from NPD pro-

jects. In the second case the European management team was also interviewed and in the third case, apart from the NPD team, most of the parties from operational processes were interviewed. This provided a wide perspective on the interface of NPD with other processes.

4.3 Obstructing issues from the three case studies

In this section the obstructing issues that were identified within the three companies are presented.

First company: R&D Telecom

The first case study concerned the centralized research department of a telecom company. Within this department seven multidisciplinary teams (N=29) have been interviewed. Typical disciplines within the teams were Electronics, Physics, IT and Mechanical Engineering. The research department normally gets orders from the business units that run the daily operations. These business units play the role of an internal client for NPD. They order the development project, use it, and pay for it. Apart from these NPD projects there is also funding by the strategic echelon of the company. For every experience it was determined after the interview whether the event concerned a situation with internal parties of the NPD project or a situation that also involved the interference of parties outside the project, that is an interface situation. From the 18 issues (the top three of 6 interviews) 7 obstructing issues were associated with interface interactions. Table 4.1 shows these 7 recurring issues.

Obstructing issues
Wrong type of project, too operational
Internal client interferes with NPD process
Internal client [within operations] doesn't know what he/she wants
No clear time target
No or vague project goals [internal client = Business Unit]
Late changes of target [internal client = Business Unit]
Internal client is not interested in results

Table 4.1 *Case 1: obstructing issues named by the interviewees. When relevant the client to the NPD project is mentioned.*

Second company: R&D adhesives

The European branch of a large and global American business-to-business company was the subject of the second exploratory case study. The centralized Europe staff organization with marketing and part of the European R&D is located in the Netherlands. They also have several production locations with small R&D units spread over Europe. This study was conducted throughout the various locations in Europe. Three development teams and the European management team were interviewed with a total of 21 people. NPD teams had participants that came from different departments, like R&D, production or sales. The management team consisted of the department heads of R&D, Purchasing, Production, Sales and the General Director. The interview process conformed to the above mentioned protocol. Table 4.2 shows issues that were expressed and rated as important by the three development teams and the management team. The selection of interface issues and the omission of similar issues brought the total of 12 recurring and obstructing issues back to 6.

Obstructing issues
No clear objectives or definition of project
No possibility to get rapid customer feedback
R&D trials have no priority in production plants
Poor knowledge of market
Trial & error while product on the market
Bad cost benefit, cost of product too high

Table 4.2 *Case 2: obstructing issues named by the interviewees.*

Third company: NPD escalators

The third case study concerned the NPD process of a medium sized business-to-business company that develops and produces escalators. A total of 15 people were interviewed, 6 of them work in the NPD department. On the operational side of the interface the departments of Purchasing, Production, Marketing and Services were interviewed. There were no representatives from the management of the company. Table 4.3 shows the data.

Obstructing issues
Other departments are inflexible
Too many changed introduction or ramp-up dates
Poor information sharing with operational departments
Unrealistic planning and inadequate control
Designs are too complex
Not enough testing before market introduction
NPD is too late because of unrealistic planning
Specifications are too late
Unclear list of parts and components
Involvement of production occurs too late
No or poor coordination between NPD and other departments
Involvement of operations is too late
Market introduction took place with unfinished products

Table 4.3 *Case 3: obstructing issues named by the interviewees.*

Because of time constraints of the interviewees it was not possible to make large and mixed groups, so apart from the NPD team the groups had 2 to 3 people. The same was true for the interviews of the heads of Marketing and NPD and therefore, this third case resulted in more recurring events without too many duplicates (see appendix I).

In the next section the 26 obstructing issues from the three cases studies will be used as a basis for the inductive processes.

4.4 First inductive step: Preliminary category development

This section shows the development of early categories based on the issues that were mentioned by the interviewees in the three case studies. After that we will discuss these preliminary categories hoping to identify similarities among them.

I will make a first inductive step by comparing the incidents that were reported by the interviewees. This results in more abstract groups that somehow have similar elements and form early, but provisional, categories. In some instances, an incident could be placed in more than one category. For example, the incident 'internal client is not interested in results' could be a consequence of poor communication between NPD and the business unit or might be due to the poor definition of NPD targets. It might even be that the outcome of NPD simply doesn't adapt well to the operational process that will bring these products to the market. According to Glaser & Strauss (1967) this is often the case. Later in the process it is possible that categories may merge into one core category which is on a higher level of abstraction and most incidents under the separate categories will become united under that category.

It is important to note that these preliminary categories are based on data that is not accompanied by rich contextual information. This implies that we must regard these categories as potential categories and use them to stimulate creativity during the analysis of the data in the focusing stage. The inductive crystallization process is an iterative and comparative process until the categories that emerge account for the incidents found in the empirical data.

Table 4.4 shows the first induction step for a group of obstructing issues that had some similarity. In the first incident it seemed that there was some sort of interference or intentional obstruction by one party to a process belonging to the other party. This interference disturbed, would disturb or even planned to disturb the ongoing processes on the other side of the interface. The incident 'no possibility to get rapid customer feedback' fits this description because, in this case, it was not possible for NPD to get feedback from the market through the sales department. The sales department had contacts with customers but was reluctant to ask the customers for feedback. In other words they would not adapt their ongoing processes. Another type of incidents, 'R&D trials have no priority in production plants', is related to the situation where the plants prefer to concentrate on their day-to-day production processes instead of creating the possibility for NPD to carry out test runs with the new products which would interrupt the ongoing process.

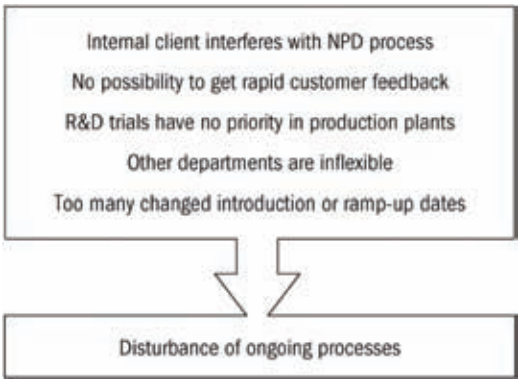


Table 4.4 *Induction step leading to a category about disturbance.*

The last incident is related to the problematic situation that becomes apparent if the planned introduction or ramp-up date is changed at the last moment which disturbs the preramp-up processes on the operational side. This preliminary category has been named 'Disturbance of ongoing processes'. That one process is disturbing another process means that in some respect the interactions between them are not very well planned, are uncoordinated or are even unexpected.

Another grouping that I was able to discern is shown in Table 4.5. All these six issues were somehow connected to flawed communication. The situation where the internal client is not interested in the results of NPD might be the result of poor communication between the explorative and exploitative processes. Also, when NPD observes that they do not have enough knowledge of the market this could imply that there is not enough information shared between NPD, Sales and the customer. When people from operational processes like Manufacturing and Purchasing say that the specifications of the new product are supplied too late, they could mean that it would have been better from their point of view to share available information earlier in the process. This resembles the difficulties about the exchange of partial and incomplete information as was have found in the literature and described in Chapter 2.

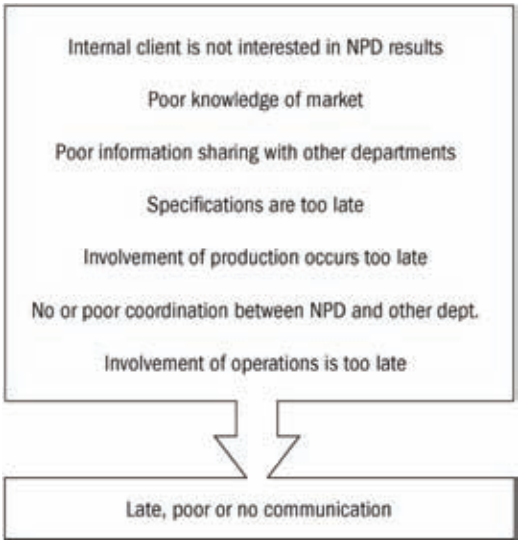


Table 4.5 *Induction step leading to a category about flawed communication.*

For all these incidents there was either no, late, or insufficient communication from the point of view of the interviewees who mentioned these issues as having an important negative influence on their work.

Then there seems to be a category about the definition of the project goal (Table 4.6). This category is related to the incidents that describe situations where there are either no targets, continuously changing targets or unclear targets.

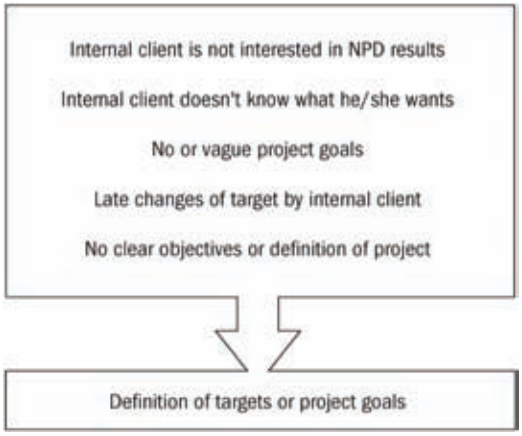


Table 4.6 *Induction step leading to a category on the definition of targets*

Somehow related to the targets category is a category that covers incidents that are connected to difficulties around planning and controlling time schedules (Table 4.7). Meeting time schedules by introducing products that are not completely finished or are not tested enough seems to cause all kinds of obstructive incidents. However, keeping the time schedule by controlling the NPD process is difficult and also causes problems. The timing of the transition from NPD to operations seems to be a recurring stumbling block.

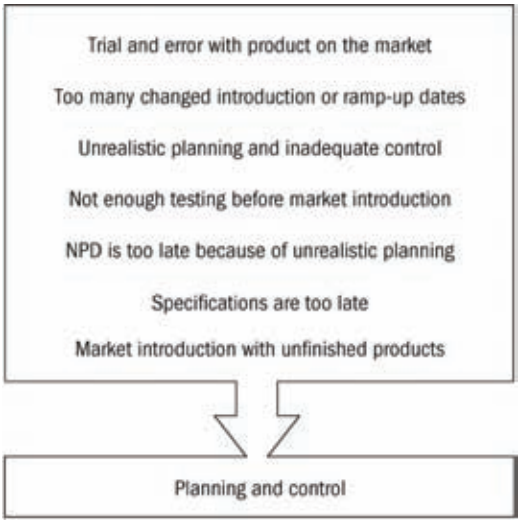


Table 4.7 *Induction step leading to a category on Planning & control*

The next category (Table 4.8) that was identified is related to recurring incidents concerning the deliverables of NPD in terms of the parts and components list, the complexity of the new product or the lack of interest regarding the results of NPD. Somehow NPD is not providing an applicable outcome that will secure a smooth transition to the next operational process.

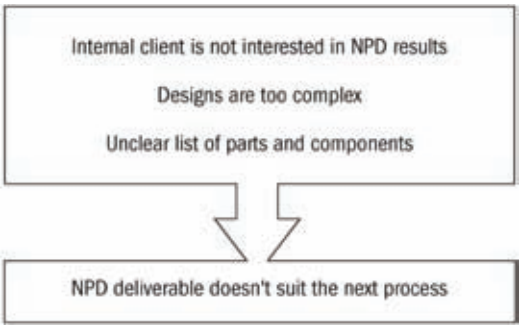


Table 4.8 *Induction step leading to a category about the NPD output*

Finally, there was a group that seems to be too dissimilar to fit within one group in this induction step (see Table 4.9). I tried to make an inductive step but was not able to discover any resemblances among these new more abstract formulations. This resulted in a small group of 'others'.

Obstructing event
Wrong type of project, too operational
Bad cost benefit, cost of product too high

Table 4.9 *Two obstructing issues that were not categorized.*

Thus, in this section we have identified five preliminary categories and one group of 'others' derived from 26 obstructing issues. In the next section we will discuss these early categories while making a second step of induction.

4.5 Second inductive step

Until now we have inductively discovered the following five tentative categories:

Disturbance of ongoing processes
Late, poor or no communication
Definition of targets or project goals
Planning & control
NPD deliverable doesn't suit the next process

Table 4.10 *The five early categories from the first inductive step.*

In this section these tentative categories will be further elaborated as a second inductive step. The aim is to develop a better feeling of what is of importance regarding interactions in this field. First part of the elaboration is to find common ground among the tentative categories that we have so far (4.5.1). The second part (4.5.2) reports on a little 'excursion' through the literature inspired by that common ground among the categories. The last part brings the literature and the tentative categories together again (4.5.3).

4.5.1 Common ground among the preliminary categories

In the following I will formulate stimulating questions related to these categories as the first part of the second inductive step. The purpose of these questions is to identify some similarities among the categories and to create a more elaborate image of the category.

Category (a) *Disturbance of ongoing processes*: Why is it that the interactions which are initiated by people in one process are so disturbing to the people from the other process? And this is in spite of the fact that they know that they must cooperate and interactions will inevitably take place? The fact that the interviewees labeled these events as recurring raises the question, why is it annoying over and over again? Are these interactions unexpected and hard to predict? Or, are they expected but still cause problems? In Chapter 2 the involvement of team members with the NPD process was discussed. From this I understood that some people are involved in the NPD process permanently and others only for specific tasks like R&D trials or getting customer feedback. Are these specific tasks so different from the prevailing daily flow of activity that the outside requests disturbs their normal work too much? Or is it difficult to switch from one task to another? How different are these tasks anyway?

Category (b) *Late, poor or no communication*: Why is it that late, no or poor communication occurs between NPD and the operational processes? What could be the reason for postponing communication? Or even, is there a reason to not communicate? Again, both parties are aware of the fact that at some point in time they must exchange information during the development process. How is this related to the behavioral difficulties inherent in the release of partial or incomplete information that academic researchers have observed and that was discussed in Chapter 2? Is it that the senders don't send properly or the receivers don't receive properly? Could awareness of being a disturbing factor in the receiving process be a reason to postpone discussions or even to avoid them?

Category (c) *Definition of targets or project goals*: Predicting the future is difficult if not impossible. However, setting a target in clear enough terms and at the right level of detail that it remains unchanged over the length of the product innovation process must be possible. Why can't this be done? Or is it that there is a target, but the other party wants it to be more concrete or at a more detailed level? In other words, do people from different processes need different levels of detail regarding the NPD target? As was described in Chapter 2, the NPD process is made up of successive problem solving cycles. This means that the solutions to those problems arrive during the development process. Every solution to a problem increases the level of concreteness of the final product. Is this freedom to develop solutions for upcoming problems during the NPD process at odds with the goals or targets that were already agreed to?

Category (d) *Planning and control*: As stated above, the NPD process needs to find solutions for problems that were unknown at the beginning of the project. This implies that the NPD process is unpredictable to a certain extent. One is not always sure about the exact date that all development and test work will be finished. Could it be that NPD is asked or forced to give a date by outside parties and that in doing so they might be too optimistic? Or is it that people within the explorative NPD process have a different attitude towards time and planning than people in the operational exploitative processes?

Category (e) *NPD deliverable doesn't suit the next process*: Why is that the people on the NPD side have trouble coming up with something that is 'fits' within the other process? The intention is probably not to deliver an unclear list if parts or a product that is too complex. No, these are not

deliberate outcomes of the NPD process. What is missing in the knowledge of each party to perceive what level of detail is needed to make it dovetail with the other process? What makes products too complex in the eyes of operational processes? Moenaert et al. (2000) speak about 'codification' as the process of making knowledge and experience explicit and accessible to others. From the perspective of the receiving party, how is the product complexity related to this notion of codification?

In Chapter 1 it was mentioned that the NPD-Manufacturing interface has a dual nature, the transitional nature form exploration to exploitation and the cross-process nature preceding the transition. Regarding both interface situations the inherent differences in nature between explorative and exploitative processes could be an important factor that influences the interactions between the two processes. Of course, Chapter 1 started with the observation that NPD and Manufacturing belong to two different strategies that require two different organizational arrangements. But from the questions posed above, these differences could be a core element regarding the framework that I am looking for.

According to Glaser & Strauss (1967) these intuitive leaps are important to follow up as they are part of the creative challenge of the grounded theory approach. At the same time, I realize that other people might have other ideas possibly leading to different bodies of literature and other research directions. It must be realized that, at this stage of the research, the apparent ambiguity between different interpretations is not causing any harm to the scientific quality of the research process. What is important to the scientific quality is the 'groundedness' of the integrated categories that will be developed later in the research process.

The next section will continue with the second part of this inductive step by reviewing literature that describes the different characteristics of the explorative and exploitative processes.

4.5.2 Literature differentiating between exploration and exploitation

Division of labor is the consequence of the insight that the efficiency and effectiveness of different tasks increases if people are specially trained in performing that particular task. The result is dedicated task forces that are usually organized in departments or even within departments around specific tasks. One will find specialized departments in most companies. But what are the essential differences that influence the efficiency and effectiveness of the two processes that we are concerned with? The process of producing several hundred similar products per day like cars, television sets or personal computers is very different from the process of creating a new and innovative product. Therefore, it is not surprising that according to Galbraith (1982) the processes of innovation (exploration) and operation (exploitation) use fundamentally opposing logics. They require two separate organizations that are specifically designed for these two purposes.

It must be noted that I should be aware that within exploitative processes minor and micro explorative processes occur and vice versa. To do justice to the essential character of the respective processes I deliberately choose to describe the pure forms of exploration and exploitation.

Perrow (1967) has developed a framework for the comparative analysis of organizations. He conceptualizes complex organizations in terms of their technologies, or the work done to a raw material. By technology Perrow means (1967, p195) 'the actions that an individual performs upon an object, with or without the aid of tools or mechanical devices, in order to make some change in

that object.' The object, or 'raw material', may be a living being, human or otherwise, a symbol or an inanimate object. He differentiates between routine and non-routine technologies by making use of the following criteria: the incidence of exceptional cases and the incidence of analyzable problems. In other words, the technology is non-routine when there are a large number of exceptions and solution search procedures are not logical or analytic. Routine corresponds with few exceptions and analyzable search procedures which result in solutions that are easy to implement and cause little or no disturbance within the routine processes. In Perrow's view, the routine organization is likely to be mainly concerned with stability and high profits achieved through the quantity of production and avoidance of innovation. In contrast, the non-routine organization will emphasize growth, quality and innovation, and will be less concerned with making profits. In this perspective the technology of the explorative NPD process is more likely to be non-routine and the technology of the operational exploitative processes will be routine.

Hage & Aiken (1969) studied the hypotheses of Perrow in people processing organizations like health and welfare organizations. They found similar results and added some elements to the differences between routine and non-routine organizations. They found that routine work is positively associated with an emphasis on efficiency as a system goal, which makes a clear reference to the predominant emphasis on efficiency within operations. They also found that routine work is not concerned with the development of new programs as a system goal, which is attributed to the mechanistic need to continue the present exploitative processes. They also found that the social structure of organizations with more routine work is found to be more centralized, more formalized and to have less professionally trained staffs.

We saw earlier that NPD and Manufacturing are sequentially dependent, i.e. Manufacturing can not start producing the new product before the design is finished. At a lower level of detail the explorative NPD processes themselves are reciprocally dependent (Thompson 1967) since changes to one element of the new product during development will influence the other elements. This is not the case with the exploitative operational processes. The output of one worker serves as input for the next worker. People within these exploitative processes are used to working with these sequential dependencies and have the tendency to wait until the work of others is complete before coming into action. Of course, there are of course parallel actions within the operational processes, but there is no need to coordinate these actions in terms of content, because the deliverable of each parallel action is clearly defined beforehand. Also, the duration and sequence of these exploitative actions will be predefined and result in what Van der Goot & Malotaux (in In 't Veld 1978) describe as the 'steady state' of the company. This steady state is formed by what they call 'piling' processes. Piling processes are, for instance, the recurring processes of an assembly line that remain steady and predictable as long as there are no unexpected outcomes. This is different from what they call 'growth' processes, processes that have an iterative character throughout the whole process where choices among alternatives have to be made at every step. Every choice brings about a new set of alternatives demanding a new choice. All these choices result in growth towards the final output of the development process, the new product. In NPD retracing earlier steps is sometimes necessary, while, on the other hand, iteration within operations is undesirable.

These fundamental differences in processes must influence the abilities of the participants. These could be qualities that are furnished by education and training but could also be inherent characteristics of the respective personalities. I said earlier that in multidisciplinary product development, the participants are usually trained engineers from different fields. From engineers we know that they are trained to be problem solvers, to analyze problematic and complex situations and

find possible new ways to resolve that situation. They feel challenged to provide new and creative solutions and this characteristic resembles the cognitive style of 'innovators' as identified by Kirton (1976). Innovators represent one extreme of a continuum. The cognitive style of 'adaptors' typifies the other extreme. According to his theory, adaptors tend to solve problems within a given boundary. In our case, this conforms to the attitude that is necessary to maintain a steady state within the operational processes, i.e. trouble shooting or problem solving within the existing framework of operations. Adaptors confronted with problems don't see them as stimuli to consider changing the framework. They will look for solutions within the framework in ways that are tried and safe. Innovators on the other hand, query the situation and its assumptions, which are necessary qualities for the NPD environment. NPD is about developing something new and 'questioning the old' and innovators will react differently to the same stimuli. They will almost automatically step out of the existing framework, most of the time without even realizing it, and develop solutions that will cause 'changes with outcomes that cannot be envisaged so precisely' (Kirton, 1980-a). Thus, one could say that for efficient exploitation of the present operations a more adaptive attitude is desirable and to be effective in the NPD processes a more innovative attitude is desirable. Kirton (1980-b) finds sufficient evidence that people who work within a particularly stable environment will incline more towards being an adaptor and people in a more turbulent environment will tend towards being the innovator. Each of these two types will feel more at home within the setting that most resembles his/her cognitive style.

The last element that will be discussed regarding this distinction between adaptors and innovators is their respective perceptions of each other. Adaptors see innovators as being undisciplined, abrasive and insensitive to other people's feelings. The innovator does not seem to be aware of the havoc they cause by bringing their rule-breaking ideas forward. Innovators see adaptors as stuffy, wedded to (the rules of) the system and too restrictive. Innovators are also less aware of the accomplishments of adaptors in terms of the smoothly running (operational) system (Kirton, 1984).

As already mentioned, for effective and efficient processes there need to be two different organizations: an innovating and operating organization. Perrow (1967) found the work of Burns & Stalker (1961) to be relevant in this respect. Burns & Stalker make a distinction between two different management practices: an 'organic' and a 'mechanistic'. The work of Burns & Stalker is in fact one of the first attempts to make a distinction between exploration and exploitation. Perrow indicates that the organic structure of Burns & Stalker is close to his non-routine technology and the mechanistic structure is close to the routine technology. Burns & Stalker were one of the first researchers to make a distinction between two different management practices belonging to these dissimilar organizations. They concentrated on whole organizations but what they say applies equally well to parts of an organization. Application of their distinction to the NPD process would make the management system of NPD more organic and the management system of the operational processes more mechanistic. In their research Burns & Stalker (1961) state that both forms are "explicitly and deliberately created and maintained to exploit the human resources of a concern in the most efficient manner feasible in the circumstances of the concern" (1961, p119). In our case this efficient exploitation of human resources exists within each of the two processes, i.e. NPD process and operations. However, in order to achieve this each of the two processes needs a different management system. Some of the characteristics of the differences between mechanistic and organic management systems are shown in Table 4.11.

Mechanistic management system
The specialized differentiation of functional tasks; tasks facing the concern as a whole are broken down
The precise definition of rights and obligations and technical methods attached to each functional role
Hierarchic structure of control, authority and communication
Reinforcement of the hierarchic structure by location of knowledge of actualities exclusively at the top
Tendency of interaction between members of the concern to be vertical
Organic management system
The contributive nature of special knowledge and experience to the common task of the concern
The shedding of 'responsibility' as a limited field of rights, obligations and methods
Network structure of control, authority and communication
Omniscience no longer imputed to the head of the concern
Lateral rather than vertical direction of communication

Table 4.11 *Some differences between mechanistic and organic management systems (Burns & Stalker, 1961).*

Thus, the management system could be more or less tuned to the actual process at hand. Innovative and developing behavior does not fit comfortably in a mechanistic management system. This will cause delays because of the fact that developers must get clearance for every move they make, which brings about frustration and further delays. They could still be effective, but not very efficient. The same is true for the processes within operations if they are managed in an organic way. They might be in some respect effective, but far from efficient regarding the task at hand. Of course, there might be little 'growth' processes (In 't Veld, 1978) within the 'piling' processes as well as the other way around. But these deviating processes will be in the minority and do not affect the overall character of the process itself.

4.5.3 Connecting literature and empirical data

Table 4.12 summarizes the differences between NPD and operational processes that have been found in the literature. However, the literature doesn't describe the interactions between the explorative and exploitative processes. They only focus on the differences rather than on the interactions.

Author	Operational processes tend to be more	NPD-processes tend to be more
Burns & Stalker (1961)	Depending on vertical interaction No initiative, wait for instructions	Depending on lateral communication Content of communication more advice rather than instructions
Perrow (1967)	Routine, non-flexible Few exceptions Avoidance of innovation Quantity and profits	Non-routine, flexible Exceptions accepted Emphasis on innovation Less attention on profit
Thompson (1967)	Sequentially dependent: wait until work is done by others	Reciprocally dependent: Sharing information because of dependency
Hage & Aiken (1969) (build on the work of Perrow)	System goal: Efficiency No initiative for new programs Tendency of continuation of old programs (processes)	
Kirton (1976)	Adaptive behavior Problem solving within boundaries Respecting 'what is'	Innovative behavior Problem identification Query the existing situation
Van der Goot & Malotaux (1978) In't Veld (1978)	Duration and sequence of steps are predefined Steady state, no iteration	Iterative character Choices among alternatives

Table 4.12 *Summary of differences between exploitative processes and NPD processes*

Next I will hypothize about these differences and discuss some of the obstructing incidents in this new light. Based on these differences a rational reconstruction can be made of what possibly lies behind the incidents. (Appendix II provides an overview of all reported incidents). Let us consider the planning and the objectives of a NPD project as one of the issues. The various parties within operations (production planning, manufacturing, sales & marketing, etc.) are interested in knowing what will be implemented within their processes and when that will take effect. They need to plan and prepare the operational processes for the implementation of the new product. Somehow they need a date and an output from the NPD process that is clear enough and fixed. For planning the adjustments to the mechanistically organized and tuned routine technologies within Operations this is necessary. On the 'organic' side, the people within the NPD process are very reluctant to commit themselves to such hard agreements. They need room for creativity to flow and ideas to emerge and don't know beforehand what the final product will be. From experience, the developers know that there will always be unplanned iterations that threaten the planned delivery date as well as the original conception of the new product. Within the 'organic' system things have to grow towards a final unknown state or output. Yet within Operations, the output is known to the last detail. So, from the differences as indicated by Burns & Stalker and Perrow one could expect that there will be problems with setting the targets as well as planning and controlling the schedule of the development process. The incidents that were recorded and grouped under the category '*definition of targets or project goals'* like 'late changes to target', and the incidents under *'Planning and Control'* like 'unrealistic planning and inadequate control' might be explained by these inherent differences. However, it doesn't provide a sufficient explanation of the incidents on the level of interactions between these two processes.

The attitude of participants from the routine processes towards continuation of the present operations and 'steady state' could cause conflicts with people from the non-routine processes if the work of NPD results in (unexpected) changes and disturbances within these operations. People on the exploitative side will try to maintain this steady state as long as possible and try to diminish

the amount of disturbances or concentrate them all in one clear time slot. The people on the explorative side might want to postpone planned tests or introduction dates because they feel that the new product is not ready yet. This disrupts the careful planning within the exploitative processes. The reactions to such changes on the operational side could be that they give the day-to-day production a higher priority or that they are not willing to be flexible in setting another date. Symptoms of these conflicts could be incidents like 'R&D trials have no priority in production plants', or 'other departments are inflexible'. In such cases, people from NPD will complain that Operations is unwillingly to cooperate during the NPD process or participate in the NPD process. The counter view is that the more innovative people from NPD have the tendency to avoid adaptors; adopters bring too many boundaries conditions with them. They might have the opinion that it is the responsibility of Operations to get involved with the NPD projects so will not invite them to 'disturb' their creative processes. One could call this a 'if they come it's OK with us' attitude. This interpretation leads to incidents that have been placed under the tentative category *'Late, poor, or no communication'*.

At the same time, innovators have the tendency to keep on improving the object of development. They tend to forget what ground they have already covered in terms of novelty. It is difficult for innovators to assess the innovativeness of their solutions, to them these are just simple solutions to the design problem. This implies that these 'simple' solutions can surprise the people from Operations who see the new product for the first time and complain that the 'designs are too complex'. These and other incidents that have been placed in the category *'NPD deliverable doesn't suit the next process'* might be understood by this kind of innovative behavior of the NPD people. Underestimating this novelty aspect will have some affect on how the NPD output fits into the operational processes.

The last range of symptoms addressed here is the issue of development projects that have been transferred to operations while the development work wasn't quite finished. These kinds of incidents might occur if NPD is late while Operations enforces the introduction date of the new product onto the market. This could bring about a range of incidents like 'not enough testing before market introduction', but also 'trial and error with product on the market'. Such a situation could also result in 'fire-fighting' and possible delays which in turn will dramatically disturb the intention of Operations to achieve a fast and smooth ramp-up.

4.6 Wrapping up scanning stage

In this stage I have created some empirical awareness by interviewing people that are, because of their work, related to the interface between explorative NPD and exploitative operations. At the same time some early categories have been identified.

During a first inductive step I identified five tentative categories that in a second step led to the sixth category on **inherent differences** between explorative and exploitative processes (Table 4.13). From the literature review in the second inductive step I have learned that the inherent differences help in some way to better understand what lies behind most of the incidents that have been empirically collected. This gives the impression that these differences might have a large influence on the quality of the interactions between NPD and Operations. However the existing literature mainly focuses on the differences and not on the interactions. For the focusing stage I need to zoom in on the interactions between NPD and Manufacturing and go from recurring events

to specific incidents related to projects; incidents that might help to understand what is really going on between NPD and Manufacturing.

Disturbance of ongoing processes
Late, poor or no communication
Definition of targets or project goals
Planning & control
NPD deliverable doesn't suit the next process
Inherent differences between exploration and exploitation

Table 4.13 *The six tentative categories that will be taken to the focusing stage.*

Although the differences between the two processes and the resulting differences between the characteristics of the participants seems to act as an umbrella over the five tentative categories all six categories will be taken to the next research stage.

5 *The focusing stage: Searching pillars for the core category*

This chapter describes the focusing stage of theoretical sampling within this explorative study. The aim of this chapter is to identify some answers to the two sub-research questions. First I will present the research setup (5.1) of this stage that states the three aims of this stage and the methodological context, the requirements for the empirical investigations, and the projects and companies that were identified based on those requirements. This is followed by a description of the data collection process and procedures (5.2) and a description of the data processing that was carried out (5.3). The results of the data processing are then given in Section 5.4 on a general level by some numbers and percentages, and on a detailed level by describing the significance of specific data incidents and illustrating these by means of data segments. This chapter ends by comparing the initial aims and results of this focusing stage and reflecting on the methodological processes (5.5).

5.1 Focusing stage research setup

In this section the setup of this stage of data sampling is described by first looking at the methodological context of this stage together with the research aims. This is followed by the requirements for collecting data which informed the choice of the companies and projects that would provide useful data. This section ends with the description of the companies and the projects that were chosen.

5.1.1 Methodological context of focusing stage

In Chapter 4 the NPD-Manufacturing environment was explored and we have seen that the differences in character between the explorative NPD processes and exploitative Manufacturing processes may influence the interface interactions. In addition, based on the recurring experiences of the 65 people that were interviewed in the scanning stage, I have identified some tentative categories that might play a role in the interface interactions. The fact that the interviewees mentioned recurring obstructive events was adequate for the first stage since it gave the opportunity to develop some sensitivity for categories that are related to problematic interactions between NPD and the operational part of the organization. It was concluded at the end of that scanning stage that it was necessary to focus on the actual NPD-Manufacturing interface for the second stage of theoretical sampling and that I needed to collect detailed interface interaction data which is related to specific product innovation projects. Recording what has occurred during the development process of a product innovation project might help to create this richer context. With the richer context it might be possible to identify some answers to the two sub research questions that were formulated in Chapter 3.

1. *What fledgling categories with what properties make a description of the interactions between NPD and Manufacturing possible?*

2. *How are the categories and properties related?*

In order to answer these questions the data from this focusing stage will be used in three ways:
- To identify new and potentially important additional categories
- To empirically validate and upgrade the tentative categories from earlier chapters
- To identify properties of, and relationships between, the categories

The second intention refers to the fact that the tentative categories that have already been identified were either derived from existing literature or emerged from the first stage of data sampling which had a wider perspective than the NPD-Manufacturing interface. Therefore, it is sensible to substantiate empirically whether these categories are relevant in the NPD-Manufacturing interface.

I would like to end this second stage with some provisional answers to the first sub-research question, that is, the fledgling categories and their properties. Although Glaser doesn't really mention criteria for the selection of fledgling categories, I have the idea that the following two requirements should be applied: (1) they must be related to relevant issues for the actors involved. (2) Fledgling categories must have a considerable number of relationships with other names and categories.

The first requirement is connected to the fact that the aim is to identify of patterns of relevant behavior between NPD and Manufacturing. The second is derived from the desire to not only describe this social process but also the variations of that process. And this is made possible by identifying the properties of, and relationships among, the categories. At the end of this chapter I will return to these criteria. Acquiring an intuitive feeling of the relationships among these fledgling categories would even prepare the ground for the following integrating stage in which I plan to combine these categories by means of their relationships into a core category. This will then answer the main research question.

The ideas for this focusing stage are still in accordance with the plan for this stage as was described in Chapter 3 - an increased focus on the interface between NPD and Manufacturing aimed at identifying in an inductive manner additional tentative categories and hopefully one or two fledgling categories (see Figure 5.1).

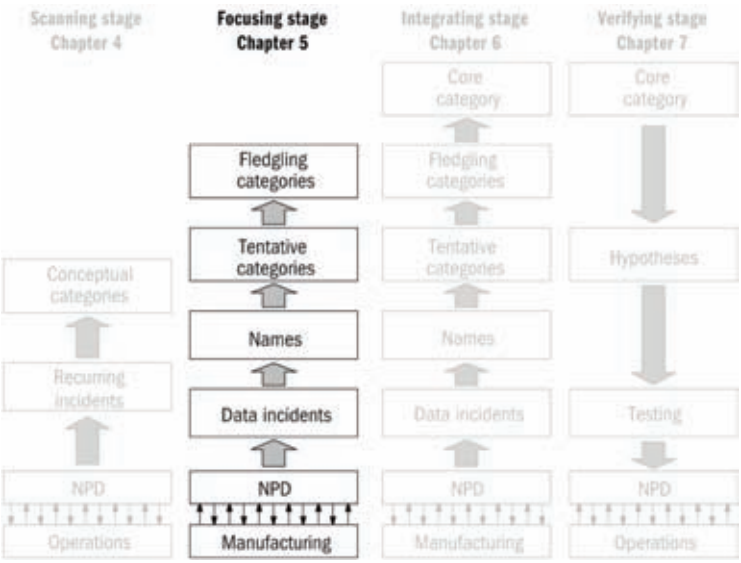


Figure 5.1 *Overview of the research stages (equivalent to Figure 3.4)*

In order to collect richer data I have decided to interview individual people that have been involved in recent product innovation projects who work on both sides of the interface. The decision to use interviews and therefore to undertake a retrospective analysis of the projects was taken because of practical reasons. Real-time longitudinal studies would simply take too long. A drawback of doing ex-post interviews is that the interviewees have to base their project stories on their memory. Therefore it was decided to look for projects that have been through the ramp-up phase no longer than a year ago.

The interviews will be used for the naming process as a first inductive step. The names themselves can be seen as the gateway to additional induction leading to tentative categories and fledgling categories. Since I already have some tentative categories and I want to verify their value, these categories will be treated more or less like names.

Because this is only the second stage in a longer exploration, tons of data aren't needed. I need data of good quality that offers enough possibilities to prepare for the integrating stage. This means that I need just enough data to reach a certain level of saturation during the analysis. The sampling in this stage begins with two companies, two projects per company and at least 2 interviews per project, i.e. one representative on each side of the interface. After the interviews the level of saturation during the naming process will be assessed by looking at the augmentation of names over the course of the interviews. If there is a clear decrease of additional names from the later interviews we could say that a satisfactory level of saturation has been reached. If such saturation isn't reached it will be necessary to add a third company with another two product innovation projects. In the next section I will discuss the required characteristics of companies and projects that will make it possible to collect data of good quality.

5.1.2 Requirements of companies and projects

It is obvious that the companies that I am looking for need to have an internal NPD-Manufacturing interface, meaning they must contain NPD processes as well as Manufacturing processes. The implication of this is that I am looking for so-called **OEM companies**, Original Equipment Manufacturers. Because the research environment of this project is the faculty of Industrial Design Engineering at Delft University of Technology we decided to concentrate on products that contain a reasonable amount of advanced technology or intelligence and are produced in series such as household appliances, consumer electronics or office equipment.

Many scholars in this area of research focus on in large global companies with an enormous variety of products. I would like to aim at a smaller type of company with a limited selection of products. Therefore I will look at **mid sized European companies** that have between 500 and 5000 employees.

To acquire data of the right quality, these companies need to be experienced in NPD and Manufacturing, meaning that they must be **specialists in their field**. Otherwise we run the risk of collecting data that contains all kinds of beginner's mistakes.

I have also chosen companies with more or less **comparable products** in terms of product size, product technology, production technology, relative quality level, and production numbers. Totally different products and production numbers would add extra dimensions to this already complicated interface situation which could blur our data too much.

In each company I will concentrate on **two product innovation projects** in order to avoid collecting data from an exceptional project within that company. I realize that two equal projects within one company might result in more of the same. But what kind of variation between the two projects would provide some range of interest? The overall aim of this study is finding out what occurs during the interactions between NPD and Manufacturing from concept to volume production. So maybe the quality of the transition of the newly developed product from NPD to Manufacturing would provide some variation. It was decided to try this by choosing a project with a **smooth transition** from NPD and Manufacturing and another with a more **troublesome transition**. The project with a more troublesome transition is expected to have been through more iterations like design changes or process changes during the final stages than the project with smooth transition. Looking at two projects with this variation might result in a richer perspective on the interface inter-

actions. Contacts within each companies were asked to identify two projects that would fulfill these requisites.

The following list provides an overview of the requirements that were applied to select the projects for investigation.

- Two Europe based midsized OEM companies
- Among the specialists in their field
- Good reputation for quality products
- Comparable type products in terms of: product technology, series production
- Two recent projects per company: one project with a smooth transition to Manufacturing and one project with a more troublesome transition

5.1.3 The companies: Audiocom and Lightcom

Two companies were found, one that develops and produces high-end consumer electronics (TV, audio, etc.) while the other one develops and produces high-end lighting products (for discos, festivals, etc.). I will call these companies Audiocom and Lightcom respectively. The products of the two companies are more or less similar in product size, product technology, production methods and final assembly as will become clear in the next section. The differences are related to the complexity of the moving parts of the lighting products that are absent in the television sets and the electronic complexity of the television sets which is less complex in the lighting products.

Audiocom has around 2400 employees and a turnover of approximately 500 million Euros, whereas Lightcom has some 1000 employees and 130 million Euros turnover. Both companies have a worldwide market presence, meaning that they are specialists in their fields and the competitiveness of their processes must be at a world-class level. So we are looking at companies that are established and have well run NPD and Manufacturing processes.

I was fortunate that another acceptable variation between the two companies simply fell into my lap. At Lightcom, the interface between NPD and Manufacturing also contains a geographical distance. The R&D department at Lightcom is about 180 kilometers from the main production facility where final assembly takes place. This is not the case for Audiocom, where R&D and the main production facilities including final assembly are located on the same premises. At Audiocom, the spatial aspect of the interface between NPD and Manufacturing is limited to different buildings. This variation makes the interface between NPD and Manufacturing at Lightcom a bit more explicit than at Audiocom.

5.1.4 The projects

In each company we were able to identify two recent product innovation projects that fitted our requirement of smooth and difficult transition from NPD to Manufacturing. In both cases the projects were identified in consultation with some employees from that company. This resulted in the following projects:

- Audiocom, high-end consumer electronics
  Audiocom.1 New television set with existing electronic chassis (older model)
  Audiocom.2 New television set with new electronics

- Lightcom, high-end lighting products
  Lightcom.1 New lighting product for clubs & discothèques
  Lightcom.2 New lighting product for music-festivals (outdoor concerts)

Each of the first projects, AI and LI, were considered to have had a smooth transition to Manufacturing by our contacts in the company. The other two projects, AII and LII, have been through a more troublesome transition. Figure 5.2 provides a schematic representation of these four products.

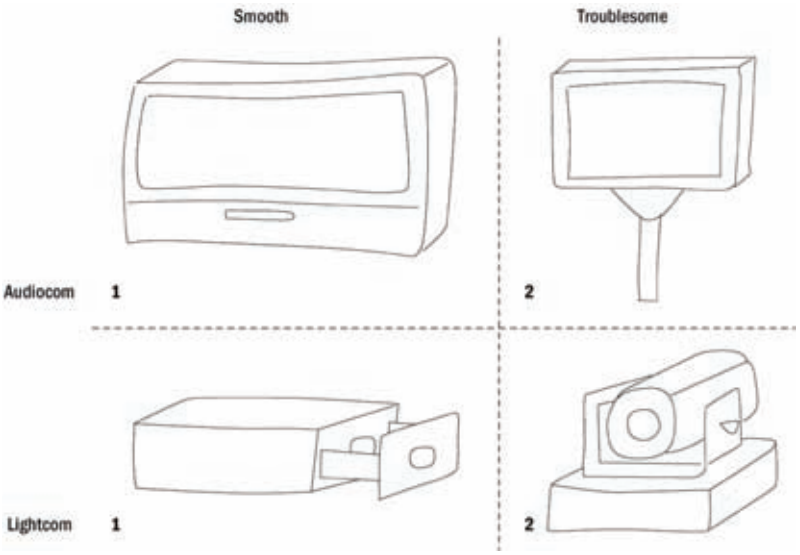


Figure 5.2 *Sketches of the four products that were discussed during the interviews.*

5.2 Data collecting process and procedure

In this section I will focus in on the process and procedures that were followed during the data collection. I will discuss successively the preparation of the interviews, the interviews themselves, the process of theoretical sampling, the projects that were discussed, and the distribution of the projects across the interviews.

5.2.1 Preparation of the interviews

To prepare for the interviews I used the experience gained from the first stage interviews as well as experience related to other product innovation projects (outside this research project). I also used information that was obtained from the literature on product innovation as discussed in Chapter 2. It is clear that a full structured interview approach with pre-established questions for all interviews is not in accordance with grounded theory. Fontana and Frey (2000) support this by saying that structured interviews aim at explaining behavior within existing categories or theoretical frameworks. However, at this point in this study, we have no firm categories, at most we have some tentative ideas for possible categories from the first stages of this research but we don't yet know what the interactions between NPD and Manufacturing are like. Therefore, the free-

dom is needed to adjust the interview protocol across all the interviews and during the interviews themselves.

The aim of the interviews is to understand what happened during the product innovation project in general, and the nature of cooperation among participants from both sides of the interface in particular. This implies that I need to get information about the product innovation process within the two companies and the process that was followed within the project. A list of possible subjects was created before the interviews started. There was no intention to just follow the list during the interviews, but the idea behind it was to help me to address the most important issues for discussion. In other words, the list was used as a reminder or guide during the interviews. Questions were prepared that touched upon the following subjects (see Appendix III for the full list):

- General issues regarding the interface between NPD and Manufacturing
- The specific setting of the project, team, target
- The product that has been developed
- The cooperation during the project
- The production and testing of the prototypes
- The development of the manufacturing process
- The transition to Manufacturing
- The pilot runs or zero series
- The planning of the project
- The fit within the existing production processes
- The ramp-up of the assembly lines
- Problems that occurred during the process

Most of the questions I will ask are related to understanding what has happened during the execution of the project and how the cooperation between NPD and Manufacturing had taken place. In the next section we will discuss the interviews.

5.2.2 The interviews

In each company we had face-to-face conversations with people who have been involved in the two product innovation projects and work on both sides of the NPD-Manufacturing interface. Each interview was taped and lasted for 1.5 hours on average and were held in English. The interviews started with a brief introduction of this research project. Then the interviewee was asked to describe his/her position and main occupation and their role within the product innovation process. From then on the interview mainly focused on the specific product innovation project the interviewee was involved in. They were asked to describe the project and what happened during the course of the project. I wanted to hear their direct experiences of the projects that they have participated in and their experiences regarding the interactions with participants on the other side of the interface. The project itself served as some kind of 'vehicle' for this discussion.

During the interviews I didn't call attention to the difference between the two projects within each company. Most interviewees were not aware of the choice for a product with smooth transition to Manufacturing and one with difficult transition. However, some interviewees participated in both projects within the company and were aware of this distinction. The interviewees also referred to other projects besides the two that were selected. This sort of happened by itself and I felt it was not necessary to cut them off. In most of these instances they referred to projects that were vari-

ants of the one that we were discussing. This seemed to happen more often in interviews on the NPD side of the interface.

The participants were also asked quite explicitly about the ramp-up phase and the problems that occurred during that period. Also the learning process of the assembly workers during the ramp-up was frequently an important part of the discussion.

5.2.3 Theoretical sampling

The sampling of informants as well as the adjustments to the interview protocol was usually based on information from three out of four of these sources:

- Within each company we frequently discussed the next stages of sampling with our contact in those companies.
- Most of the interviews were listened to immediately after they have been recorded.
- After the interviews memo's were made. These notes, which could form an important source in grounded theory, were either content related or were early ideas about potential categories.
- The interviewees themselves were asked at the end of each interview who else to contact regarding the project.

Although I was able to listen to most of the interviews immediately after our conversation and to sketch a few notes, it was not possible to make full transcripts and analyze the data before the next interview. The transcripts were made after all the interviews were finished. This is not fully in accordance with the method of grounded theory as described by Glaser & Strauss (1967) and Glaser (1998), but given the circumstances of listening to the tapes, having discussions with the peer researchers and company contacts, taking notes, and making some minor adjustments to the interview protocol, it was the best I could do.

5.2.4 The interviewees

Both companies had been visited prior to the start of the interviews to get acquainted with and informed about the projects that were going to be studied. The first people to interview were chosen by the contact person within the company. From there on I asked them who according who the thought should also be interviewed regarding that specific project.

From the total 14 interviews, 6 people could be considered to be from the explorative NPD side of the interface. Consequently, there were 8 people from the exploitative Manufacturing side. The interviewees on the NPD side were all directly involved in the projects. The interviewees on the Manufacturing side were not actually assembling or producing the products under investigation but belonged to the supervisory staff within manufacturing, i.e. workgroup leaders, operations managers, and line managers. These were the people that NPD was interacting with during the project. In normal situations, NPD doesn't have any contact with the people who actually produce or assemble the products. Although I talked informally with some of these production and assembly employees, there were no formal interviews.

In Figure 5.3 the spread of the interviews among the projects is showed.

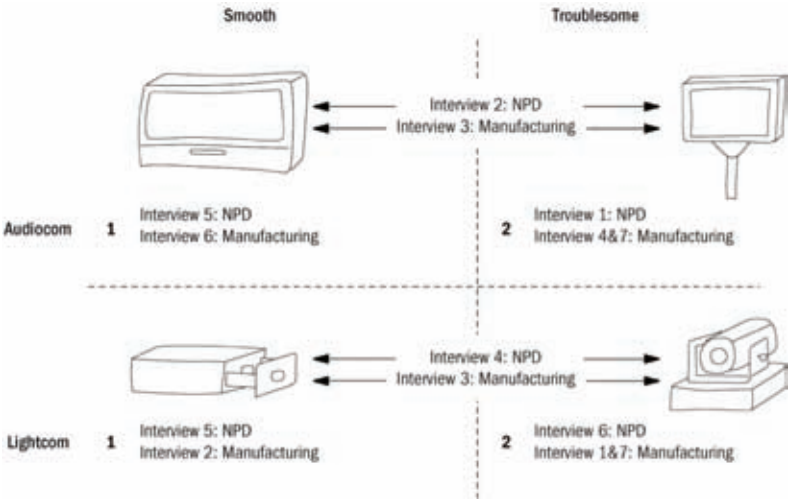


Figure 5.3 *The interviewees and the projects they were involved in. Four interviewees were involved in both projects.*

For all projects we had at least one interviewee from NPD and one from Manufacturing. It so happened that in both companies we had an interviewee from both backgrounds who could tell us about both projects.

All 14 interviews were held over a period of 3 weeks. Appointments with the interviewees were made depending on their availability and not in a predetermined sequence. This resulted in a random mix of interviews across the four projects and the two companies.

5.3 Data processing

As described in chapter 3, within grounded theory data processing is called the constant comparative method and comprises four activities:

- Comparing incidents
- Integrating categories and their properties
- Delimiting theory
- Writing theory.

These four activities don't run in parallel but span the entire study in an alternating way. This implies that across the various research stages incidents are constantly compared to each other and related to possible categories. Also, some possible theoretical explanations might be written up for publication in an early stage to be discussed with peers at conferences. Such a way of working prevents the researcher from submerging too long in the data and getting swamped by his/her own observations. Especially for this kind of research, it is advised to step away often from the individual process and thought worlds of the researcher to link up to the thought worlds of peers. Locke has formulated this as follows:

> *"….managing the tension between total immersion and analytic perspective or distance implies that researchers should parse their analytic time in such a way as to create periods of to-*

tal immersion in analytic activity working alone alternated with periods of external discussion and examination working with others." (Locke 2001, p 87).

In fact, the four activities could also be seen as data processing functions on different levels of abstraction, i.e. from concrete data incidents to more abstract theoretical considerations via stepping stones like conceptual categories and their properties. Also, in this study I used this process of alternating activities. This is illustrated by the 13 publications that were produced during the course of this study and were based on preliminary which intermediate results from the various stages of theoretical sampling. From 2001, 3 scientific journal publications and 11 conference papers have been published (for the complete list, see appendix IV). These publications and the presentations held at conferences made fruitful discussions with co-authors, coaches and peers possible.

The following section will report on the processes and results that are related to the first activity within this second stage of theoretical sampling: comparing incidents. As stated in Chapter 3, comparing incidents starts with the initial step of interpretation called 'naming', i.e. assigning names to data incidents. Data incidents are segments of text that contain quotes from interviewees that seem relevant to the research topic. The names that are assigned to these segments form an interpretation by the researcher which will indicate what is behind the narrative of the interviewees. As such, this naming process creates an overview of what the data contains. In parallel to this naming process comparing data incidents with similar names or names that seem closely related to each other could help to converge toward the fledgling categories being the pillars I am looking for in this stage.

5.3.1 Application of grounded theory

At this point in the research process we have not started with a blank sheet of paper. The previous four chapters have revealed some interesting issues that might support the analysis process and which will have consequences for the way the data is examined. In Chapter two we discussed the existing literature which addresses the interface between NPD and Manufacturing. There we identified some theoretical frameworks that are related to our research area which we expect to play a role in NPD-Manufacturing interactions so could develop therefore into a category. The consequence of having tentative frameworks at the outset of the comparing process is that a small adjustment to this part of the grounded theory method will have to be made.

In this step of the analyzing process two things will be done in parallel.

1. The data will be scrutinized in search for 'names' as is normal within grounded theory. At this stage it is important to be as open-minded as possible to be able to detect additional categories. The reason for this scrutiny is that I can't rule out that there may be other potential categories submerged in the data, categories that provide additional perspectives on the interactions between NPD and Manufacturing.
2. In parallel with this, the data will be searched for data incidents that fall under the umbrella of the tentative categories from earlier chapters and mark them accordingly. I have to do this because these tentative categories, and certainly those that come from Chapter 2, have not empirically been established in this research. Although these tentative categories seem about one stage ahead of where we are now in this research process they still will be treated as names. I expect that if we find a lot of data incidents that are related to some of these categories that they could serve as fledgling categories that deserve additional attention in

the next integrating stage of this research project. At this moment we only want to find out if it is worthwhile to further investigate these tentative categories in the next and integrating stage.

In summary, during the analysis we want to find out if we are able to identify possible other factors which lead to potential new categories and are able to identify those data incidents that refer to the tentative categories from earlier chapters. In the next section I will summarize the frameworks that were identified in the first four chapters.

5.3.2 Tentative categories from Chapters 2 and 4

Here I will review the tentative categories from the previous chapters, revisiting them in order of their appearance in the previous chapters. In Chapter 2 we discussed the literature and identified interactions across the interface with incomplete information, information about the product which was still under development and is therefore by definition incomplete. **Incomplete information** (**1**) will be the first tentative category that we will take with us on our journey through the data. The second tentative category is **learning** (**2**). We have seen in the literature that there are some forms and levels of learning that take place during the product innovation process and on both sides of the interface. In fact, without any learning there will be no new product. The third is related to **prototyping** (**3**), because this is an important interface bridging activity as we know that most companies use prototypes, like mock-ups and pre production products which are used for tests by consumer panels. The last category that was identified is related to the amount of **involvement and the location** (**4**) of the people who are participating in the product innovation process. This forms the last tentative category that we derived from the existing literature which was discussed in Chapter 2.

In Chapter 4 the first stage of theoretical sampling was carried out and this resulted in five more options for possible categories. The first tentative category that emerged is related to mutual **disturbance of ongoing processes** (**5**) that seem to be caused by unplanned, unexpected or even unwanted interactions between the two processes. We also identified obstructing interactions that were somehow caused by **communication flaws** (**6**) between the two processes in terms of communication that was either too late, poor, or even omitted. Then we saw that the **definition of targets or project goals** (**7**) formed another tentative category that might influence on the interactions between NPD and Manufacturing. This is related to the **planning and control** (**8**) of the NPD projects, because if targets are not clear or keep changing this will jeopardize existing time schedules. Recurring obstructing events around the **NPD deliverable** (**9**) also seem to influence the interactions. For instance, it is important that the production method needed for the new product have to fit in with existing Manufacturing processes. Finally, in the last section of Chapter 4 we followed an idea and searched the literature for characteristics that describe the **inherent differences** (**10**) between explorative and exploitative processes. These differences were of some help in understanding the critical incidents that had been recorded in the first stage. Therefore this last perspective will be added to this list of tentative categories may help in understanding the interactions between NPD and Manufacturing (see table 5.1).

	Tentative category	
1	Incomplete information	Tentative categories from Chapter 2
2	Learning	
3	Prototyping	
4	Organizational setting	
5	Disturbance of ongoing processes	Tentative categories from Chapter 4
6	Late, poor, or no communication	
7	Definition of targets or project goals	
8	Planning & control	
9	NPD deliverable	
10	Inherent differences	

Table 5.1 *Tentative categories derived from Chapter 2 and 4*

During the analysis the tentative quality of these ten categories will be assessed to determine which of these to concentrate on during the integrating stage. The next section will describe the naming process which occurs in parallel with finding data incidents for the tentative categories mentioned above.

5.3.3 Naming and comparing process

During the naming process it is necessary to carefully read and study the transcripts of the 14 interviews line-by-line in search of text segments that seem to describe something about the relations and interactions between NPD and Manufacturing. These text segments, or data incidents as they will be called, will be named by interpreting what the subjects describe. Posing questions about the data, like Table 5.2 illustrates, should enhance the creativity of the researcher in terms of opening up the data incidents to a wide range of possible interpretations (Locke 2001).

- What is happening in this text fragment?
- What are possible problems or situations behind the problem that is mentioned?
- What does these basic problems or situations make me think of?
- Did I already see similar situations or problems and what did these look like?
- What were the similarities or differences between those data incidents?

Table 5.2 *Possible lead questions that assist the naming process*

It is expected that in some cases more than one name can be assigned to a data incident. From a scientific research perspective this may sound ambiguous, but at this point in the research process following the method of grounded theory one needs to be as open-minded as possible. Researchers need to scrutinize the data for hunches, ideas, and 'names' in order to provide them with something solid enough that can lead them toward less ambiguous conceptual categories, complete with associated properties. These conceptual categories are theoretical representations of the factors that, in our case, seem to clarify interactions across the NPD-Manufacturing interface. Thus, by using these leading questions and 'scrolling' through the categories, names, and data incidents that have already been detected and reviewed, I hope to gain additional insights and identify proper name(s) for the segments under study.

At this critical stage it is essential to be as detailed and receptive as possible and use every clue or foothold that might support the later steps of analysis and theory building. If the level of naming is too abstract some essential conceptual elements of the theoretical framework might be missed or, even worse, I might be ending up with trivialities. On the other hand, the level of naming could also be too detailed if the names don't rise above the actual product innovation project that is discussed in the interview. This in its turn will have consequences for the generalizability of the findings.

5.3.4 Coding of data incidents

During the naming process I need to code the data segments to be able to compare the different data segments that fall under the same name but belong to different interviews, different product innovation projects, and different companies. The position of the interviewee is especially important: is this particular narration coming from a Manufacturing or NPD perspective. Because the total product innovation project is discussed irrespectively of the position of the interviewee, we also need to know which of the two periods of interactions between NPD and Manufacturing is addressed by the data incident: preramp-up or ramp-up. Finally, we need a code that indicates the position of the data segment in the interview. I ended up with the following coding scheme (Figure 5.4):

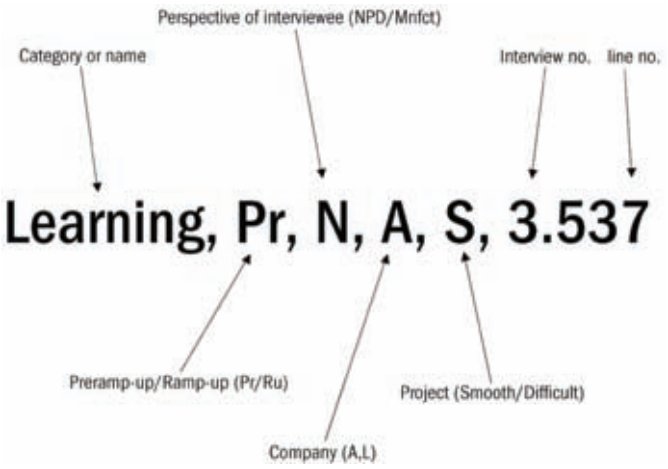


Figure 5.4 *Coding scheme of data.*

In the remainder of this chapter the results of these two parallel analysis processes will be showed. Although comparing and naming occur mainly parallel with each other, for readability reasons they will be discussed separately.

5.4 Results of the comparing and naming process

In this paragraph I will present an overview of the results of the two parallel analysis processes as described above. I will do so on three levels: a general overview of the data incidents, the overview of data incidents as they relate to the tentative categories, and finally an overview of the additional names that were identified.

5.4.1 General overview of data incidents

Although the research method of grounded theory is not about number crunching I will present some general numbers and figures that illustrate the data and help to understand what the data is about.

In the 265 pages of transcripts 435 data incidents were identified that were somehow connected to the interface between NPD and Manufacturing. Most of these data incidents or smaller fragments of these incidents received more than one name, with an average of three names per incident. In total I ended up with 1310 text segments that were identified and named passing through the data the first time. This includes the text segments that fall under the 10 tentative categories we started with. In fact 68% of these 1310 text segments belong to these 10 tentative categories as we will discuss in the next section. The distribution of data incidents over the companies was almost equal, 632 on Audiocom and 678 on Lightcom.

Section 5.3.4 made clear what kind of coding scheme would be used for all the data segments. One of these codes indicated whether the data segment concerned the preramp-up or ramp-up period. Already in the first interview that I analyzed was realized that a third code was needed: a code that refers to the last activities within the preramp-up period (the NPD process) and the first activities within the ramp-up period. The following is an illustration of such a text segment.

> *"…we developed one thing … one small new thing here […] for the production line. It is a sound component. It is a sound type box where we test all the [TV] sets. […] A testing gear. It is testing different frequencies … it tests the loudspeakers but also it tests if there are any unwanted noises in the set. [....]*
>
> *This one [the new test] made a lot of problems […] because it found sounds in the set which …if it had been [done] with other televisions, it would have passed completely unnoticed, but we actually lowered or made a very fine filter suddenly. …Of course we tried to make the design so that it was good in relation to noise, but not good enough. So we had to put a lot of soft foam into the product. …" (Audiocom.NPD.1.518)* [18]

The interviewee, from the NPD side, says something about the design process as well as the trouble it caused when it was introduced on to the assembly line. This combination code, that will be called 'transitional', was used for all data segments in which the interviewee discusses both periods in one data segment. It must be noted that I am not adding a new period of interactions within the product innovation process, a period between preramp-up and ramp-up, but I needed the additional code for data segments in which the interviewee discusses the ramp-up and refers back to the preramp-up NPD process or the other way around.

In the end roughly 30% of all data incidents (129 out of 435) were labeled with this additional code. Table 5.3 gives an overview of the data incidents related to these codes.

[18] All data segments that are used in this book will show the following coding: (Company (Audiocom, Lightcom), Position Interviewee (NPD, Mnfct), number of interview, line in text). If some words of the interviewee are left out this is indicated by […] and the addition of authors notes is between similar brackets: [authors note]. Remarks and questions by the researcher are in bold.

Preramp-up	35%
Transitional	30%
Ramp-up	35%

Table 5.3 *Overview of data incidents and codes related to the period that is addressed in the incident.*

It is clear from this table that the data incidents that were detected address the two interaction periods, preramp-up and ramp-up, in an equal way. This means that there is no extra weight given to one of the two periods. Also there seems to be an interesting amount of data incidents that encompass the interface by addressing both periods.

Looking at what lies behind these percentages by distinguishing between the position or 'function' of the interviewee (NPD or Manufacturing), we see that at Audiocom the interviewees from NPD and from Manufacturing address the preramp-up and ramp-up periods in a more or less equal way. Table 5.4 shows the spread of data incidents over the three codes as a percentage of the sum of data incidents (i.e. 'N') that were found in all interviews belonging to that position, respectively NPD and Manufacturing.

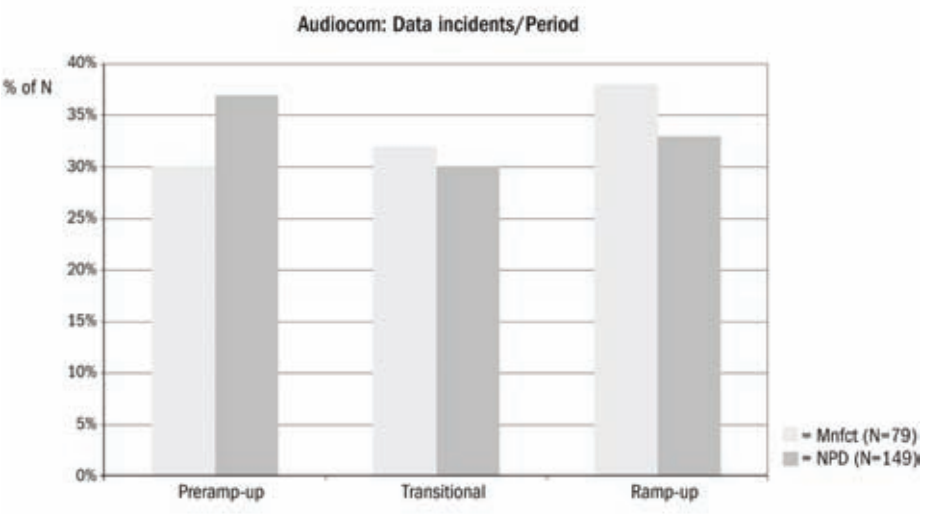


Table 5.4 *Spread of data incidents over the three codes and per 'function' at Audiocom. It is clear that there is an almost even spread of incidents over the three codes by NPD as well as Manufacturing.*

It is clear from this table that the data incidents from NPD people at Audiocom address the preramp-up period and the ramp-up period almost equally. This is also the case for the Manufacturing interview incidents, which means that, at least during the interviews, the interviewees seem to have enough knowledge and understanding to be able to address the other process although that is not part of their day-to-day work activities. They are even capable of addressing processes on both sides of the interface regarding one subject or one part of a product.

At Lightcom this is completely different. Table 5.5 shows that the majority of data incidents relate to their 'own period', meaning that the NPD interviews show more incidents about the preramp-up period and the Manufacturing interviews show more incidents in the ramp-up period.

In the way they discuss the product innovation projects there is relatively little focus on what occurs in the other process.

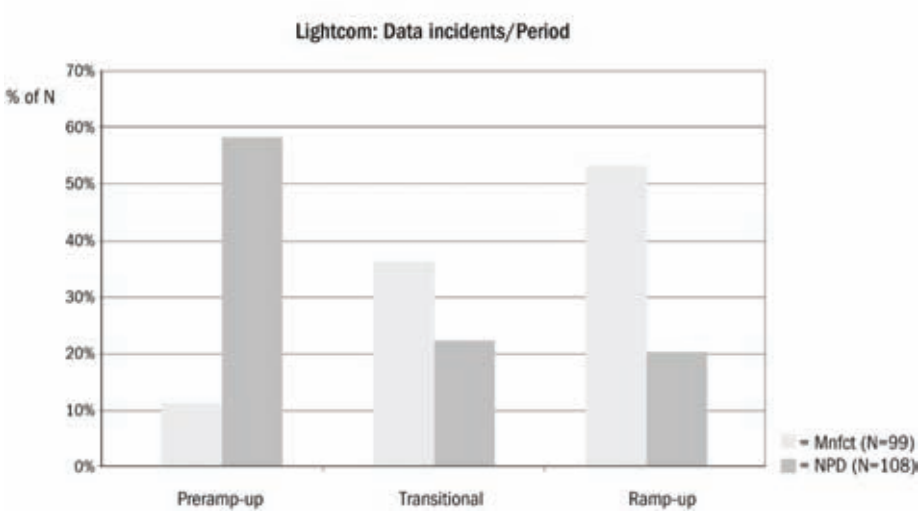


Table 5.5 *Spread of data incidents over the three codes and per 'function' at Lightcom. This figure clearly shows the small amount of incidents mentioned by interviewees from Manufacturing that refer to preramp-up period. On the other side, the interviewees from NPD mentioned only a small amount of incidents that refer to the ramp-up.*

The differences between the Audiocom (table 5.4) and Lightcom (table 5.5) graphs are striking. At Audiocom there is an almost horizontal spread over the three codes, and at Lightcom there is a sharp decrease of data incidents not related to their own period. One could conclude from this that NPD at Lightcom is not as involved in Manufacturing as NPD from Audiocom and ditto for the involvement of Manufacturing in NPD. This difference could be caused by the fact that the geographical site of Manufacturing at Lightcom is 180 kilometers from the premises where NPD is located. Another reason for the large difference could be that at Audiocom, NPD remains responsible for the new product until the production volume is at the required level. This is not the case at Lightcom where NPD must only be available for troubleshooting during the early stages of the ramp-up period.

Although I am aware of the fact that we must be cautious with quantitative aspects of the data, these kinds of relative comparisons provide some information about the character of the data set.

5.4.2 Overview of results regarding tentative categories

The tentative categories from the first four chapters covered 68% of all text segments (N=1310). Table 5.6 shows the respective percentages of text segments per category. The sequence of these categories has been altered to rank from high percentage of data incidents to low percentage. It is important to note that this ordering forms no indication of the importance of the categories as being influential factors on the interactions between NPD and Manufacturing. The percentages only refer to how often the interviewees talked about a subject that was then assigned to the categories by my own interpretation. Because there were only minor differences be-

tween Audiocom and Lightcom regarding the distribution of data incidents over the categories it was decided to bring them together.

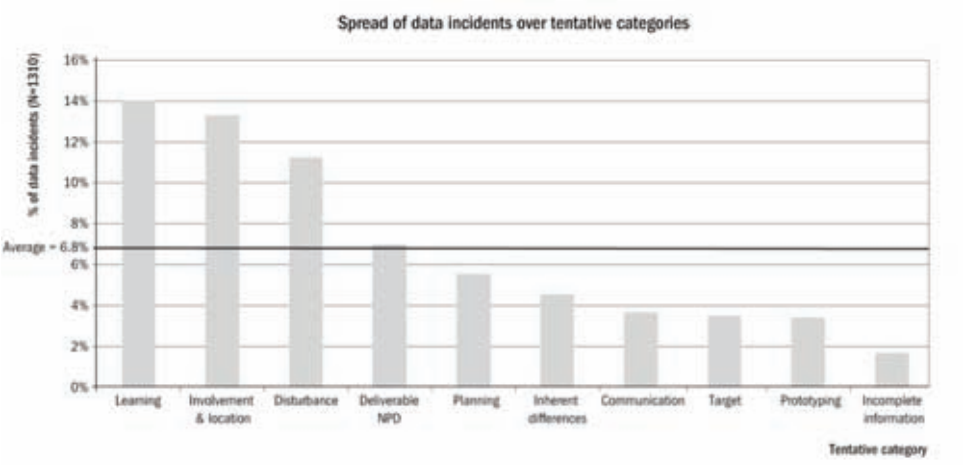


Table 5.6 *Percentage of total data incidents assigned to the 10 tentative categories, arranged from high to low. The average of 6.8% is indicated by a line.*

It is clear from this chart that *Learning, Involvement & location, Disturbance,* and *NPD Deliverable* stand out above the average (6.8%) of the 10 categories. These four seem to be the most promising candidates for further elaboration in the integrating stage. However, during the analysis I realized that these 10 tentative categories where not equal in terms of their level of abstraction, meaning that some were formulated on an overly concrete level while others were too abstract. The consequence is that the more concrete categories were really like 'names' while the more abstract categories are too general to help in the theorizing process. Of the four tentative categories that are mentioned above, three will be taken to the integration stage of this research after I have briefly reviewed them. The fourth, *Involvement & location,* wasn't as I expected as will be made clear in the next section and will therefore not be included in the next research stage. In the following the 10 categories will be addressed in the same order as in table 5.6, from high to low percentage of data incidents.

Learning

This tentative category seems to be a promising candidate to become a fledgling category. The fact that 14% of the text segments is related to learning processes implies that learning plays an important role in what takes place between NPD and Manufacturing. This is not really a surprise since, as was shown in Chapter 2, some forms of learning that the literature mentions is clearly related to the product innovation process. In short, we have discussed learning on the level of:

- the overall product innovation process (e.g. Buijs 2003)
- the problem solving cycles related to product and process development (e.g. Clark & Fujimoto 1991)
- the individual learning activities of designers (e.g. Dorst 1997)
- performing deliberate experiments during the ramp-up period (Terwiesch & Bohn 2001)
- learning curves during the ramp-up

Apart from the deliberate experiments during the ramp-up, the interviewees mentioned all these forms of learning. Of course both companies performed deliberate experiments regarding the production and assembly of the new product, but these took place before the ramp-up period during the preproduction series and were aimed at detecting issues that must still be addressed. The next quote illustrates this form of learning.

> *"…So we started up first to make the concept verification, as a mechanical and electrical […] verification. Let's say at this moment here we should get the knowledge of what problems we still have in the mechanical part and the electrical part. The mechanical part in assembling it […] and the electrical part […] about how to adjust the electronics …" (Audiocom.NPD.5.344)*

The interviewees didn't mention such experiments during the ramp-up phase being done in order to speed up the learning process. A related form of learning also fits in the tentative category on *prototyping,* which is the consecutive design-build-test cycles. This will be discussed later in this section under *prototyping.* Yet another form of learning is directly connected to interactions between NPD and Manufacturing and will be discussed separately under the new name of *understanding*. When people interact it is necessary that they understand each other correctly as will be illustrated later (Section 5.4.3).

In most situations combinations of different forms of learning have been seen. For instance, the learner on the assembly line first needs to become familiar with the new product, then has to develop the skills to assemble the product and finally, must attune his skills in order to achieve at a certain routine level that is required for volume production. These involve three consecutive forms of learning.

Finally, some interviewees mentioned learning across the consecutive product innovation projects. This form of learning refers to the learning that accumulates from project to project. However, this will not further be discussed because it is not involved in the NPD-Manufacturing interface.

In summary, *learning* seems to be a possible fledgling category and therefore further elaboration will take place during the next stage of this research, the integrating stage.

Involvement & location

Regarding this category, I expected from the literature, as was discussed in Chapter 2, that the amount of involvement and the location of the various multifunctional NPD participants would affect the interface interactions. Apart from the anticipated spatial influences within Lightcom, where Manufacturing and NPD are 180 kilometers apart from each other, I detected only a limited number of such data incidents. In those occasions the consequences of part-time involvement or being at separate locations was mostly obvious which resulted in *disturbance of ongoing processes* on one side of the interface and were therefore listed also in that tentative category.

The reason for the large number of 'hits' is that this category had been enlarged to include text segments that in some way told something about the product innovation process. This means that the specific process elements that the interviewees spoke about were included in this category. The rationale behind this is that most interviewees talked about the process and the structure of the product innovation process in an integrated way. They spoke about the process and the related responsibilities of the respective parties. The following quote illustrates this intermingling.

> *"…One person was responsible for that part, that it was OK. And he had a firm both to develop and to produce it. …they got the drawing from us, how we wanted it to look … they only got the design concept from us and what we wanted … aluminum and so on and how it should look. But they could make the construction from that…"*
> *(Audiocom.NPD.5.1162)*

It appears that all the people were very much involved in the projects and told about the project from their own viewpoint and described the roles of the other actors. They did not directly speak about the organizational setting and the influence of that on the project.

Another element related to the involvement of the actors which makes it difficult to discuss separately, is that I didn't witness what really happened during the product innovation projects. In Chapter 2 I stated that I could imagine that when people were only involved part-time they would need to shift from exploitative work to explorative work. This switching is probably most visible during the first part of a meeting. During the interviews I was not able to reach that level of detail regarding the interactions between the actors. This is mainly due to the choice of ex-post interviews instead of on-line observation.

During the interviews I got the impression that a lot of cooperation between NPD and Manufacturing seems to have an informal character. Of course, the interviewees mentioned formal elements and structures like project teams, development phases or frequent project meetings, but I was unable to detect the influence of these structural elements on the interactions between NPD and Manufacturing. I believe that to reveal these influences one has to be a witness to the process. Therefore I have decided to leave this tentative category behind and only use clear interview statements about the organizational setting if they are relevant to other categories.

Disturbance of ongoing processes
As mentioned earlier, the part-time involvement of Manufacturing in the preramp-up processes sometimes interferes with their day-to-day production activities. They will need to concentrate on this development work for a short period of time and will therefore need to switch from one type of work to another. This particularly interesting form of disturbance was named *switch* and will briefly be discussed in Section 5.4.3 and explored at length in the next research stage.

Other data incidents that refer to the tentative category of *disturbance of ongoing processes* include unforeseen interruptions like design iterations. A design iteration is, in fact, the redesign of an earlier solution that somehow proves to be unsatisfactory and therefore requires an extra design cycle. This is an unexpected activity that interrupts the ongoing product innovation process. As such, design iterations are considered problem solving cycles and also fall under the category of learning.

Postponing the ramp-up is another form of disturbance that was mentioned quite a few times and connects this category to the category of *planning* that will be discussed shortly hereafter.

Finally, both companies seem to undergo a considerable number of disturbing events that are related to their suppliers. It occurs frequently that suppliers are not able to deliver their goods to the required quality, in the right quantity or at the right time. These incidents seem to play an important bothersome role in preramp-up and ramp-up processes. Although suppliers have been excluded from this research, they seem to be an important influencing factor regarding the

interactions between NPD and Manufacturing. Therefore, the relevant text segments were named *suppliers*, a name that will be discussed in section 5.4.3.

All in all, this tentative category on *disturbance of ongoing processes* seems promising enough to become a fledgling category that makes further elaboration in the integrating stage worthwhile.

NPD Deliverable

This tentative category surfaced in the scanning stage (Chapter 4) as 'NPD deliverable doesn't suit in next process' to indicate that the deliverable at the end of the NPD process is not good enough to proceed the next process according to the interviewees. They either perceive it as being too complex, not adequate or useful, or not complete enough. In this focusing stage the interviewees mentioned similar problems, like testing equipment that is perceived to be too complex or software that isn't up to the required standard. But at what moment should the deliverable be assessed? Is it at the moment of preproduction or at the start of the ramp-up phase? And from what perspective must the deliverable be judged, from the NPD perspective or from Manufacturing? From the data it becomes clear that there is not one clear deliverable but there are many interim deliverables over the course of the development process that are successively handed over to actors within Manufacturing. These can be the drawings for injection moulding to prepare the moulds, the specifications of certain parts and components, the Bill of Materials (BOM), production sequences, etc. However, there doesn't appear to be one clear deliverable that is handed over from NPD to Manufacturing. The actors from NPD even seem to continue with final development activities during the ramp-up. But the Manufacturing perspective on this is different because they expect the product to be ready when the ramp-up begins.

> *"…But if the development department are able to have the parts ready and tested, and the quality is OK, then we can reach that ramp-up [schedule]. But the only reason why we can't reach the ramp up is that in our experience, there are still problems with the product…" (Audiocom.Mnfct.3.860)*

The ramp-up schedule is based on the belief that the product will be ready at the moment the ramp-up starts. If the product isn't finished, and that seems to be the rule rather than the exception, then Manufacturing feels that NPD has fallen short in their activities. Under the name *expectations* this discussion will be continued (5.4.3).

However, some of the details relating to for instance the procedures and thresholds for testing the product on the production line need to be developed during the ramp-up. This will be discussed in section 5.4.3 under the names *tolerances* and *testing*.

In summary, we can say that there are many interim deliverables from NPD during the course of development activities and that these are important to keep the innovation process going. On the other hand it looks like the tentative category of *NPD deliverable* will not become a fledgling category because it is too static. Although it is a relevant category and it does have relations with other names it misses action elements that are necessary for describing what is going on between NPD and Manufacturing. Maybe, an orientation towards action should be a third requirement for a tentative category to become a fledgling category. I will come back to this issue in Section 5.5.2.

Returning to the *NPD deliverable*, on a more abstract level the interim deliverables form important stepping-stones in bridging the gap from exploration to exploitation and that raises the question about the final deliverable from the explorative activities. What can we say about this explorative deliverable because it seems to be the major driver behind all interactions. This perspective will be discussed further in the integrating research stage (Chapter 6).

Planning

In both companies the planning schedules of the NPD process aim at reaching the market as soon as possible. Most of the 73 data incidents that were identified around planning are somehow related to this time-to-market focus and refer to time overruns and working with unfinished elements like unfinished testing equipment, unfinished software, or parts from suppliers that were not yet up to specifications or were just not available. Although the interviewees didn't explicitly mention the planning problems due to unexpected snags during the development process, there certainly were time overruns caused by these problems. The data incidents that were related to these difficulties could also be included under *planning*, but I chose not to do that to prevent ending up with an undifferentiated collection of data incidents associated to time problems as a result of problematic development topics for instance. Thus it was decided to only label those incidents that explicitly and directly mention time related issues.

In both companies I heard interviewees talked about postponing the ramp-up and launch dates in order to get things ready to prevent a lot of 'fire fighting' and energy consuming interactions like reworking products that have been produced and are waiting in stock.

> *"…well I think we make that big mistake that we are too much focused on how to reach the production start-date and also the launch date that we didn't stop at the time that we recognized that there is a problem…" (Audiocom.Mnfct.7.468)*

A less prevailing focus on the production start-date would have made room to investigate the obstacle that occurred and maybe to postpone the start-date which would have avoided the friction that came up later when they couldn't neglect the problem anymore.

> *"…There were things from suppliers, that were not finished at the right time, so we had to built up the product partly, then put it away, and take them back again in the line [after the parts were available], and finish the building of the product and make the tests…" (Lightcom.Mnfct.1.299)*

Also in this case, postponing the start of production until the parts were available would have caused less disturbance during the ramp-up period. These kinds of planning related issues affect the interactions between NPD and Manufacturing. Especially the rush towards a certain date puts a lot of pressure on the people involved and more dangerously, it also puts pressure on the quality of the product delivered at the promised date. We saw a fine example of this at Lightcom where the new product had to be presented at an exhibition in order to create customer enthusiasm and to get some feedback.

> *"…But the big error was too early launch of the product …[at an exhibition]. [Afterwards they concluded:] We only launched a prototype of a design that was not even good enough to go into production. So we had to start all over…" (Lightcom.NPD.5.20)*

Due to the time pressure the design was not thought out very well and therefore received a lot of feedback from the customers. In fact, too much feedback to continue with the existing design which forced them to start all over again. And again under time pressure since the new product was already announced in the marketplace. This situation at Lightcom is not an exceptional case. At Audiocom there are also comparable problems caused by self-induced time pressure as was illustrated in one of the above data segments.

All in all, these data incidents are very much alike the recurring obstructing events that have been recorded in the first stage (see table 4.7) which had initiated this tentative category of *planning*. Although these findings reinforce the interface problems related to the planning of explorative NPD processes, at this moment we have not really built enough insight to understand the mechanisms behind these problems. We can only observe that the difficulties around the planning of NPD processes greatly influence the interactions between NPD and Manufacturing but we don't know how the planning process is carried out and who enforces the dates that were agreed upon. In Chapter 4 it was hypothesized that the different attitudes on both sides of the interface towards time and the process of planning could play a significant role which could eventually lead to problems. Manufacturing wants hard and nonnegotiable dates and NPD is not able to control their explorative processes sufficiently to keep those dates. One of our interviewees from Manufacturing describes his perspective on such a situation.

> *"…I think that a typical problem of our R&D department is that if they have a term here, a date, they start with hard working, but the closer they get to the date, the more they work. So you have a milestone here [far in the future…], they have a lot of products they are working on, but [suddenly they realize] now we are getting closer, now we can not wait anymore and then … like this [miming a gesture of working very hard] … instead of, we have this period here between those two milestones, let's middle out the resources and work continuously on this product. Then they will have the result much earlier in the phase and they can begin to make tests…" (Lightcom.Mnfct.1.662)*

This interviewee thinks that the dominant process characteristics of his own exploitative Manufacturing environment are simply transferable to the explorative NPD environment. By doing this he implicitly characterizes the NPD process as being predictable, without any exceptions and without time consuming iterations. In other words, the interviewee seems to believe that NPD could control their processes better if they used methods that come from the exploitative environment. At the same time, he does not acknowledge the differences between exploration and exploitation that may be the source of the planning problems.

In conclusion, it seems that there are two main issues which relate to planning. One of them is that due to the dominant preoccupation with reaching a planned time-to-market date, the manufacturing process sometimes starts before everything is ready and available. The second is that the actors on each side of the interface seem to have a different perspective on time related issues. But all in all, the tentative category on *planning* seems not promising to become a fledgling category.

Inherent differences

In Chapter 4 the literature was explored to find some support for the insight that the inherent differences between the two processes might influence the interactions between NPD and Manufacturing. However, the literature could only help to explain some of the obstructing

events that were mentioned by the interviewees in the scanning research stage. It was expected that by collecting rich data about these interactions it would be possible to identify some empirical support for this influence and to identify additional differences between the two processes. Unfortunately, I could only identify 60 data incidents that somehow address the differences between NPD and Manufacturing. The interviewees sometimes spoke about the specific characteristics of 'the other party' but mostly to indicate that the other party lived in another world. The interviewees then used such a description to explain, on a general level, why interactions and communications are sometimes difficult.

What becomes clear form the text segments is that it is very hard for the actors on each side of the interface to deeply understand the other process. They know that the other process is different they also know that it should be different, but it is hard for them to accept the consequences of these differences. It could be that they don't know that some of the problems they experience are in fact the result of these differences which are essential aspects of these processes.

For instance, most actors within the Manufacturing sphere of both companies seem to expect that the product is totally finished once it comes into production. They apply their definition of a finished product to the product that comes from NPD, meaning that they are convinced that at that moment most problems must have been solved. Otherwise, they seem to think, why would it be ready for production?

> *"…It is very hard for our assembly people to understand why the product is not finished when we receive it from R&D and often it is very hard for R&D to understand, why it is such a big problem for the assembly people. It is a different world, they are coming from…" (Lightcom.Mnfct.7.316)*

So, Manufacturing doesn't understand that NPD is not able to solve all the possible problems beforehand. But what Manufacturing people overlook is that problems can only get solved if they are detected. From the NPD perspective, it is clear that having solved all problems before the start of production is a kind of utopia, because as one interviewee from NPD mentions: "Prototypes don't show all the problems" (Audiocom). Of course, Manufacturing knows that some problems always come up during the ramp-up phase and they are willing to accept it but still they believe that NPD could do a better job and solve more problems before production begins.

> *"…Well it is also always easy to see in the mirror what has happened […] but again I think, maybe some reviews from experienced engineers could have seen that this mechanical design regarding the fan and so on should have been better…" (Audiocom.Mnfct.7.334)*

These and similar text incidents show that the actors from the two worlds sometimes have trouble accepting that they deal with two different processes that somehow need to be joined together. The actors don't seem to see that what they judge as 'insufficient behavior' from their perspective is in fact normal behavior from the other's perspective. Why is it so difficult for the participants to see this reality even after working together for a long period of time? Are they unable or unwilling to see it?

What in fact happened is that by looking at these inherent differences during the scanning stage the two processes were polarized too a larger extend than was found in the interviews. Of course, the characteristics of an explorative process are very different from those of exploitation, but this

research project focuses on the interface between the two, and more specifically, on the transition from exploration to exploitation. It seems that by doing this we end up in the eye of a 'functional' storm with some turbulence on the edges. This implies that the polarization recorded in the scanning stage (Chapter 4) is too far apart and is therefore possibly too abstract. What happens during the interactions seems to be much more sophisticated then just bridging the divide between the processes and the participants. This will be discussed further in the integrating stage when the core category is presented.

Communication

The less than average number of 'hits' regarding the category of *communication* seems somewhat surprising. The trouble with this tentative category that I found during the analysis is that it is too abstract. During the data analysis not many data incidents pointed to this tentative category which was originally named *Late, poor, or no communication* (Chapter 4). The interviewees simply didn't say much about communication in that sense. They did talk about communication in relation to the organizational setting or in relation to suppliers.

> *"…nine out of 10 products are waiting of suppliers, because their process is longer than our development period, or typical they get involved so late in our process that they can not deliver in the time we asked them for…" (Lightcom.M.1.339).*

Looking more closely at the data analysis we can see that in many cases the data incidents named under *communication* were also appropriate for a new name that relates to the understanding on both sides of the interface concerning the subject of discussion. *Understanding,* in fact, deepens the category about *communication.*

All in all, communication does not really seem to be a part of the discussion during the product innovation project, only in differentiated form and in direct relation to the project. However, one could see communication issues behind almost every data incident and this would imply also that other tentative categories like *prototyping, incomplete information,* and *deliverable NPD* must be assigned under *communication.* If I did that such a category would be too abstract to be useful for this study. Therefore I have decided to only use the data incidents that are relevant to other categories that we will discuss in the next stage.

Target

The data incidents that relate to the definition of the target for product innovation show largely two kinds of targets. The first one seems to correspond to what we have seen during the first stage and is related to the needs of the customer (see Chapter 4). This target concerns the kind of product, its functionality, its quality, its retail price, etcetera and is supposed to be defined at the onset of the product innovation process. At Audiocom I have seen that if during the development process such a target, in whole or in part, is not attainable then an unclear process begins to search for a new target.

> *"…the task was to design a television that was cheap in our terms, that is around […] retail and we ended up with something which we had to … we ended up to almost double the price. But we had some […] turbulence here trying to find what to do…"*
> *(Audiocom.NPD,2.125)*

Because the concept was already too expensive due to decisions made earlier in the NPD process, they now had to find a new balance, in fact a new target that would compensate the customers for the higher price of the product.

> *"…to make a bit more performance, …a bit more functionality. We have added the functionality later, because the price was there and we couldn't move the concept that… well… in terms of the price, but we could increase the performance and functionality…"*
> *(Audiocom.NPD.2.135)*

A higher market price than originally planned would have, according to the interviewees, consequences for the Manufacturing processes in terms of a change in expected production numbers. Other consequences were delays in time-to-market and extra development costs. It is not clear from the interviews how far these consequences have influenced the interactions between NPD and Manufacturing.

However, the second form of target did show influence on the interface interactions and concerns the very last **details** of the product that is under development. In the interviews two groups of details were identified: details that are measurable and testable like tolerances or reliability and a second group of details that are subjective and difficult to measure like surface finishing or image quality. Both groups of details are only possible to define towards the end of the NPD process when everything around the product reaches its final state. In both companies I heard about interface problems related to these issues and I will discuss it further under the name of *tolerances* in the next section.

Prototyping

In Chapter 2 we have seen that prototypes approach the real product in one or more dimensions. Since such prototypes can serve as a communication platform for the actors from the different up-stream and down-stream functions. They can help bridge the interface to the down-stream processes like Manufacturing. By having successive design-build-test cycles the prototype becomes less an approximation and more and more the final product produced with the real production tools on the real production line.

Both companies that were looked at make use of prototypes during their development process and also involve the downstream functions to discuss the various aspects of the new product.

> *"…they [NPD] made a good preparation for these meetings, so there were models, and some drawings and something which we could look at and then… during the meeting we all… I think we were….our [Manufacturing] technology manager was involved and the software person was involved and the mechanical architecture person was involved, and electrical…" (Audiocom.Mnfct.3.55)*

However, during the interviews I was not able to come down to the level of the interactions that took place while the different functions were discussing the prototypes. Afterwards I came to believe that this is only possible as a witness to these discussions, e.g. by ethnographic research. Nevertheless, what I heard about prototyping was still informative regarding the aims of this research.

I heard about the two forms of prototypes that were described by Ulrich & Eppinger (1995), the Alpha prototype check the functionality and fulfillment of consumer needs and the Beta prototype to check for reliability and performance. In addition to that I found forms of prototyping that serve other purposes in the interface between NPD and Manufacturing. I will discuss these briefly and illustrate them with a data segment.

The first is at Audiocom where a model was designed and made at the beginning of the NPD process to serve as a 'master' model throughout the entire process.

> *"…It is not a working sample, it is just a wooden sample, but it is very accurate, regarding the physical design, because it is our main parameter […] So all the small roundings and surfaces are correct […] we call it our design model and we can't make anything that differs from that, without acceptance from the designer […] we make the drawings, mechanical drawings from the master model and then we have … sometimes we even make a model from the drawings.* ***Again?*** *Again, and compare it with the other one. There might be some differences when you make transformations to the CAD-system, because it [the model] is handmade. …" (Audiocom.NPD.2.312)*

Another form of prototyping that I heard about from our interviewees is related to the manufacturability of the new product in terms of checking that all the parts together will fit in the final product.

> *"…a first prototype and it was made in wood and papers and glued together […] It was to see if all the ideas [parts] could stick together and to review what problems could be inside the product…" (Audiocom.Mnfct.3.196)*

It turned out that late prototypes were also necessary to finalize the NPD process, like the development of the software to test the products at Audiocom or developing and adjusting the software for the movement of the head (lamp) within the product at Lightcom.

> *"…So we can't make software for the product unless we have a full mechanical product to run…" (Audiocom.Manufacturing.1.141)*

But late prototypes are also used to make assembly time studies and develop the assembly procedures.

> *"…And when we have a prototype we have our time study girls, who take the product apart and go through it and take time on every operation, and that is a system called MOST, where we put the time on every operation…" (Lightcom.Mnfct.1.506)*

This activity of doing time studies using late prototypes is obviously linked to the learning that must take place during the ramp-up of the production line. I will come back to this in the next chapter.

Although Clark and Fujimoto (1991) consider the fabrication of prototypes to be 'hidden manufacturing' activities in the middle of development processes, I believe that these activities are an element of the explorative process more than they are part of the exploitative process. Prototype builders, who are often the developers themselves, are typically exploring all kinds of possible solutions while struggling to obtain functionality and manufacturability.

> *"…[the] engineer is sitting and trying to… to… to obtain the functionality… **Development engineer?** Yes, and he is… well in his mind he is struggling with a lot of, … is this possible, is this possible, and [at the same time] building up prototypes…" (Lightcom.NPD.4.71)*

Of course, some parts in the prototype might come from regular exploitative manufacturing processes, but the process of constructing the prototype using these parts should be considered as explorative. It becomes interesting in regards to the research topic if these prototype parts have to be provided by Manufacturing and are not regular parts but special parts in some respect. This implies that Manufacturing might need to switch to an explorative activity for a short period of time in order to produce such a special part. I will return to this issue later in this chapter when I discuss *switch* as one of the newly identified names and in the next chapter.

The last elements regarding prototyping that have been identified in the data concern the last phases of the preramp-up period where the prototypes are made by using more and more of the final production tools and manufacturing system ultimately moving towards the 0-series that use the real assembly line with the assembly personnel. As well as Beta-testing the products that come out of these early production processes, the various parts of the Manufacturing system are also subjected to their final tests. And not the least thing of importance, the people involved in the Manufacturing system are becoming acquainted with the new product and are starting to learn how to produce and assemble the new product. This will further be discussed in Chapter 6.

Incomplete information

I was somewhat surprised that only 22 text segments were identified that address the issue of working with incomplete information during the development process. A reason could be that incomplete information is considered to be a normal situation between NPD and Manufacturing and therefore is not mentioned that frequently by the interviewees. What they did mention however illustrates, in a positive sense, what Clark & Fujimoto (1991) said about product engineers being reluctant to release incomplete information. In both companies there seemed to be a positive attitude on the NPD side towards exchanging information about the product under development. However, that doesn't mean all interactions with incomplete information are as effective and efficient as the participants would wish. On one hand, this seems to be related to the skills of the actors that were mentioned by Smith & Reinertsen (1991): the ability of senders to assess the impact of their information and the ability of recipients to imagine a future situation. On the other hand, there seems to be a relationship with the moment in time that these interactions take place. If manufacturing receives information about a new product that they have to give feedback on, they must invest time to do so.

> *"…The problem is that […] they have actually to… to…to try …to investigate to give a good feedback. To go back and say 'OK, how will this be in production'?…" (Lightcom.NPD.4.51)*

Apart from the skills that are necessary to work with the incomplete information, the willingness or possibility to spend time on this activity by the receiver seems to influence the quality of such an interaction. I will come back to this issue later in this chapter when I discuss the *switching* from activities belonging to one process to activities in another process and in the next chapter when I elaborate on the tentative category about *disturbance*.

Another thing that came up in the interviews is that some actors on the operational side of the interface, from Manufacturing but also from Purchasing, seem to not be able to start their work be-

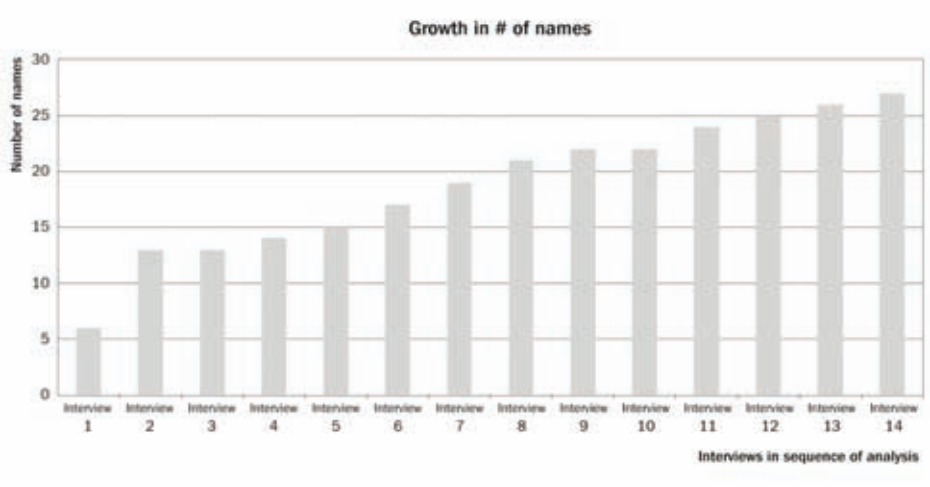
fore all information is available. For situations that are sequentially dependent, this seems logical. However, this kind of dependency is not always agreed upon by those on the other side of the interface as the following quote illustrates.

> *"…So that is their base … that they have all the data and then they do…. a thing… and they don't do … it again and try again. They do one job and that's it. And they wish to have that all the time. They don't wish to do a little here and then wait…" (Lightcom.NPD.4.26)*

The interesting thing about this situation is that although we are talking about actors from the exploitative side of the interface like Manufacturing and Purchasing, the type of work that is meant here has an explorative character. This work concerns things like doing assembly studies or having preliminary conversations with possible part suppliers about prices. This kind of work is maybe not seen as belonging to the explorative process and seems to call for additional skills and actions for those who are based on the exploitative side of the interface and who receive partial or incomplete information. In the next chapter we will go deeper into those subjects that are related to the skills and behavior needed for learning.

5.4.3 Overview of naming process and descriptions of the names

In this section we will discuss the results of the naming process. The increase in the number of names during the analysis of the first two interviews was considerably and then gradually grew to 27 names by the end of the naming process (see table 5.7). The interviews were analyzed in the order as they were held per company, first the seven interviews from Audiocom and then the seven from Lightcom. It was clear from the first interviews that were analyzed that most new names had been detected and then towards the later interviews occasionally an extra name came up.



Interview No	Perspective	Company
Interview 1	NPD	Audiocom
Interview 2	NPD	Audiocom
Interview 3	Manufacturing	Audiocom
Interview 4	Manufacturing	Audiocom
Interview 5	NPD	Audiocom
Interview 6	Mnfct	Audiocom
Interview 7	Manufacturing	Audiocom
Interview 8	Manufacturing	Lightcom
Interview 9	Manufacturing	Lightcom
Interview 10	Manufacturing	Lightcom
Interview 11	NPD	Lightcom
Interview 12	NPD	Lightcom
Interview 13	NPD	Lightcom
Interview 14	Manufacturing	Lightcom

Table 5.7 *Growth of new names over the naming process.*

Earlier in this chapter it was said that we needed to pay attention to the level of saturation that was reached with the limited number of projects that were investigated. From the trend curve in this figure one can see that an acceptable saturation was reached towards the end of the analysis and therefore it seemed not necessary to add a third company with additional projects in this research stage.

The threshold criterion for a name to be included in the list was that the particular name must have been found in the data from both companies. Names that were only encountered in one company and are related to only one data incident were dropped. The meaning of only 17 names will be discussed in the following section. The other 10 names can be found in Appendix V. The 17 that were chosen for discussion here show a strong relationship with the two fledgling categories *learning* and *disturbance* (see table 5.8).

Name	Text incidents related to:	Discussed
Testing	The testing of products during production	Here (1)
Suppliers	Products developed & delivered by suppliers	Here (2)
Tolerances	Running-in and subjective tolerances as well as tolerance chains	Here (3)
Understanding	Understanding between actors	Here (4)
Normal problems	Problematic situations that are somehow expected to occur, at least not surprising	Here (5)
Late adjustments	Interdependencies among concurrent development activities	Appendix V
Momentum	The kinetic energy of processes	Here (6)
Balanced design	The balancing between requirements	Appendix V
NPD attitude	The attitude of NPD regarding development	Appendix V
Switch	The switching of an actor from one type of work to another for a short period	Here (7)
Empathy	Emphatic behavior from one side of the interface to the other	Here (8)
Running-in	The running-in of production processes	Here (9)
Customers	The indirect influence of the customer on the quality of the product	Appendix V
NPD Philosophy	The deeper conviction of NPD on how to develop products	Appendix V
Procedures	The development of procedures before and during the ramp-up	Here (10)
Modularity	The use of modules in different products	Here (11)
Newness	New elements according to the interviewees	Here (12)
Functioning	The functioning of the new product	Appendix V
Weak signals	Weak signals of future problems	Here (13)
Front loading	The deliberate identification of future problems	Here (14)
Purchasing	The involvement of the Purchasing Department	Appendix V
Matching levels	The efforts to match the abstraction levels of interaction	Here (15)
Future state	Envisioning the future state of the new product halfway through the process	Here (16)
Revision	The revision of a existing product	Appendix V
Culture	The company's culture	Appendix V
Expectations	Agreed upon expectations	Here (17)
Quality departm.	The involvement of the Quality department	Appendix V

Table 5.8 *Overview of the names that were discovered in the data in order of detection. The first column gives the name, a short explanation follows in the second column and in the third column is indicated where that particular name is discussed, either here in Section 5.4.3 or in Appendix V. The number indicates the sequence of discussion.*

The 17 names that are discussed below are introduced in terms of what they signify followed by some quotes that illustrate their meanings. Their possible relationship with the two fledgling categories will further enrich these two categories, because some of the names will be akin to their properties. We will discuss the 17 names in the order of their appearance in table 5.8.

1) Testing

The first name that was discovered is related to the testing of products and was found in 68[19] text segments, being 5% of the total. Products are tested in many ways at many points during the product innovation process. In other words, testing that is done to the final product takes place in the later phases of the NPD process, during the manufacturing process itself or shortly after that. These are tests to check the quality of the final product after it has been produced by the real production line and before it is delivered to the customer. The tests performed on the various prototypes are different from this and are mostly used to find out if the correct development solution was chosen and if the final product which contains that solution is going to fulfill its functional requirements.

Because of the relatively large amount of text segments, it seems a fairly rich area. There is more than just the activity of testing. Before one can start performing tests on products, test programs and test procedures must be developed, software must be created, test locations must be set up, and test equipment must be manufactured. Apart from all this, the people who have to perform the tests must learn to operate these devices and they must also become accustomed to making decisions about the various thresholds for product rejection. Testing the kinds of electronic products that were looked at means that the product itself might contain part of the testing system, which means that some components in the product could be dedicated for testing. The functionalities around testing, whether they are inside or outside the product, are sometimes not directly related to the functioning of the product. This means that the customer who uses the product will in most cases not even be aware of these 'hidden' test functionalities. This seems to have implications for the NPD process. In both companies I found that explorative as well as exploitative activities related to testing are not really given a lot of attention compared to the attention paid to the product itself. NPD mainly concentrates on the product functionality and appears to leave the testing activities to other people and later stages. A person responsible for production line development at Audiocom formulates the focus on customer functionality as follows:

> *"…the main task for software development is to get the right software to the customer, not to the production [for test equipment] […] it is more difficult to get resources for software development for production than it is for the software for the customer…" (Audiocom.NPD.1.52)*

> *"….normally the test constructors are not very much in contact with the development department." (Audiocom.NPD.1.614)*

> *"….but there need to be enough resources for this sort of work. […] We need many people in early phases, but they are just doing other tasks…" (Audiocom.NPD.1.634)*

This situation can result in late adaptations to the testing equipment, to the software, and to the product itself. This could also lead to 'untested' test equipment or test equipment that is not ready for full production, like during the difficult ramp-up within Audiocom.

[19] The names that appeared early in the analysis it is interesting to mention how often they were found, because they were detected in the first interviews that were analysed. For the names from later interviews this is not the case. Some of them, especially those detected in the last series of interviews, were only found a couple of times during the first analysis. These were checked in earlier interviews, but only for their occurrence.

> *"…we had some problem with the test equipment as I remember . It didn't look very… that is a subjective view, but it didn't look very finished to me, it was very much on a prototype level…". (Audiocom.NPD.2.579)*

As a matter of fact, the testing problems formed one of the causes for the unsmooth ramp-up of this product. From this particular case we can see that when the explorative NPD activities which are related to the product are finished and the ramp-up begins, some people expect that the explorative activities which deal with the test equipment are also ready to make the transition to more exploitative activities. But this could never be the case since the test equipment can only be tried out on the first new products that come from the real assembly line. This is obviously not the case for subassemblies that could get tested at other lines or even by the supplier that produced the subassembly.

I have already mentioned that the people who perform the tests have to learn about the test procedures and sometimes even have to develop these themselves. They must also develop some awareness of the threshold criteria for rejection. This is more complex than it looks, because some of the quality requirements are rather subjective and don't have clear thresholds at all. These subjective elements make the ramp-up an interesting learning process that seems to contain explorative as well as exploitative processes. At the same time it connects testing to the tentative category of *learning* that will be elaborated in the next research stage.

2) Suppliers

Suppliers were mentioned in 80 text segments, which is 6% of all text segments. There seem to be quite a few problems associated with suppliers who are involved in the product innovation process. Many of the issues that the interviewees mentioned are associated with the ramp-up of the manufacturing processes at the suppliers, mostly products, parts or sub-assemblies that are new to the supplier. For the new product that is being developed, the outsourcing company might also need some suppliers to deliver newly developed parts, like plastic covers or lenses. The ramp-up of these new products from the supplier seems to cause difficulties sometimes.

> *"…then they [suppliers] run into problems because it is typical new parts for them to produce as well…" (Lightcom.Mnfct.1.345)*

What seemed to happen in those cases is that the suppliers deliver their new products to the 0-series or preproduction of the outsourcing company. At that moment, these products are found to be satisfactory, because the suppliers pay a lot of attention to these 0-series products. After the 0-series, both the outsourcing company as well as the suppliers ramp-up their manufacturing processes. The products coming out of these ramp-up processes might exhibit all kinds of little problems, which is normal during a ramp up. For example small tolerance problems with the supplier's products might cause the total production line of the outsourcing company to come to a halt. This is illustrated by the next quote from one of the people at Lightcom.

> *"…But one of the other things we typically see, when we do the 0-series we maybe have delivered from the supplier some glass [lens] with new specifications and that is a 0-series for him as well, to see, …OK, this looks good. We can use this one. And when we get to the real production and when we use his real production as well, … [then we realize] … this isn't the same good quality we saw in 0-series…" (Lightcom.Mnfct.1.421)*

And in Audiocom I hear the same thing.

> *"… we say that the supplier he should not deliver parts that are not OK. He is also stressed, so he tries it and it works and go right through to the production line and we find out it can't be fixed here, because something is wrong…" (Audiocom.Mnfct.3.488)*

So we see examples of these problems in both companies. What Ulrich & Eppinger (1995) call 'facilitate supplier ramp-up' is obviously not very well implemented in the daily practice of the companies that I have been looking at. But on the other hand, apart from this remark, Ulrich & Eppinger don't provide actionable theory or practical advices on how to facilitate such a ramp-up.

I also saw other interface problems related to suppliers, like two suppliers that have to cooperate in the design and realization of one module. This makes the interface between NPD-related activities and Manufacturing-related activities even more complex. In Chapter 2 it was decided that because of the additional complexity which the involvement of suppliers brings about, we won't focus on this potential category in this book. However, it must be mentioned here because our interviewees happen to talk about the supplier involved interface problems quite frequently.

In summary it appears that especially those suppliers that are developing **and** delivering new parts or components seem to cause most of the problems. In fact, they have an interface between NPD and Manufacturing similar to the one we are discussing in this study. This results in a Russian Doll like image: the interface between NPD and Manufacturing contains a supplier that has a similar NPD-Manufacturing interface. This complexity seems to have considerable influence on the NPD-manufacturing interactions of the outsourcing company and is therefore related to the fledgling category of *disturbance of ongoing processes.*

One final remark needs to be made: triggered by these interviews and in cooperation with other researchers, in a journal publication I presented a first draft of a typology of supplier-involved NPD-Manufacturing interfaces (Smulders et al. 2002). In the remainder of this thesis I will only refer to suppliers if this is relevant to the discussion.

3) Tolerances

As mentioned above, tolerances play an important role during the running in of production processes. In general, the tolerances of a part indicate that the physical variances within these parts are still acceptable for use in the end product. As such, tolerances are very relevant to the quality of the final product. During the interviews, I enlarged the content of this name to also include subjective and unmeasurable tolerances, as will be shown below.

From the interviews I have learned that there are a few problematic situations associated to tolerances and the interface between NPD and Manufacturing. One of these is tolerance problems related to the ramp-up period. It is not surprising both companies had problems with ramping up plastic parts that have been injection molded. The following two text segments from Audiocom illustrate this.

> *"…we also had some problems there, with a cabin part [= the back cover of TV-set]. The molding process on large plastic parts can effect the actual measures of the plastic part. If you don't have the correct process you might have some tolerances that don't fit and it takes time to run*

the production of large plastic parts and to have the exact way of dealing with all the parameters in the molding process…" (Audiocom.NPD.2.838)

"…if they only have made parts for 20 products, they have no statistic material to see if part nr. 500 is running out of the tolerances. They have to make thousands of parts before they … they know if their production machine is capable…" (Audiocom.Mnfct.3.478)

And at Lightcom we found tolerance problems in subassemblies that in themselves constitute a total of acceptable tolerances but when brought together crossed a threshold as can be read in the following text segment.

"…because you have a lot of mechanical parts that have to fit together and you have the optics through the product, has to be with very small tolerances between the lenses the way you place the lenses and then you see the tolerance chain on everything is maybe going in the outer tolerances of all the parts in the same time. You see deviations in the output of the product. But you first will be aware of that in the moment that you have running the production for a while…" (Lightcom.Mnfct.1.438)

Then there are problems with tolerances on the NPD side in regards to deciding what is or is not acceptable or describing some of the design details of the product. Some of these details are very difficult to define before the product is completely finished. For example, one of these could be the assembly of the wiring. In light products and television sets there are a lot of wires that need to be connected to each other and to different parts of the product. It is not until the assembly of the 0-series begins that one can see how the people on the assembly line will discover how to put the wires in. Changing the lengths of the wires is then sometimes necessary.

"…that will be something like a very small change, like this wire needs to be 2 cm shorter or 2 cm longer…" (Audiocom.NPD.5.514)

Other design details that are hard to determine during the NPD process are the subjective tolerances, tolerances that are not measurable and so must be developed during the ramp-up process. In fact, an explorative activity during a process that is, at that very moment, making the transition from explorative to exploitative.

"…If you turn up the volume, you get a coming sound from some of the mechanical parts. That is a very difficult process to run, because you have to make a lot of subjective work. Subjective decisions, is it good enough, is it not good enough…" (Audiocom.NPD.2.524)

It is clear from this text segment that it is hard for people to detect the right level of 'tolerances' in order to master the testing process on the assembly line. This process is, in fact, an explorative process on a micro scale and is therefore related to the category of *learning* that will be further elaborated in the next stage.

4) Understanding

Early on in the naming process an important communication variable was identified: understanding. If one party gives information to someone on the other side of the interface, this information needs to be understood correctly by the receiver, i.e. the receiver needs to perceive the same meaning as the sender intended. This is necessary for efficient and effective interactions.

> *"…so the man in the test equipment department he has to be good at communication to tell this problem, so they can understand it…" (Audiocom.NPD.1.626)*

During our analysis I decided to also include under this name what the interviewees said about having or getting knowledge about something. I then realized that apart from this cognitive understanding and knowing, there also exists such a thing as physical understanding: knowing how to do something. This is related to what actually happens during the ramp-up of a new product. The word 'complex' in the following two text segments refers to the fact that other people does not readily understand assembly activities of the DVD unit. They must first create this understanding before they can assemble it.

> *"…Again in the for example the DVD units that compared to the rest of the concept, in fact it was a very complex function to do the assembly on…" (Audiocom.Mnfct.7.417)*

> *"…So the basic concept is very good for production, but the DVD unit again was a new function, we had to implement it in a known design, known architecture of the product and where you have this space you can put it in that way and of course ….we came up with a very complex unit. Complex with the unit itself and also about the wiring around in the product was very complex…" (Audiocom.Mnfct.7.423)*

Finally there is understanding related to the comprehension of the processes on the other side of the interface.

> *"…now, I have a background from product development, and I know a lot about the things, and how they think and how they develop a product, the software, the hardware, the mechanics and so on. That has of course been useful when I changed to production…" (Audiocom.Mnfct.4.42)*

It will not be surprising that understanding is one of the properties of the category on *learning*. But there is also in some way, a connection with *incomplete information*. When the receiver doesn't understand what is said to him this could be because the information he receives seems incomplete to him while this is not the case for the sender. This name of *understanding* will further be discussed in the next stage.

5) Normal problems

This next identified name might seem strange at first glance: *normal problems.* Normal problems refer to problematic situations that are more or less expected to occur at generally recognized moments during the innovation process. For example, in nine out of ten cases there will be tolerance problems with large plastic parts during the ramp-up period.

> *"…So we always have a lot of problems, when we start up there [ramp-up], with those big surface parts.* ***For all the televisions?*** *Yes pretty much for all…" (Audiocom.Mnfct.6.244)*

I have identified two types of normal problems: problems that have known solutions and problems that have familiar strategies which are used in order to identify a potential solution.

> *"…So they [NPD] are focused on developing new things and very often they have to take solutions that they have tried before, but not in all cases these solutions are very good for production…" (Lightcom.Mnfct.1.29)*

> *"…And cooling is always a big problem and that is one of the reasons we sort of changed the process right now. A lot of engineering we put in the concept phase, so now we will have a working model, with cooling working and everything in the concept phase…" (Lightcom.NPD.5.486)*

In fact, both types of normal problems refer back to what was learned from former product innovation projects. I didn't realize until I write this that every time an interviewee mentions something that is expected to be **difficult** in his opinion, they are referring to past experiences and thus to more or less normal problems that are expected to occur during every product innovation project. It could also be that less difficult elements like specific procedures might be the result of past problematic situations that have been implemented to overcome or prevent such a situation. However, this additional perspective is too broad for our purpose of naming. Furthermore, this research concentrates on the interface between NPD and Manufacturing within the boundaries of one single project. We are not directly looking at the learning that takes place across the various NPD projects.

6) Momentum

In the data I identified something that points towards processes on the other side of the interface from the interviewee that have the propensity to keep on going; there seems to be some sort of *momentum*.

> *"… sometimes they choose a solution that causes quality problems, known quality problems, introduce it again and again because they do not have the time to rework that solution…" (Lightcom.Mnfct.1.31)*

The processes on the other side of the interface seem to proceed on their intended path irrespective of small interventions from across the interface to which endeavor to alter it. There seems to be some impetus (kinetic energy) hidden in the explicit or implicit string of activities so that the interventions from the other side doesn't seem to have the right kind of influence on the process.

> *"…That they are focused a lot of…on doing their production. It is not easy to do 0-production up there. Because they are focused on doing, what actually is their normal production…" (Lightcom.NPD.4.569)*

The name of momentum gives an interesting perspective on the interactions between NPD and Manufacturing and especially on the tentative category on *disturbance of ongoing processes*. Momentum could proof to be a valuable property of that fledgling category. Therefore, I will take momentum with us to the next chapter.

7) Switch

In the discussion on the tentative category on *disturbance* (5.4.2) a group of interactions was discussed that showed a relationship with changing from one line of work to another for a short period of time. This was named *switch*. The following quote illustrates this.

> *"…So, you try to get feedback from these people, but that is … the problem is… is … to convince them to…. to …. use time uhhh… with very little knowledge about … well to go out of their normal and everyday life what they are going … to something that is totally new and then give feedback…" (Lightcom.NPD.4.41)*

Here it is clear that the daily processes and activities must somehow be interrupted in order to pay attention to the request that comes from the other side of the interface. This switching therefore could become a property of the tentative category of *disturbance of ongoing processes*.

8) Empathy

In the cooperation between NPD and Manufacturing somehow the respective participants need to have some *empathy* regarding the characteristics of the processes and actors on the other side of the interface. Especially for NPD, it is necessary to develop a sensitivity to what it is like to work at the assembly line having to assemble hundreds of products every day.

> *"…I [someone from NPD] could put in a clock even if it is a bit difficult, but I have to make only one product today, because it is a prototype. So it doesn't matter if it is difficult. But on the assembly line they have to put in 300 and they have to do it correctly. That is why it should be easy and it should be very …what is it called? …you should only do it in one way…" (Audiocom.NPD.2.1029)*

For some interactions more empathy could increase the efficiency or effectiveness of the cooperation between the two processes.

> *"…But they don't have the same... feeling therefore what is going on... So one small problem in production, that may stop the production line with 25 people working there, they don't have the same urgency to solve the problem as I do, because I have 25 people waiting and in this company they are not just waiting, they are waiting in my office…" (Lightcom.Mnfct.3.93)*

As such, *empathy* may be somewhat related to the category of *disturbance* that I will discuss further in the next chapter.

9) Running in

The aim of the production line ramp-up is to reach a certain balance regarding many aspects of the manufacturing process. Such a balance is necessary to reach the intended quality of the end product. During the ramp-up there are many sub processes that need to go through some kind *running in* stage. Especially the molding processes of large plastic parts seem to need such a running in period.

> *"…If you don't have the correct process you might have some tolerances that don't fit and it takes time to run the production of large plastic parts and to have the exact way of dealing with*

all the parameters in the molding process. And it affects also the design of the component…" (Audiocom.NPD.839)

But not only plastic parts seem to suffer from those kind of problems, also metal parts need to be run in.

"…And we have some problems with …. you know sometimes when you have starting a new product, the product can be OK when it is finished here, kindergarten … when the first series is over, we can see it is OK, but we make 200 to 300 machines we discover some problems with the metal parts…" (Lightcom.Mnfct.2.263)

The *running in* problems seem to be allied with the *normal problems* that we discussed earlier in this section. But there also seems to be some connection to the tentative category of *learning.* Where they are relevant and illustrative, these data incidents will be used in the next chapter.

10) Procedures

Immediately before and after the ramp-up of the new production line all kinds of procedures must be developed and introduced on the work floor. These procedures seem to play an important role during the final conversion from the NPD deliverable to the activities within Manufacturing and Assembly. So far, I have identified procedures for assembly, testing, production and approval. The following four text segments illustrate these, respectively.

"… speaker wires… has to be a… to put together, just before putting in to the printed circuit board, that they were doing it in another way, [they need] do it in the same way as we put those in at the [preproduction] stage" (Audiocom.NPD.5.693)

"…So what we had to find is at what stage of volume….at what volume step we shall do the test. …" (Audiocom.NPD.5.969)

"…What we should check up there was that the solder profile was correct…" (Audiocom.NPD.5.1000)

"…And then we say that parts approval procedure has to be finished before production start. That will say for example the big plastic frame, everything that has to be … new things that have to be used, have to be approved, complete 'the book'. Is the quality OK and so on for the test part. All those things has to be ready before we can start production…" (Audiocom.NPD.5.1088)

In the interviews I also heard about problems that occurred during the ramp-up which were linked to missing and unclear procedures or procedures that were not communicated very well. It is not clear who is responsible for developing all the procedures. In a way one would say that the procedures constitute the ultimate *NPD deliverable*. But I also saw that some of the procedures were developed during the first weeks of the ramp-up and form more or less the final explorative activities. In any case, in the next chapter *procedures* will be related to the category on *learning* and to the *NPD deliverable.*

11) Modularity

Companies nowadays try to work with modularly designed products to lower development and production costs. However, modules or parts that were originally designed for another product can cause trouble in their new situation. At Audiocom they used the electronic 'engine' of an existing product (already in production) for a new model.

> *"…Although it was an engine that was already known and was used in production, it suddenly had to be used in quite another way in this TV and a lot of printed circuit boards were situated in another way and let us say such things like electronic magnetic shielding etcetera was suddenly a problem…" (Audiocom.NPD.5.246)*

The problem seems to be that for such complex products the reuse of an existing module might cause the developers to pass over important stages of their development work. In this case, they took the module as it is and developed the rest around it, without recreating a balanced total design. This might not be problematic and result in cost savings for simple products, but for complex designs the reuse of a module might introduce unforeseen *disturbance of ongoing processes* because of downstream problems and additional interface interactions.

12) Newness

The incidents that were named under *newness* refer to circumstances that were according to the interviewees, new in relation to former projects. Newness as it is meant here offers a continuum that ranges from small changes in, for instance the layout of the assembly line to the introduction of a completely new testing system or installing the first DVD unit in the product. At the same time newness is a subjective measure depending on the viewpoint of the individual observer. This makes it hard to fill such a continuum unambiguously on the company level. It is also not clear what criteria the interviewees used by to label something as being new. Sometimes the amount of problems caused by the new element seemed to be the measure, and sometimes the fact that they had never done anything like it before. But also a new combination of existing or known elements could indicate newness, like we can read below.

> *"…there are some new functionalities in it, actually there is a lot of new functionality, but the main part of this product was putting all the functionalities that we have in the factory into one product. So, and that in itself is a huge step but not a lot of new technologies.*
> *That … that … uhh… the learning process of that is difficult…" (Lightcom.Mnfct.3.398)*

Here we see that this new combination of existing technologies (knowledge) resulted in a longer and more difficult learning process. Regarding newness, it is important to realize what the possible consequences are of the implementation of new elements into an existing organizational environment. As a result, the people within the environment sometimes need to go through a time consuming adjustment or learning process. On the NPD side, newness seemed to be seen as something that needs extra attention and or extra design iterations. But then it is a matter of identifying those new elements and not overlooking them.

> *"… so, any time that we have to develop something that is new then it needs more coordination, it needs more feedback [from production], it needs more … let's say more loops […] of course, it also goes wrong sometimes. Because you … you actually … where it surprises you. When you do a project and you think 'this is so easy to do', and you do something and you think 'this is just like ..' and then it isn't…" (Lightcom.NPD.4.169)*

Overlooking the consequences caused by new elements is what seems to happen quite often and is maybe related to the 'surprises' in production that were mentioned in Chapter 1. But newness is a relative concept because sometimes just the replacement of a component by another supposedly similar component might have unwanted and unforeseen consequences as we can see below.

> *"…There are a lot of problems with the PCB's [PCB=printed circuit board] of the [product], because they used a new component on the PCB and the component was not compatible with our software loader. So we could not upload the PCB with software […] they [NPD] thought they were finished with the PCB.* ***They [NPD] thought they were ready?*** *Yes, but you know when we have 0-series, we start with ten products and all of them were OK, […], but when we started the first ordinary production we were starting with twenty machines and when we where done with the twenty machines, we found out that there were problems with our uploading of software…" (Lightcom.Mnfct.2.140)*

It seemed so simple to buy a new component for the PCB which supposedly had the right specifications for the planned features of the new product. However, the old specification to upload improved software releases was overlooked and caused a lot of trouble later in the process. The name *newness* appears to share aspects of *learning* in terms of the identifying the consequences of new elements and with the category of *disturbance* if such a detection process is not adequate enough. The following two names are very much related to this detection and prevention process.

13) Weak signals

The issue of *weak signals* is related to the prevention of troublesome situations in the downstream processes. As was discussed under *newness,* NPD aims to solve as many problems as possible before production starts. Most of these problems are detected during the successive design-build-test cycles which are related to constructing & testing prototypes. Sometimes the information about possible future problematic situations is too weak for taking action as we can see from the following quote.

> *"…We saw too many problems in the ramp-up phase that we could have solved before, if we had focused on the indications we saw.* ***There were indications?*** *Yes, there were indications, we just were too busy getting on with the product I think…" (Audiocom.Mnfct.7.473)*

Such haste is mostly caused by the pressure to reach the market introduction date. And the same interviewee also mentions that a lack of diversity within the group of people who were involved in the project resulted in not picking up these weak signals.

> *"…we were all part of this group and all had the same focus and the same picture of what was going on and sometimes we were a bit blind I think, we didn't see indications…" (Audiocom.Mnfct.7.515)*

Sometimes it is even a deliberate choice not to react to these signals and continue with development until there is a production stop or when the costumers complain.

> *"…we are aware that the solution isn't the most optimal and sometimes we ask to make another solution instead and we know that they [NPD] realize that. But they don't do it, because they don't have the time. They don't have the engineers, the resources to put on it, and afterwards*

they don't work on the product again, unless we have directive production stops, or the market complains about the product…" (Lightcom.Mnfct1.75)

The most important thing is that NPD solves most of the problems before they reach the ramp-up, at least those problems that somehow could be foreseen.

14) Front Loading

The second name that is related to this upfront problem solving is *front loading*[20]. In Chapter 2 we discussed the role of prototypes as being early problem detectors. Having meetings that solely focus on future problems is what was heard at Audiocom.

"…We have a lot of meetings during development where we sit and write down, we call it a storyboard, where we question and write down 'what can go wrong?'. What can go wrong? What can go wrong? What can go wrong? How many ways can we do this? and so on, what result will that give? Trying to remove all the problems, and all the possibilities of problems." (Audiocom.NPD.5.849)

But according to the same interviewee one has to be prudent with removing all possible issues.

"…But we also have to be careful, if we go in and say 'this can rattle and this can rattle' and we say that before we see it, then we add on a lot of costs that we do not know if it is really necessary. Because you never, never get rid of it [that solution] again. So we go in and say 'this one here rattles' […] We look at it and we say. 'if it rattles [during ramp-up] we have a solution'. But we do not do anything before we see it rattles…" (Audiocom.NPD.5.853)

However, involving the people from Manufacturing is not always that easy because they don't know the product yet.

"…it is very … it is difficult if you have […] some development people that are working on the project all the time and have the product in their mind and then you ask [Manufacturing] people to come in to give their opinion…" (Lightcom.NPD.4.34)

Front loading is not only about solving product problems before they occur, but also a matter of being prepared for anomalies once the product goes into production as the following quote illustrates.

"…I saw the problem in the concept phase, in the construction phase […] What will I do? And that was not a problem for me, because I had the idea about a special group for starting up new products…" (Lightcom.Mnfct.2.240)

Unfortunately, there will always be problems that can't be foreseen during the development process although the participants will believe that all problems have been detected.

"…I will probably underestimate the next products as well…" (Lightcom.Mnfct.3.416)

[20] Front loading is a concept introduced by Thomke & Fujimoto (2000) and aims at detecting possible down-stream problems early in the design process.

This underestimation is a strange phenomenon and demonstrates that reality is, in most cases, much more detailed than can be imagined beforehand. At the same time it points towards an aspect of *learning* (problem solving) that must and will take place during an action which can be impossible to attain before that action.

15) Matching levels

With *matching levels* it is meant that the actors try to find the right abstraction level for having effective and efficient interactions with the other party. In the preramp-up period the matching is related to finding persons within Manufacturing that are able to discuss issues at the required level regarding the state that the development process is in.

> *"…Because, many …e.g. mounting, you can say 'OK, this is maybe not very easy but you can do a fixture and then you can work around it.' So, you are trying to find a level with the production people, or the service people … or … and try to find […]. You need to have somebody who can actually … who can discuss on that level. You cannot take a third person that doesn't know anything about the product and do that…" (Lightcom.NPD.4.110)*

And this matching also seems to be important during the ramp-up, but then in a reversed form. Meaning, that the presence of NPD during the ramp-up makes it possible to stay in contact with what is happening during the start of the production line and to know the concrete issues that are of concern.

> *"…the cooperation, the communication between us is so close, so they [NPD] see the problems we have, they see and hear and feel them, because during the ramp up phase, when we have these problems we need them [NPD] to help us to find what is wrong here. When we have found the reason we have to work together to find some practical and good solution which satisfies both the product quality and the production…" (Audiocom.Mnfct.4.278)*

This name is, in fact, a more detailed version of what we discussed earlier as *understanding* and therefore might also prove to be a property of the fledgling category of *learning*.

16) Future state

For being able to discuss the design of the new product in the preramp-up period it is necessary for the participants within Manufacturing to imagine the *future state* of the product and its manufacturability. But this is also necessary to make calculations on the future cost of the product.

> *"…We typical ask the people here on the [production] line 'We have a new product [prototype] here, how can you produce it? What does it take to you to make production of this in the line you have already?'…" (Lightcom.Mnfct.1.494)*

However, this is not always as easy as it sounds. From the NPD side they have a different view on that.

> *"… but the problem is … we have actually more … I would say, the worst supplier we have […] is ourselves, is the production.* ***As supplier?*** *Yes, so that is actually …* ***Why is that the worst supplier?*** *Because they are not as focused on selling as the other suppliers. […] it is … it is difficult [to get a price], because they have to use time on that and they are not used to … they are focused in there on their production … every day production. […]*

We actually have to take the part and ask somebody to give their price on it, an outside supplier…" (Lightcom.NPD.4.482)

It seems that imagining the future state of the product as it will be in production and make calculating the cost sometimes takes too much effort for the actors in Manufacturing. This particular kind of situation is also linked to what was discussed under *momentum* and *disturbance* because it is not easy for NPD to intervene in the activities of the actors within Manufacturing and ask them to do something different.

17) Expectations

The last name that is discussed here refers to what the actors on both sides of the interface believe that the other will deliver and is termed: *expectations.* To be able to cooperate efficiently and effectively it is necessary to know what you expect from each other.

"… I think an important issue here [in the cooperation between NPD and Manufacturing] is to agree on the expectations. What do you expect from them [NPD] and what do they expect from you, so I think that is really a key point to agree on, the [mutual] expectations…" (Audiocom.Mnfct.4.94)

Because of this explicit focus within Audiocom there seems to be less trouble with creating and keeping such agreements. On the other hand, the frequent interactions between NPD and Manufacturing within Audiocom seem to prevent the occurrence of diverging expectations. Within Lightcom the geographical distance between the NPD premises and Manufacturing makes it more complicated to create such mutual expectations.

"…The problem is that there are two different pictures of what they [R&D] have to do and of what production has to do…" (Lightcom.Mnfct.7.356)

Because of this mismatch in expectations it is not surprising that Manufacturing within Lightcom is sometimes surprised that some of the development work seems to continue during the ramp-up. In their eyes these development activities are *disturbance* of the ongoing ramp-up processes.

5.5 Reflections on focusing stage

The overall purpose of this stage was to collect richer data to be able to identify some answers to the sub-research questions. The intention was to use the data for three things (1) to discover new conceptual categories, (2) to check the empirical value of the tentative categories from the earlier chapters and to upgrade them into fledgling categories, and (3) to identify properties of and relationships between the categories.

These findings need to support the theorizing process in the next, integrating research stage. Apart from discussing these aims, in this section I will also reflect on the research approach, and the companies and projects that were used as subjects.

5.5.1 First aim: identification of new categories

Besides appraising the tentative categories that we began the focusing stage with, I also wanted to become open to other possible categories that could help describe the interactions between NPD and Manufacturing. There were 27 identified names that all relate to the interface between NPD and Manufacturing. The growth in the number of these names was large at the outset of the analysis process and gradually decreased to a few new names towards the end. At that point it was then concluded that sufficient saturation had been reached. This implied that there was no need to include a third company in this study. This saturation must be seen as an indication with a relative character because it is strongly linked to the level of knowledge and understanding of the NPD-Manufacturing interface that has been reached in this research project at this moment, that is, a first plateau of saturation.

Under the 27 extra names that have been identified there are two names that seem to be important for the participants in relation to the interface interactions: *testing* and *suppliers*. This was at least true in the two companies that I investigated. These two can't be properties of the social process that I am looking for. *Testing* seems to be more a subject of interaction whereas, *suppliers* form an extra party, but both don't seem to be specific forms of interaction.

Testing refers to the testing of the products during the Manufacturing process or shortly thereafter. From the data gathered in this stage it seems that *testing* deserves additional attention from the NPD & Manufacturing participants during development. The connection of *testing* to *learning* and with the NPD-Manufacturing interface is, as described in Section 5.4.3, that the production people seem to be responsible for the development of test procedures and to learn about the associated thresholds for product rejection. From the interviews it becomes clear that this is sometimes a difficult process that seems to occur during the preproduction series and during the ramp-up and therefore is encompassed by the NPD-Manufacturing interface.

The name *suppliers* and what it refers to is also not a property of either of the two categories. From the data it becomes clear that the suppliers are an important party regarding the NPD-Manufacturing interface of the outsourcing company. They seem to cause *disturbance* within their client company and these issues are especially disruptive regarding the ramp-up and the interactions between NPD and Manufacturing. But as I said in Chapter 2, I will not further include *suppliers* in this study as an extra party.

5.5.2 Second aim: appraising and upgrading the tentative categories

Before it was possible to upgrade the tentative categories, the empirical quality regarding the interface under investigation needed to be verified. The results of this focusing stage clearly indicate that all ten categories are relevant regarding the interactions between NPD and Manufacturing. However, what I have learned during the data analysis is that not all of the ten tentative categories at the start of this second stage were formulated on the appropriate level of abstraction.

Regarding their formulation I found that some tentative categories were too abstract while others were too concrete. Being too abstract, like *communication,* resulted in a kind of data incidents repository that doesn't really support the theorizing process. Data incidents merely fit or did not fit under the category umbrella as a kind of black and white choice which missed the nuances that are necessary to create a better understanding of our substantive area of research. So, categories that were too abstract didn't result in the stepping-stones of understanding what is being

looked for. On the other hand, the categories that were too concrete, like *incomplete information* and *differences,* could not be developed into categories either because they seemed to only enlighten a small aspect that I then called a 'name'. However, these new 'names' seemed to relate to the tentative categories that had been formulated on the suitable level of abstraction. This implies that they might be of use as properties belonging to the conceptual categories in the theorizing process in the next stage.

We also have tentative categories, like *prototyping, involvement & location, target* and *planning* that seem to be influential regarding the interactions in our substantive area, but we are missing detailed information of what really happened during the interface interactions that are associated to these potential categories. I then suggested investigating these issues in another project by witnessing the actions and processes which involve them, i.e. witnessing prototype fabrication and discussions, target setting discussions or planning sessions.

The upgrading of some of these tentative categories into fledgling categories might support the integrating process in the next stage. In the beginning of this chapter two requirements for the selection of 'fledgling' categories were mentioned: (1) they must be relevant to the actors, meaning that the potential categories must encompass a considerable number of text incidents. (2) Fledgling categories must be central to most of the other names and categories which is indicated by their interrelationships.

However, during the analysis it became clear to me that for a category to be close to becoming the core category it must have a certain behavioral character because I am looking for a social process. The tentative category *NPD deliverable* which seems to be a major driver behind most interactions misses this actionable character and it therefore didn't make much sense to relate it to the other categories. Therefore, I realized that a third requirement for a fledgling category was necessary, an orientation towards action. The two other categories, *learning* and *disturbance of ongoing processes* are sufficiently action oriented to assist in the process of describing what is happening between the actors from NPD and Manufacturing, that is, to answer the main research question. In addition, they are obviously also relevant to the interacting participants because of the relatively large amount of the data incidents that they cover. In the next section, I will review the second requirement in light of these two categories.

As said earlier, the tentative category *NPD deliverable* is not action oriented enough but it still seems to be very relevant. Therefore, this category will be investigated further in the next stage to discover its role during, and influence on, the interface interactions. This will be done by finding answers to some additional guiding questions.

5.5.3 Third aim: Discovering properties and relationships

This third aim forms a first step towards integration by identifying relationships and properties among all these categories and names and the fledgling categories. It must become clear if such a 'web' of relationships is promising enough for further integration towards a core category. These interrelations also provide insight about the third requirement for a category to become a fledgling category. As described in the last section, *learning* and *disturbance* seem to be the most promising categories for further elaboration. During a further analysis of these two, an important empirical connection between them was identified: unexpected problems. Unexpected problems disturb the ongoing processes to such an extent that an explorative learning cycle is needed to solve

them. In fact, this is a new name that includes data incidents that were placed under *disturbance* as well as under *learning*. During the first data analysis these data incidents were not given an extra label. A further analysis shows that 85 incidents, being 6.5% of the total, were labeled under *learning* as well as under *disturbance*. This relation appears promising. What about the other categories and names, how are these related?

Out of these 27 names, 16 names (the 17 discussed earlier minus *suppliers)* seem to have relevant connections to the two fledgling categories. From the 10 tentative categories that this focusing stage began with, 2 could become the fledging categories and 2 categories do not seem to be at the right abstraction level (*communication* and *involvement and location)*. The other six also appear to be related to the two fledgling categories. Figure 5.5 provides a conceptual overview of possible relationships that the 6 tentative categories and 16 names might have with the 2 fledgling categories of *leaning* and *disturbance*.

There seem to be roughly three groups of relationships: one group about subject related interactions between NPD and Manufacturing, one group of potential properties of the interactions and a last group of specific forms of interactions. However, depending on the situation, a subject related interaction like planning could also be a specific form of interaction. On the other hand, *prototyping* which is now placed under a specific form of interaction, could also be a subject of interaction. *Switching* can also be seen from two relational perspectives: as being a specific form of interaction but maybe also as a property of an interaction, for instance if the actor needs to switch from troubleshooting in the exploitative area to evaluating a new design as part of the explorative process.

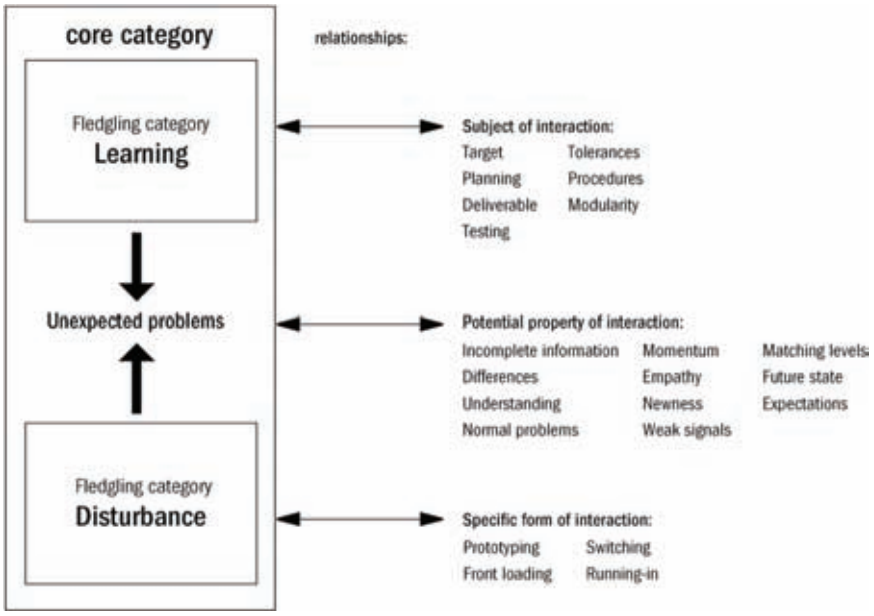


Figure 5.5 *The fledgling categories and their potential relationships with the theoretical concepts. The concepts are not unambiguously divided over the three groups of relationships. Prototyping for instance, now seen as a specific form of interaction, could also be seen as a subject of interaction.*

But all in all, the two categories *learning* and *disturbance* and their relationships with all the other concepts seem to fulfill the three requirements for becoming fledgling categories and to take them to next stage for further integration into one core category. In other words, what has been identified during this focusing stage provides some footholds for answering to the two sub-research questions:

1. *What fledgling categories with what properties make a description of the interactions between NPD and Manufacturing possible?*

2. *How are the categories and properties related?*

The two fledgling categories and the category of *NPD deliverable* together form the main pillars that will be used as the framework to construct the core category. Therefore, these will be taken to the next and integrating research stage.

5.5.4 Reflecting on the research approach

The research approach that was applied in this focusing stage seems to have fulfilled its expectations. It was possible to sort out the tentative categories and select the ones that look most promising for further elaboration as fledgling categories. At the same time, some new potential categories that might be investigated in future research activities were revealed. I also identified some promising properties and relationships among them that will be used in the theorizing process of the next stage.

However, there are two elements regarding the research approach that has perhaps limited the data collection. The first is that due to the setup circumstances most of the interviews were held shortly behind one other without the possibility of being made into transcripts, let alone giving me time to analyze these transcripts. Although the data-set that was collected proved to be quite rich, I believe that spreading out the interviews, giving time for a subsequent analysis of the transcripts in between them, would have resulted in more focused interviews during the later part of this research stage. I would then have been able to concentrate more fully on some of the more interesting names and categories that came up rather early in the analysis. This would most probably have resulted in a more focused data-set instead of the broad and large one that was collected. On the other hand, the 'broader' set might be more appropriate for the exploratory character of this study and might even open new directions for future research.

The second element is related to the decision to hold retrospective interviews. Some of the names that were discovered up to this point do indeed influence the interactions between NPD and Manufacturing but due to our retrospective approach it was not possible to reveal the real interactions between actors from NPD and Manufacturing which belong to these names. To further investigate these issues I have the impression that it is necessary to be a witness to the actual discussions. The present research by Kleinsmann, Buijs & Valkenburg (2005) forms just such a research project. She is collecting data in an on-line situation which concentrates on shared understanding among developers during the development process.

All in all, the data that has been collected in this focusing stage proved to be useful enough regarding the aims of this exploratory study and therefore the ex-post approach was a good one.

5.5.5 Reflection on the selection of companies and the projects

The choice of only two companies, Audiocom and Lightcom, and four projects was satisfactory. Although Audiocom seemed more professionally organized than Lightcom, both companies were very serious about their product innovation processes and product innovation structures. Both companies seemed to 'lie in wait' for opportunities to improve these processes and all the interviewees I spoke with showed a high level of involvement regarding their work and their openness to new ideas. The fact that the NPD-Manufacturing interface at Lightcom also showed a geographical distance proved to be an interesting variation; at Lightcom the mutual involvement in each other's processes seemed to occur less often than at Audiocom.

The variation in projects, one smooth transition and one troublesome transition, also resulted in richer data. This means that some things that were a minor problem for the smooth transition caused larger but similar problems for troublesome transitions. This provides more variation which could be useful in describing the properties belonging to the categories. But again, I have the impression that for a deep understanding of the differences and similarities in interactions between two such projects one has to be there, one has to be a witness to what happens. Not just an ordinary witness, but a knowledgeable witness, someone whose perspective is informed by a research exercise such as this one so that he/she knows what to look for.

In conclusion, it can be said that this second research stage delivered more or less what was aimed at. However, I would advise future grounded theory researchers to spread the interviews over a longer time period in order to be able to analyze the data in between interview cycles. This would probably make such a stage more efficient.

6 *The integrating stage: On attempting to synchronize*

This chapter describes the in-depth analysis and integration of earlier categories into one core category. The aim of this chapter is to provide answers to the main research question. The chapter begins with some methodological issues regarding this aim and the formulation of some facilitating research questions (6.1). This is followed by a description of the processes and the necessary knowledge to achieve volume production by the end of the ramp-up (6.2). Section 6.3 describes the conceptualizing process as a stepping-stone towards the core category. In Section 6.4 the core category of synchronizing incongruous mental models is presented together with the concept of a 'noetic template' as being the end result of the explorative activities. This is followed by a description of the maturing process of the noetic template over the development phases (6.5). The influences on the mental models of the actors by the synchronizing processes are described in Section 6.6. This chapter ends (6.7) with evaluating the results in the light of the main research question, considering them as the outcome of the grounded theory approach, and a reflection on the research activities that took place in this integration stage.

6.1 Integrating stage research setup

In Chapter 3 we discussed the possible stages within the research process of this project. It was then stated that this third stage of data sampling could become an integrating and theorizing stage in which the findings of the previous stages would be integrated into a conceptual core category (see fig. 6.1). The general process of this integration stage is, like in the first two stages, to engage in an inductive process that uses data incidents, names, categories and the fledgling categories that were identified earlier. However, as opposed to the inductive process in the last two stages (Chapters 4 & 5) that had a diverging character, the inductive process in this integrating stage has a converging character and can be regarded as being a conceptualization process. This will be clarified later in this chapter (6.3).

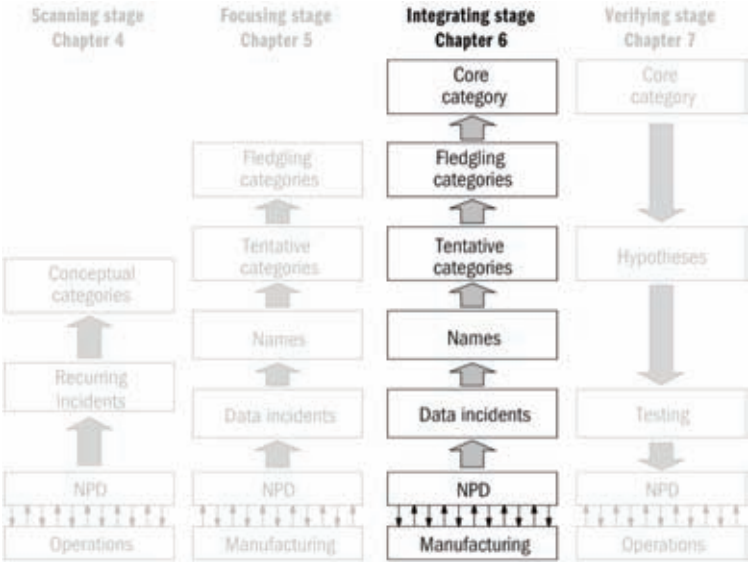


Figure 6.1 *Overview of the research stages (equivalent to Figure 3.4)*

The preliminary answers to the sub-questions, as were discussed in section 5.5.3, are promising enough to continue the research process as planned with this integrating stage and aim to result in reasonable answers to the main research question as reformulated in Chapter 3:

What happens during the interactions between the actors from NPD and Manufacturing?

The two fledgling categories *Learning* and *Disturbances of ongoing processes* together with their properties and/or relationships with other categories will serve as 'pillars' that will hopefully lead towards the identification of a core category. The core category describes, at least hypothetically, the pattern of behavior within interactions between NPD and Manufacturing and forms what grounded theorists call the basic social process.

However, a description of the interaction process isn't enough to fully understand what is going on, because such a description overlooks what the participants in NPD and Manufacturing are interacting for: it misses their goal, what they are trying to accomplish by interacting. The future goal reveals

the intentions of the actors and provides additional explanation to the description of the interaction processes itself. It is the intentionality of the actors that guides the interactions between them. According to Weick (1979), to historicize a future outcome and treat it as if it has occurred enables us to make sense of what led to that situation[21]. It is helpful to describe such a future situation in the "future perfect" allowing us to view it as the situation that will have been reached. The end of the ramp-up period when the Manufacturing process has reached the targeted volume production is the future situation the participants are aiming at. In Chapter 5, when we discussed the tentative category *NPD deliverable,* I wondered what the deliverable of the explorative activities could be. There didn't seem to be one specific deliverable that is handed over to Manufacturing, but instead a series of interim deliverables (drawings, specifications, BOM) that are successively supplied to Manufacturing. Therefore the following additional research questions were needed to guide the research activities during this integrating stage.

- *What is the final outcome of the explorative activities?*
- *What are the participants interacting for?*
- *Can we speak of a deliverable or what else forms the output of exploration?*

The answers to these questions helped in formulating the conceptual answer to the main research question. In Section 6.2 the situation at the end of the ramp-up will be described which forms part of the answer to the above questions. Later in this chapter, in Sections 6.4.2 and 6.5, further answers will be provided.

The two fledgling categories are treated differently in this stage. Based on the insights gained during the first two stages of this research I know that apart from the relationships among the categories, names and properties some footholds are needed to be able to integrate the categories into a core category. As we have seen in Chapter 2, there is a large body of available literature about *learning* that provides theories on individual learning as well as on organizational learning. These theories could provide supportive stepping-stones during the inductive processes. The same holds for the category *disturbance of ongoing processes.* The literature on organizational change and change management, although mainly concentrating on higher levels of aggregation than the level of the individual actors, seems intuitively related to the disturbance of existing individual activities by the actors of our two processes. This journey through the literature resulted in additional bodies of literature that also appears to be related, like literature on knowledge management & knowledge creation, literature on mental models & team mental models, and literature on shared understanding.

Within the process of grounded theory one must be careful with the application of existing theories and prevent forcing the data into that theory (Glaser & Strauss 1967). However, later in the theorizing process, and especially during the final conceptualization, there is more room for using existing theories as the following quote from Glaser (1978) illustrates.

> *"Later as the generating continues, comparisons with extant theory may link it [the emerging theory] to a number of diverse theories which touch upon various aspects and levels of the emerging theory. This linking, at minimum, can place the generated theory within the body of existing theories." (Glaser 1978, p. 38).*

[21] This resembles the process of 'rational reconstruction', that is in use in philosophical research. See e.g. Habermas 1986. Rational reconstruction stands for reconstructing the rationales that underpin a certain observed behaviour.

He refers to this use of literature as 'reading for ideas'. By staying as close as possible to the data, the trap of coercing the data is avoided. In our case this was not an issue because the aim of this project is not to develop a new or additional theory on *learning* or *disturbance*. I only used these theories as ladders (or rungs of ladders) to support the theorizing process to guide me to the core category.

It is impossible to give a detailed description of the conceptualizing process that has occurred during this integrating stage because of the countless times that I dipped into and out of the empirical data and jumped up, down, and sideways among the categories (names) and the respective theoretical ladders, including the ladder that I was 'constructing' myself. It was during this creative, analytic, and open-minded process that gradually a conceptual framework emerged that seems to provide understanding of most aspects of the interactions between NPD and Manufacturing. My experiences resemble how Glaser describes this process:

> *"Grounded theory is multivariate. It happens sequentially, subsequently, simultaneously, serendipitously, and scheduled" (Glaser, 1998).*

Thus, it is impossible to describe the process of theorizing, but it is possible to provide the reader with some stepping-stones and to show the groundedness of the resulting core category by means of illustrative data incidents.

In the following section (6.2) I will describe the situation at the end of the ramp-up in 'future perfect' in terms of the process and in terms of the knowledge necessary to reach volume production.

6.2 Situation at the end of the ramp-up

In this section the situation at the end of the ramp-up is described in terms of knowledge related to the production process and product. This knowledge needs to be weaved together to reach volume production at the end of the ramp-up period. In Section 6.1 it was made clear that we need to know the final outcome of the interactions between NPD & Manufacturing in order to reveal the intentions of the participants. This future situation tailors the actions, attitudes, and behavior of the actors while interacting with each other and therefore has explanatory power regarding these interactions. In this case the future situation is equivalent to the situation at the end of the ramp-up and is more or less the same for the all projects that I have been looking at.

The future situation is described by differentiating between process related knowledge (6.2.1) and cognition related knowledge (6.2.2). Both types of knowledge need to be available to reach the downstream situation of volume production.

6.2.1 What is necessary for volume production

As was said earlier in Chapter 2, the ramp-up ends at the moment that the production rate in terms of quality and volume has reached the required level. In other words, when the Manufacturing system has reached a full exploitative state without any explorative activities going on. In this research we are investigating the interactions between actors from the explorative NPD process and actors from exploitative Manufacturing processes in relation to a product innovation project. But the strange thing is that the participant's interactions within the scope of the project aim at

making the transition possible from exploration to exploitation. Thus, the explorative activities aim to achieve a situation that doesn't contain any explorative activities regarding the production of the new product. These last explorative activities make exploitation possible, meaning the efficient use of the new competencies that were developed by exploration. This implies that:

1. Production start-up problems have been identified and solved
2. The actors on the assembly line are able to function in a routine basis regarding
   i. The operation of the line
   ii. The assembly of the products
   iii. The testing activities during assembly
3. The total production system is in a state of 'smooth' operation

In the following sections we will briefly discuss these goals.

Production start-up problems are identified and solved

Every start-up of a new product brings many problems to the surface. Small issues like parts that don't fit easily, tolerances that are not yet determined, test procedures that are not settled, assembly difficulties, suppliers that are not able to deliver (or have their own start-up problems), etc. These mostly minor difficulties fall under what was called in Chapter 5 *normal problems* and need to be solved quickly during the early stages of the ramp-up. These 'teething troubles' are expected to occur at some point and, in a way, the function of the ramp-up period is to detect and solve those problems. Seeing these issues as situations with missing or faulty[22] knowledge makes it understandable that these problems hamper the collaborative process that is necessary to align the 'bits and bites' of product and production related knowledge.

The earliest moment to detect these teething problems is during the operation of the total production system. The preproduction series is not the same as 'live' production in terms of the parts, the machines, and the people as we also discussed in Chapter 2. For instance, the parts supplied by suppliers during the ramp-up are sometimes lower in quality as compared to the parts from the same supplier for the 0-series.

> *"…when you get components for the first series, they are absolutely perfect and then it drops down, the tolerances get a little bigger…" (Lightcom.NPD.4.354)*

These kinds of problems are typical for the process of *running in* production lines for new parts as was illustrated in Chapter 5. Especially injection molded plastic parts seem to suffer from these running in problems. To reach full exploitation, it seems necessary to go through a learning process in which the Manufacturing system in full operation becomes refined by the learning of the actors leading to the required level of volume operation. That is what the ramp-up is for, detecting problems and solving them. It is similar to the sea trials of a new ship, a full service test in real-life conditions to test the performance of the ship and reveal the problems that can only be discovered during such a test.

We learned from our interviewees that during the first part of the ramp-up, people from NPD are usually present at the production site. However, the empirical data doesn't provide enough insight

[22] 'Faulty' knowledge refers to the situation where a design solution made upstream proves to be the wrong one. The knowledge developed for and incorporated in that solution is the wrong knowledge regarding its application. This results in a design iteration, that is, to redevelop that specific part and thereby develop new knowledge.

into the interactions among the participants during these early production stages. This implies that I don't know exactly what happens during those interactions.

But, by the end of the ramp-up there are no longer any explorative activities going on that are needed for the continuation of the exploitative processes.

The actors in Manufacturing are able to operate on a routine basis

At the end of the ramp-up, and if everything has been worked out all right, the whole manufacturing system works on a routine basis, meaning that the product innovation process has reached its full exploitative state.

Although we know that there are many more routines involved in running the whole operational system, the interviewees mainly talked about the assembly line as the place where everything comes together. The assembly stations are designed in such a way that the work at each station, in terms of time elapsed per station, is more or less the same. This implies that the workers on the line each have a limited amount of time to assemble, test, and adjust whatever needs to be done at that particular station. In order to be able to do the work within the time constraints the workers need to arrive at a certain level of routine, meaning that they need to be able to do the work almost without thinking, and certainly without considering or exploring possible options for how to handle their tasks on the assembly line. To a certain extent, the same routine level should also be expected for activities related to troubleshooting on the line. The workers must be able to react quickly to 'normal' problematic situations and they should know what to do in such a situation. The people on the assembly line are trained to solve the most common and expected problems as the following quotes illustrates.

> *"… We were training [the people] what will you do if you don't have any washers for example. If there is a quality problem, what must you do then. … And so on, because I want them to recognize the situation when it happens; "oh, I have seen this before, and I do this and this". There is no stress, because they have the solution, and then they don't have to go and ask …[other people]…" (Lightcom.Mnfct.7.234)*

This resembles what was described in Chapter 4 under routine technologies, solving problems with known and easy to implement solutions (Perrow 1967). These issues are not really seen as problems that require additional learning in terms of the identification of new solutions.

Another thing we can learn from this data segment is that the actors aim at 'front loading' possible problematic situations on the production line that might disturb the *momentum* of the production processes. In the next section this notion of momentum will be further elaborated.

Total production system is in a state of smooth operation

The final aim of the ramp-up period is to reach a state of smooth operation of the entire manufacturing system, which implies that the manufacturing system operates at its desired volume of 'x' products per time unit. This requires a certain rhythm of moving products, parts, and people in and around the assembly line in a routine way. Parts from external suppliers and internal production lines are delivered to the people on the assembly line at the right time, in the right amount and quality, and at the right location. These parts are then assembled in the right order, by the right movement, and at the right speed until the products are finished and are ready for shipment.

Apart from a smoothly operating Manufacturing system, this system also seems to build up a certain 'kinetic energy' that I labeled *Momentum* in Chapter 5. The relations among these different processes, actions, and activities are so interdependent that changing separate activities is not that easy anymore.

In both companies I saw examples of subassembly problems or missing parts when it was decided to continue manufacturing the products, finish them and put them in stock to change the wrong or missing parts later. This extra work seems to be less troublesome than bringing the Manufacturing system to a halt and 'destroying' the momentum.

> *"…It showed up that it was also a hardware failure. And the designer had to go up and work on it. It took him a week approximately to find a solution. And we then decided to produce … to continue our production and accept that we had to put them [the products] away and re-open them…* ***Change it afterwards?*** *Yes, change it afterwards…"*
> *(Audiocom.NPD.5.581)*

This and other similar data incidents shows the importance of not disturbing the smoothly running Manufacturing system and to preserve the existing momentum. Another illustration of this momentum related to a smoothly running Manufacturing system is the introduction of small changes that bring the system back in a slightly altered smooth operation.

> *"…I think the most difficult thing is when it is a product, which is already in production and we come with some changes and we have a normal production going on at the same time and on the same line. That is the most important thing. When we have the daily production symbolized with this big arrow and we come with some new development, things which we would try to do in parallel with the normal production. That … here that is normally trouble, because the production group has some daily targets to reach and we come here and disturb them with new products or things they should do in a different way. I think it is much easier to start a completely new product, than we don't disturb the normal production. It depends of course of how many changes do we put in the normal production…"*
> *(Audiocom.Mnfct.4.121)*

According to this interviewee it is even better to introduce a new product into the Manufacturing system than to disturb the existing smoothly running Manufacturing system with small changes.

In the next section I will describe the various kinds of knowledge that need to be developed in order to arrive at volume production.

6.2.2 Knowledge that needs to be developed for volume production

I will present the situation of volume production as a culmination of the knowledge related to the new product and/or to the production process that must have been developed, transferred, installed, and put to use within Manufacturing. To reach this fully exploitative state (at least) two main bodies of knowledge need to be developed:

1. The relevant details of the new product
2. The relevant details of the product related to its production
    i. Details related to the production of parts, components and subassemblies

ii. Details related to the assembly of these parts, components and subassemblies into one product

I briefly discuss these forms of knowledge and illustrate them with relevant data segments.

The relevant details of the new product are known

All specified knowledge about the new product could be considered to be design details. Meaning that the developers have intentionally thought about it and have chosen that specific solution within the design. What actually happens during the NPD process is an increase in the knowledge content of the new product. This is a continuous learning process of developing and revealing new details until there is enough knowledge built up to produce the new product. Midstream prototypes normally will not contain all these details. One of the purposes of prototyping is to reveal development flaws, i.e. to reveal those issues that still need to be worked out or elaborated and to get an impression of what possible solutions there could be. Another purpose is to test the details that were already developed in order to find out if these can remain as they are or if they need some extra attention.

It seems very logical to have explicit details regarding the new product by the end of the ramp-up or even at the outset of the ramp-up. However, certain aspects of the product might only get revealed during the ramp-up itself. One group of details that we discussed in Chapter 5 becomes particularly important: the tolerance chain of parts assembled together. The operators in Manufacturing have to get a grip on the variations in tolerances of the individual components during the ramp-up.

Overlooking details and mistakenly believing that all content is known might result in unexpected problems during the ramp-up or even later during use (e.g. Toyota recalls 770.000 cars)[23]. In both companies I found instances of such ramp-up problems. I will describe one such situation at Audiocom. In this case, during the preramp-up stage the developers detected that a certain spot inside the television could become too hot. Mounting a fan for additional cooling was believed to be the solution, but during production the fan kept on causing problems.

> *"… I think during the development … basically the engineering design, they discovered that the heat was too high and we had to do something and then the solution was the fan and it was tested and it was found OK, and we started production. And I think also some of the tests samples we made in production were also OK, but when the number was increased the problem became more serious with that [fan]…" (Audiocom.Mnfct.4.360)*

But, the fan caused many more problems later because it made too much noise once it was built into the final product. It had been tested in prototypes but the problem surfaced later during the ramp-up. This implies that although one might think that everything has been tested and that all content is believed to be sufficiently developed, there can still be things left to discover and improve, resulting in extra or altered design details which thereby increases the level of knowledge

[23] Consider the following quote: WASHINGTON (AP) "Toyota Motor Corp. said Tuesday it is recalling more than 770,000 pickup trucks and sport utility vehicles because of problems with the front suspension that could hinder steering. The company said the recall – one of its largest – covers 774,856 vehicles in the United States. […] Toyota said the surface of ball joints that connect to the front suspension may have been scratched when they were made, which could lead to wear and tear over time. Excessive wear or looseness in the joint could force drivers to use more effort steering." (The Japan Times: May 19, 2005)

about the product. Or as the interviewee at Audiocom formulated *"…prototypes don't show all the problems…"* (Audiocom.Mnfct.4.235).

The relevant details of the Manufacturing system are known

The details of the new product inform the development and fabrication of dedicated tools for producing the different parts of the new product like the molds for the injection molding of plastic parts. Only occasionally is a complete new production machine or a new factory building constructed as a result of a new product. Most new products will be manufactured with available machines and buildings. It is clear that what we discussed as *newness* in the last chapter is related to the dedicated adaptations of the existing manufacturing system. All these adaptations and new tools need to be developed and fabricated before the ramp-up can begin. In the two companies that I studied, the process development activities were run in parallel with the later stages of the product development activities. This is similar to what we discussed in Chapter 2 on concurrent engineering and integrated product development.

As well as specific tools, the following list provides a (not exhaustive) overview of other elements related to the manufacturing system that the interviewees mentioned.

- Assembly time studies
- Layout of assembly stations and the assembly line
- Assembly tools and fixtures
- Logistic system
- Testing equipment
- Procedures for testing, assembly, production and approval

I will now briefly address these issues.

In the last chapter when we discussed *prototyping* it was shown that late prototypes are also used for assembly time studies and possibly also for specific assembly tools and fixtures. The time studies themselves and the design of the product in terms of sub assembly divisions seems to inform the layout of the assembly line, in other words, the number of assembly stations and the amount of work per station.

It is of course logical that based on where all the separate parts of the product come from, internal production or external suppliers, a total logistic system needs to be developed and organized. In this light is it interesting to know that Audiocom has been investigating how to organize the development of the supply-system concurrently with the development of the new product (Gubi 2004). As was noted earlier, especially the organization, supervision, and control of supplier's deliveries during the ramp-up require additional attention. Missing parts or parts that come in too late from suppliers seems to be the rule rather than the exception. And as I have indicated, part of these supply problems seem to be related to the NPD-Manufacturing interface because of changing contacts from the outsourcing company who the suppliers talk to. That is, suppliers talk to people from NPD, to people from purchasing or procurement and maybe even to people from inventory management.

Another reason for missing parts during the ramp-up could be late changes to a product that disturbs the planning of the ramp-up as the following quote suggests.

> *"…but then again last minute changes are quite difficult to get parts for. So if you have a last minute change on anything we have a purchaser who needs to go out and find these components... and a lot them, because we produce uhhh... we can sell everything the first 6 to 12 months that we produce and we produce them as fast as possible…"*
> *(Lightcom.Mnfct.3.443)*

Then there is the development and construction of the testing equipment including the software to perform the tests. The significance of the *Testing* category was illustrated in Chapter 5. It is important here to mention that at the end of the ramp-up the people on the production line need to be fully aware of the thresholds for accepting or rejecting products or parts that have just been produced. This detailed knowledge that is related to testing procedures needs to become available to the people on the assembly line. It is problematic however (as was discussed in Chapter 5 under *Tolerances*) that this knowledge could have a subjective and implicit character, meaning that although it might be available at the outset of the ramp-up it is difficult to transfer to the people on the assembly line. This know-how or tacit knowledge is not easy to codify and is therefore hard to transfer to others because it is implicit to the people who use it (Nonaka 1994). The people on the assembly line have developed this expertise during the ramp-up in concert with the development of their testing and assembly skills as will be shown later.

6.3 Conceptualization process

This section aims to shed light on the conceptualization process. In Chapter 3, I mentioned that Glaser & Strauss (1967) use words like 'generating', 'emerging' and 'getting insights' to illustrate the need for creativity during the inductive process of conceptualizing. Glaser states that the inductive process "leans heavily on the analyst's creative boost" (Glaser 1978, p. 20) and "Grounded theory is ideational; it is a sophisticated, careful method of idea manufacturing. The conceptual idea is its essence." (Glaser 1978, p. 7). What Glaser means is that the method of grounded theory provides tools, like theoretical sampling and comparative analysis, that need to support the researcher in this creative and inductive process. Besides these, Glaser also mentions the role that the existing literature plays as a source of inspiration. The inductive process can then be regarded as an interplay between the research questions, the emerging categories with their properties, the empirical data and the existing literature.

Of course, the researcher must exhibit good practice by making clear to the academic community that he has treated the data in a careful way. Unfortunately, a researcher can never completely describe the thinking process at the heart of the creative leap which is believed to occur during the inductive processes. As mentioned in Chapter 3, the researcher must illustrate the contours of theoretical sampling and may show the emergence of the major categories (Locke 2001). However, it is of prime importance that the researcher demonstrates the relevancy of the conceptual ideas within the area of investigation by illustrating them with the empirical data. In the case of this research project the inductive leap has been considerable as will become clear in the next sections. In the following I will elucidate the creative leap by elaborating on the insights gained from Section 6.2 by relating them to the testimony of actors from NPD and Manufacturing. These connections provide stepping-stones towards the development of the core category in Section 6.4.

An intensive analysis process with a dominant inductive aim during the second stage of this project (Chapter 5) resulted in two fledgling categories on *learning* and *disturbance*. These categories must be seen as clustered observations of NPD-Manufacturing interactions (that lead eventually to volume production). In Section 6.2.2 it was shown that a large amount of knowledge must somehow become available to make volume production possible.

In Chapter 1 I questioned whether all knowledge that is necessary for being able to produce and assemble a product is developed by NPD. The empirical data made clear that this is not the case. A lot of knowledge required for production is already available within Manufacturing but needs to be linked somehow to the new and unique knowledge that belongs to the product under development and is brought to them by the actors from NPD (Figure 6.2).

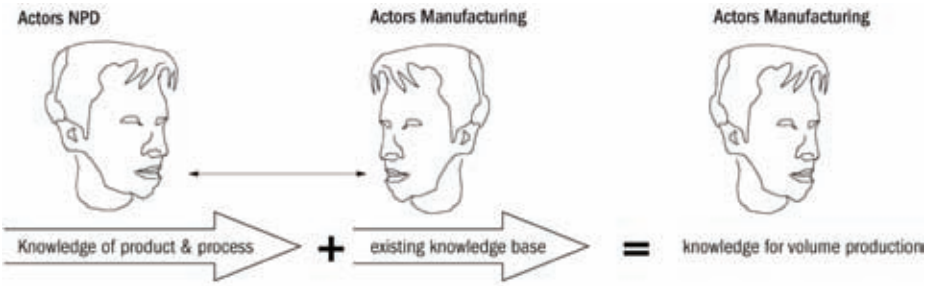


Figure 6.2 *Interaction process between actors from NPD and Manufacturing leading to some kind of knowledge system that is necessary for volume production. This knowledge system together with the physical manufacturing delivers the new product.*

The production and assembly of earlier products is responsible for this knowledge base within Manufacturing. But how is the new knowledge connected and added to the existing knowledge? In the next section this question will be answered by introducing a core category that describes what seems to occur during the interactions between the actors from NPD and Manufacturing while they aim to achieve the state of volume production (Section 6.2).

6.4 Core category: Synchronizing incongruous mental models

From the data it becomes clear that all people involved in a product innovation process seem to be aiming more or less at the same target, albeit related to their individual field of expertise. Everybody tries to fill all the empty knowledge 'boxes' belonging to the new product. Whether they use newly developed knowledge or existing knowledge, their goal is to fill all the necessary knowledge gaps regarding the new product and its Manufacturing process. At the same time the possible ambiguities inherent in the production of the new product get minimized. In the following sections the core category will be introduced and discussed and is considered to be a conceptual answer to the main research question that was formulated in Chapter 3.

What happens during the interactions between the actors from NPD and Manufacturing?

In the first of three sections, this core category is introduced in more general terms. In Section 6.4.2 the concept of a noetic template will be introduced as being the resultant of the interactions between NPD and Manufacturing. This will help the reader to better understand some spe-

cific data incidents regarding interactions between NPD and Manufacturing in the preramp-up period (6.4.3) and the ramp-up period (6.4.4).

6.4.1 What is synchronizing incongruous mental models

This study aims at understanding what happens during the interactions between actors from NPD and Manufacturing. The last section made clear that during the interactions knowledge is exchanged from one actor to the other. To describe how such an exchange process might occur I will use the concept of mental models[24]. Mental models are, according to Senge (1990), "deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action". And Kim (1993) states: "Mental models represent a person's view of the world including explicit and implicit understandings" (Figure 6.3).

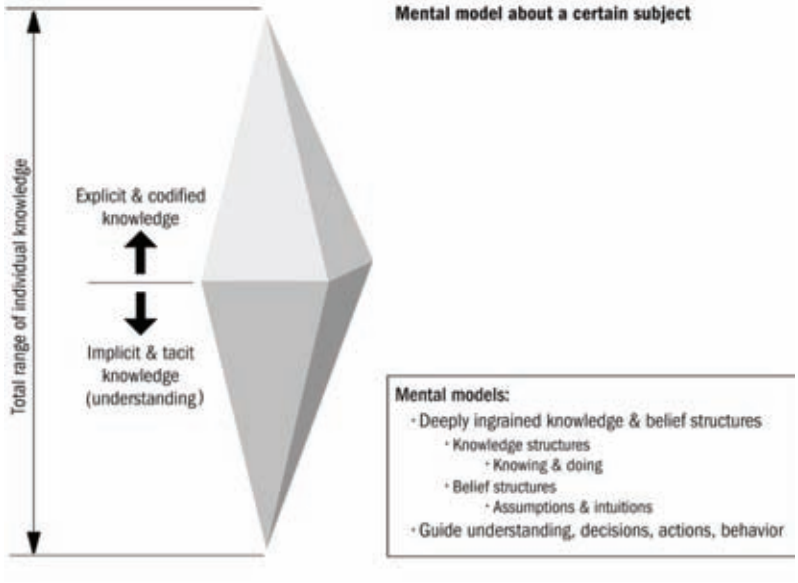


Figure 6.3 *Schematic representation of a mental model about a certain subject. The knowledge that is contained by such a mental model is believed to be explicit as well as implicit. Explicit knowledge can be shared with other actors whereas the implicit and tacit knowledge & understanding is difficult to exchange.*

Because mental models are built up over many years of education, training, experience and work (e.g. Senge 1990, Kim 1993, Cannon-Bowers et al. 1993, Nonaka 1994, Mohammed & Dumville 2001), they become ingrained with a very deep understanding of that specialized line of work. This profound understanding goes deeper than explicit understanding that can be taught because it contains lots of implicit and tacit knowledge and is also referred to as implicit understanding and tacit understanding. Consider the following quote:

> *"There is a story about a farmer's wife who won a national strudel-making competition in Austria. Asked by a journalist to say how she made strudels, the farmer's wife looked puzzled. Eventually she said: "well, I put on my apron, wash my hands, roll up my sleeves and then I go*

[24] According to Kim (1993) the vast majority of an organization's knowledge resides within the mental models of the individual employees. And "mental models are a mixture of what is learned explicitly and *absorbed implicitly."* The latter makes the articulation and sharing of knowledge so difficult.

> *into the kitchen and make strudels." I feel a little of her puzzlement when I am asked to talk about how I study organizations: I find an organization, get into it, and then I study it. Research, like strudel making, has elements of craft about it, so that some of the knowledge acquired by those who do it is tacit knowledge, embedded in the skills of the craft, and it is sometimes difficult to be explicit about these skills, which are easier to transmit by example and by apprenticeship." (Turner 1988, p. 108).*

This example illustrates two things. First it is a simple illustration of tacit knowledge. Second, the NPD-Manufacturing interface is like the journalist-farmer's wife interface, but works both ways. For instance, an actor from Manufacturing understands why something is not going to work very well in production, but is unable to articulate that insight and make it explicit enough that the actor from NPD, who has a different mental model, understands the same truth. On the other hand, the actor from NPD has an implicit and thorough understanding of the new product. He knows all about the considerations and rejected alternatives that underpin the design at a certain moment. Like the implicit knowledge within Manufacturing, it is impossible to make all that NPD knowledge explicit and ready to convey to other actors until they have the same deep understanding. One cannot transfer understanding, because comprehension is an individual process that is guided by the individual mental model. The only thing that actors can do is to look for those knowledge components that could link the two dissimilar forms of understanding or mental models. This process of interaction that aims to connect the incongruous mental models[25] is what I call synchronization and seems to be an important social process among the actors[26].

The participants from NPD and Manufacturing have different mental models because they work in different 'worlds'[27] [28]. These worlds are so dissimilar that the mental models belonging to NPD and Manufacturing might even be considered incongruent. The processes, the underpinning assumptions and their goals are so dissimilar that participants need different knowledge, different thinking & interpretation[29], different actions and different re-actions.

Synchronizing the disparate mental models doesn't seem to mean that the participants aim to 'equalize' their mental models. On the contrary, their different mental models probably must remain distinct to not loose the advantage of specialization[30]. They may only need to connect in such a way that the future Manufacturing process becomes as easy and cheap as possible within

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[25] This synchronizing process shows similarities with what Bucciarelli (1988) describes about the social process among designers from different disciplines (electronics, mechanics). He mentions a negotiation process among parties with different interests.

[26] The idea that designing is a social process already exists (Bucciarelli 1984), but only recently does this perspective seem to attract more attention from academics (Lloyd & Deasley 1998, Bucciarelli 2002, Boujut & Tiger 2002, Love 2003)

[27] Bucciarelli (1988) introduced the notion of 'object worlds' that are "patterns of belief grounded in the object and how these guide (rule) participants' thought and action" (1988, p.162). This is caused by differences in technical specializations, dialects, symbols, metaphors, craft sensitivities, etc. This supports the suggestion that there are considerable differences between the mental models of NPD & Manufacturing.

[28] This resembles the notion of departmental 'thought worlds' as mentioned by Dougherty (1992). According to her, a departmental thought world has 'an intrinsically harmonious perspective' on a subject that shows no or little overlap with perspectives held by other departments.

[29] Von Meier (1999) reports on the conflicting perspectives between engineers and operators regarding technological innovation. However, each perspective is internally consistent and rational. This shows similarities with the assumed internal consistency of the mental models within NPD and Manufacturing.

[30] I feel strengthened in this by what Bucciarelli (1988) mentions regarding his negotiation process among designers: "They do so [negotiating] without necessarily fully reconciling their different views of the design" (1988, p. 167). Another supportive remark is made by Boonstra (2004) He states that shared sense-making could result in common actions while at the same time preserving the 'pluriformity' that is involved at the outset of the sense-making process. These observations seem to substantiate this idea of the preservation of mental models during synchronization.

the constraints of the chosen product concept. This synchronization is necessary to arrive at a balanced design that takes into consideration the different viewpoints from each mental model. Of course, actors from NPD will have some knowledge structures that belong to the various manufacturing processes such as injection molding, assembly, metal working, etc. This could be explicit knowledge that generally falls under the various Design-for 'X' -strategies (Figure 6.4).

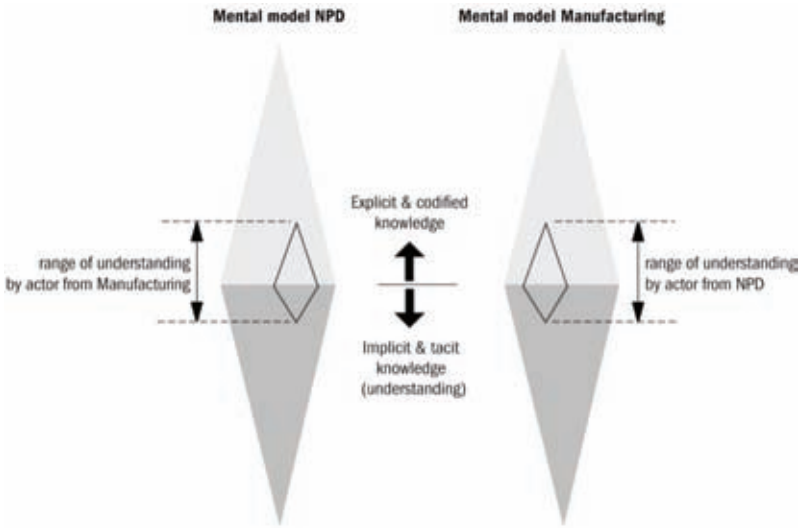

Figure 6.4 *Schematic indication of NPD's mostly explicit understanding of the Manufacturing processes. This is equally true the other way around, that is Manufacturing seems only to understand NPD to a limited extent.*

This explicit knowledge and understanding together with limited implicit understanding of Manufacturing processes is what actors from NPD probably use while synchronizing with the people form Manufacturing who have the deeply rooted tacit understanding of these processes[31]. This basic knowledge makes it possible to take downstream constraints into consideration without interacting with people from Manufacturing. But the designers will never have the same deep understanding about the Manufacturing process as the actors from Manufacturing and therefore NPD still needs to interact with them, hence the synchronizing activities. Conversely, the Manufacturing based participant will use knowledge from earlier products to relate to the new product, but they will never be able to comprehend the new product in the way the NPD participant understands it. Linking up the tacit understanding and tacit knowledge that resides in the mental models of NPD and Manufacturing is the most challenging and troublesome part of the synchronizing activity.

By synchronizing their individually held mental models, NPD and Manufacturing both aim to finalize the design of the product and its production process[32]. This brings us back to the discussion in Chapter 5 about the *NPD Deliverable* and to the additional research questions formulated at the beginning of this chapter.

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[31] According to Clark & Fujimoto (1991), designers must have such "basic knowledge about downstream constraints in order to be able to predict the consequences of their solutions" (1991, p. 240).

[32] The synchronizing of incongruous mental models seems to be a detailed description of one of the processes within, what is termed by Boonstra (2004), 'interactive learning'. He states: "The heart of interactive learning is that feedback processes become visible, that there is room for processes of self-organization, that interactive processes between actors are initiated, that multiple voices are heard against a background of multiplicity and diversity, that meanings and assumptions become visible, that a shared sense-making comes through dialogue, that joint alternative actions are developed, and that processes of discovering, choosing, acting, reflecting, and learning are initiated" (2004, p. 16).

6.4.2 End result of the synchronization process: a noetic template

In Section 6.1 the following additional and supportive research questions were formulated.

1. *What is the final outcome of the explorative activities?*

2. *What are the participants interacting for?*

3. *Can we speak of a deliverable or what else forms the output of exploration?*

These questions will be addressed in this section by combing the notions about the knowledge gained by the end of the ramp-up (Section 6.2) with the concept of mental models.

What is discussed in Section 6.2 about the various knowledge structures that must be in place by the end of the ramp-up seems to form an important outcome from the explorative processes. If this is the case, the final outcome of all exploration is the volume production of the newly developed product. It is good to note that from this viewpoint, the deliverable of the explorative process doesn't really exist, because one cannot hand over a new production process as a deliverable. The new production process in action can then be considered to be the outcome of all the explorative activities. This implies that we can no longer speak about **the** NPD deliverable. It was already mentioned that there seem to be many interim deliverables like drawings and plans. But what bridges the gap between the plans and the manufacturing system in action?

Let's have a closer look at the knowledge structures that underpin this outcome and relate them to the notion of individual mental models. At the end of the ramp-up there are knowledge structures and action structures spread over a large number of participants in Manufacturing who work closely together. Each individual actor will have his own mental model to operate from, that is, his own frameworks and routines[33] that are somehow complementary to those of his colleagues. Such an individual mental model contains explicit as well as implicit knowledge, the know-that and the know-how necessary to perform his task in coherence with the tasks of his colleagues.

Thus by the end of the ramp-up there has come into existence a network of complementary mental models that, by bringing them into action together, form the exploitative processes. All these complementary mental models together make up what I will refer to as the '**noetic template**'[34] of the new product (Figure 6.5).

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[33] According to Kim (1993), mental models consist of frameworks and routines that are related to conceptual learning and operational learning, respectively. Conceptual learning is related to the 'why' question and could challenge the status quo and could result in new concepts (frameworks). Operational learning is learning at a procedural level like learning the steps to complete a particular task.

[34] Noetic is synonym of 'intellectual' and 'mental'. Noetic comes from the Greek word 'nous' which means 'mind', 'intellect', 'understanding'. Here I will use 'understanding' as a meaning for 'noetic'. I have found the notion of 'noetic system' described by Sir Julian Huxley as an introduction to the English translation of the book The phenomenon of man, by Teilhard de Chardin, "…man's thought and his resultant psychosocial activity would simply diffuse outwards: it would extend over a greater area, but would remain thinly spread. But when it is confined to spreading out over the surface of a sphere, idea will encounter idea, and the result will be an organised web of thought, a noetic system operating under high tension…" (Huxley 1958).

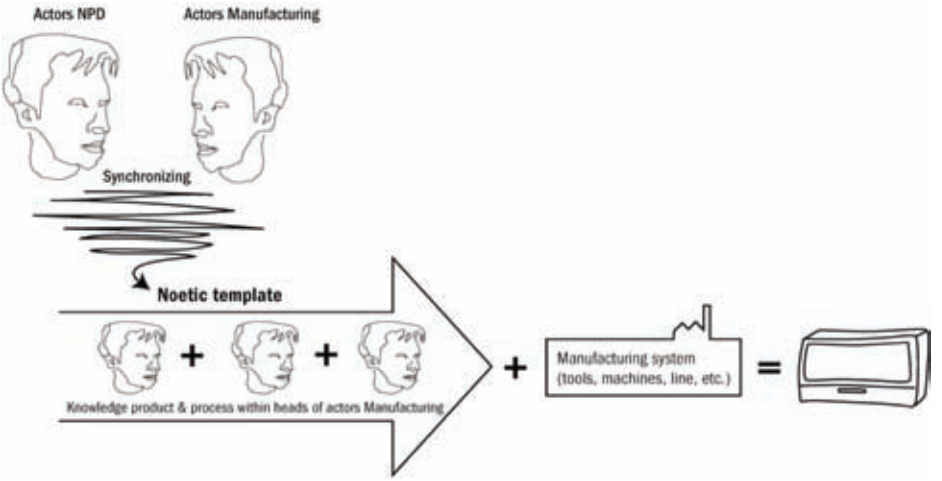

Figure 6.5 *Schematic representation of the synchronizing process that leads to a Noetic Template that is made up by a network of individually held knowledge structures.*

This noetic template, as an accumulation of individually held mental models, will come into existence by the individual and collective learning processes during the course of the preramp-up and ramp-up. In Section 6.4 I will elaborate on the concept of a noetic template by describing and illustrating the various states it moves through as it matures.

First I will continue by discussing and illustrating the basic social process among the actors using text incidents from the preramp-up (6.4.3) and ramp-up (6.4.4).

6.4.3 Synchronizing during preramp-up

In this section the synchronizing interactions between NPD and Manufacturing in the preramp-up period will be discussed.

One relatively large set of data incidents that serve as a good illustration for the core category are the interactions that touched on prototyping. In Chapter 5 when the tentative category on prototyping was discussed, it was noted that although the data did not reflect the actual interactions, it was still possible to observe that prototyping forms an important interface bridging activity. Let us consider one of the same quotes that we have seen in Chapter 5 and elaborate on it using the idea of synchronizing mental models.

> *"…they [NPD] made a good preparation for these meetings, so there were models, and some drawings and something which we could look at and then … during the meeting we all … I think we were … our [Manufacturing] technology manager was involved and the software person was involved and the mechanical architecture person was involved, and electrical…" (Audio-com.Mnfct.3.55)*

This quote shows that NPD did their best to prepare the meetings to discuss the prototypes. By bringing or presenting more than just one representation of the new product they aimed at a better understanding of the new product by the participants of the operational chain. This understanding is only possible when these participants are able to connect the new information on the

product to their existing mental models by making linkages to, what Postrel (2002) calls, docking points[35]. What in fact seems to be taking place during such meetings is, apart from identifying development flaws, to synchronize the mental models from the NPD side with the mental models of the Manufacturing side. This is a mutual synchronization process because the actors from Manufacturing start building up a mental model related to the new product and the actors from NPD receive comments from Manufacturing that result in changes to their mental models. The actors from Manufacturing formulate these comments by using their own mental models which incorporate explicit and implicit knowledge and understanding of Manufacturing processes.

The following quote from Manufacturing illustrates that at various stages of the design it is necessary to synchronize.

> *"… when the main structure was decided and when the detailed architecture was decided we made a prototype, a first prototype and it was made in wood […] and papers and that was glued together and something like that.* ***And what was the purpose for the prototype?*** *It was to see if all the ideas could stick together and to review what the problems could be … So we made … we said we made a 50% prototype, a 80% prototype and a 100% prototype. We made our first prototype in 50% OK-product and we made … and we made a lot of reviews on it and we have … we got a lot of experience and we reworked a lot and then afterwards we made another prototype, an 80% prototype where all the reworks, the changes were included.* ***The lessons learned from the 50% were in the 80% prototype?*** *Yes. And we reviewed a lot of that [prototype] and afterwards we made one 100% prototype…" (Audiocom.Mnfct.3.194)*

The fact that successive design-built-test cycles are necessary as the design grows to its final state might be illustrative of the fact that it is not possible to synchronize the mental models from NPD and Manufacturing only once during the development process. In other words, at every stage there is new information concerning the design that requires an additional synchronization cycle. Apart from synchronizing during prototype discussions, it even happens on a regular basis as the following segment shows.

> *"…those four [from NPD] and one assistant manager from the assembly factory, which was me and one from the mechanical factory and one from electronic factory […] and we discuss it [the new product] every week, which problems there are…" (Audiocom.Mnfct.3.179)*

Later in the NPD process when the level of detail is close to the final version they not only involve the group leader from Manufacturing but also asked the actual assembly workers to come over to NPD and give their opinions on the design, opinions that are based on their specialized assembly mental models.

> *"…I have a mechanical production technician, he was involved. So he had it here, he had … a desk where he could meet in the development department, so some… I think some weeks he worked two or three days a week in the development department and they were making wiring in the product and they were making models and he invited the workers.* ***The actual people that do the assembly?*** *Yes, he invited them to look for 'is that good or not good for the assembly factory? This wiring, or this wiring?' and therefore it was very, very good cooperating be-*

[35] Lynn et al. (2003) mention that for information to become internalized and understood it should be congruent with the mental model or schema of the individual. This means that the new information must somehow merge with the existing knowledge in the form of the mental model.

tween the development department and the operations…"
(Audiocom.Mnfct.3.140)

From this we learn that even at the most detailed level of the assembly process one should involve the actual assembly people who have the deep and tacit understanding of the assembly process. Meaning, that NPD needs to synchronize their mental models with the mental models of the actual assembly workers to get the design right regarding their role within the noetic template. The knowledge itself of how to assemble and place the wires is not made explicit and remains within the minds of the assembly workers, meaning that it becomes an element of the knowledge that resides on the Manufacturing side. NPD at this point only needs to know if assembly is possible if they finish the design of the product based on the state it was in during this evaluation. At the same time, the existing mental models of the individual assembly people, which consists of frameworks and routines, is being altered. On the framework side by their additional understanding of the new product and its possible assembly process and on the routine side by adding the skills of the new assembling process. Later, the assemblers who were involved in these preramp-up interactions are the same people that assemble the 0-series and even become 'teachers' during the ramp-up.

6.4.4 Synchronizing during the ramp-up

The start of the ramp-up is, of course, a crucial moment and is to be considered as one extensive interaction between NPD and Manufacturing. "Going live" as it is called at Lightcom means that the noetic template in its current state of maturity is 'manoeuvred' into its exploitative position, the new production line.

In the following text incident we see that some people from Manufacturing who have been working on preproduction series like the 0-series, act as teachers during the start of the ramp-up phase.

"…when we start up the production we have those 4 or 5 people, who have seen it, and have been in the team building up the 0-series. They educate the others and go around as supervisors to train them and to answer their questions…" (Lightcom.Mnfct.1.359)

It is good to realize that this group of actors have already become part of the growing noetic template.

It is possible that only one product will be produced the first day of the ramp-up because so many things need to be made clear to the people who have never seen the new product before. The following text segment shows the complexity of this learning process and illustrates the development of a complete mental model for the people involved in Manufacturing.

"…they never saw this station before, they never put in these acoustic parts before, so they have to learn to … how the place around it is working, where the parts are placed, they should take the parts and put them into the product and mount them, or screw them together or glue them together and they should learn to read the description of how to assemble. And they should learn how to see which numbers of parts should be fixed into the product and they should learn to recognize the parts and to … to … scanning databank, they see it on the screen in the computer, they see which parts numbers should be placed into [the product on that station] and they take the part out and scan it, and then check it. They should learn all these things,

> *they should learn to look for quality, for their own quality and for quality of the parts. They should turn the parts over [and look if there] 'are there some quality problems here?' 'Oh, there is a small scratch here' 'what shall I be do, calling for somebody. Is that OK, or not OK?' Is it not OK, … they should learn everything about surfaces … and they should secure that the next station is getting a good quality [from them]…" (Audiocom.Mnfct.3.717)*

Such a new mental model contains skills for production line activities and knowledge and understanding of the product and the production system. And as was said earlier, all the mental models of the people working in Manufacturing should become aligned in order to arrive at the final state of the noetic template that is needed for full exploitation.

During the ramp-up there is still a synchronizing role for the mental models that reside within NPD. Some of the NPD actors will need to provide their deep understanding of the product to facilitate the growth of the noetic template on the Manufacturing side. See for instance the following quote.

> *"…They [NPD] could help the adjusting person here in the station, because the design department, they know exactly how to adjust the tubes and everything like that […] we had … there was a person from the development department helping education. Perhaps we could do more on this in the future…" (Audiocom.Mnfct.3.754)*

It is obviously not possible for NPD to put all their information and understanding of the product that was developed by them into explicit procedures; the mental models of the NPD actors contain too much implicit knowledge and tacit understanding of the new product. Again, this is considered to be a synchronizing process where the individual mental models on both sides of the interface remain intact, but that aims to make such connections to insure that the growth to maturity of the noetic template is enhanced.

The following quote illustrates that during the early stages of the ramp-up both groups of participants, NPD and Manufacturing, synchronize their mental models by discussing the issues that arise.

> *"…It is the development department, the designers and also people from the assembly factory, that have some ideas of how we could do this and how could we do that […] I think it was a very good [ramp-up] process, because the people from [NPD] … the designers were here at the production line when we did this [Ramp-up], so they were part of the persons that where going around the whole day …" (Audiocom.Mnfct.3.579)*

At both companies the people from NPD were present at the start of the ramp-up period. They need to be because, at that moment, NPD is still part of the maturing noetic template. Later in the ramp-up, and that was only seen at Audiocom, the interactions between NPD and Manufacturing become limited to short daily meetings to discuss minor issues and those times when the production process must be stopped because of bigger problems.

Sometimes the interactions between NPD and Manufacturing in the preramp-up period have not resulted in a satisfactory synchronization of the mental models. The following example shows that assembly problems that occur later in the ramp-up phase usually result in design iterations.

> *"…we still have a few things that our mechanical designers are working on. Another solution of … we have a glass frame … they are developing another way to do it, because it is to tricky to do it in the present way, to assemble it in the factory. Now they are assembling it in the ugly way, that will say, it is difficult for them, it takes time. It is OK for the costumer, the costumer cannot see anything, it is only it takes too much time, too difficult, …[the assembly people] have to check it too much and so on … they have to be careful about quality. So they [NPD] are working for the moment on another way to do it and it is … in a week or two we have the solution we think, and the tools are finished, so we can get the parts for it…" (Audiocom.NPD.5.599)*

The assemblers have learned how to put the product together but they were unable to arrive at the required routine level of assembly, that is, they were unable to reach the desired volume production. In other words, the attained noetic template at the end of the ramp-up is not sufficient. If such a situation is caused by an overestimation of the skills & knowledge of the assembly people then it implies, based on the synchronization idea, that there was not enough synchronization between NPD and Manufacturing during the preramp-up period.

6.5 The growth of the noetic template over the development phases

In Section 6.4.2 the concept of a noetic template was introduced as being the outcome of the explorative process. However, the noetic template must somehow grow since at the beginning of the NPD project there is no such noetic template, only various fractions of existing knowledge related to preceding products. In this section, the following four states of the maturing noetic template are discussed. These four states are grounded in the empirical data, meaning that they are based on what the interviewees mentioned about their various activities during the transition towards volume production. These four states refer to what seems to be a shift in activities and/or a change in the involvement of people from NPD and Manufacturing. The distinction between the preramp-up and ramp-up period that was made in Section 2.2.4 as being the two important periods of interaction between NPD and Manufacturing is, in view of the insights gained during this project, an oversimplification of reality regarding the interface interactions. From the four states of the noetic template, three fall before the ramp-up and correspond to three periods of interaction during the preramp-up phase.

From the interviewees, I have learned that the preproduction series marks an important stage regarding the interface between NPD and Manufacturing and, therefore, the phase which includes the preproduction and 0-series is mentioned as a separate phase of interactions between product & process development and the ramp-up. The period of the ramp-up itself remains undivided because the data did not indicate any obvious intermediate states. Each of these four states seems to mark some kind of a refinement at the end of the four development phases. The respective states of the noetic template and the four development phases are indicated in table 6.1 as well as the differentiation described in Section 2.2.4.

Distinction in Section 2.2.4	Distinction of development phases based on state of noetic template	State of noetic template At the end of that phase
Preramp-up	Concept development	Conceptual noetic template
Preramp-up	Product & process development	Actionable noetic template
Preramp-up	Preproduction + 0-series	Implantable noetic template
Ramp-up	Ramp-up	Performing noetic template

Table 6.1 *Based on the empirical data four states of the growing noetic template were identified that are the result of four corresponding development phases. Three of these states fall within the preramp-up period.*

In the next sections these phases and the corresponding states of the noetic templates will be discussed.

Result of the Concept Development: Conceptual noetic template

At the end of the concept phase, what Audiocom referred to as the Concept Commitment, the product specifications together with the outer appearances of the product get frozen. At the same time there are already some ideas about the production of the new product. This is more an assessment of production possibilities as one of the interviewees from Audiocom formulates it.

> *"…we have to know that there is a fair chance that we can make this. We can not develop a product which is completely impossible to produce…" (Audiocom.NPD.2.210)*

This assessment seems to be done without the involvement of Manufacturing. This implies that the noetic template related to the new product at the end of this first development phase is only shaped by the mental models that the actors from NPD have about Manufacturing (see Figure 6.3). This mental model has been built up by their past experiences like earlier products. The actors within NPD will have some knowledge and understanding regarding the most important production processes. It is good to note that during this phase the synchronizing of mental models seem to occur without the actual involvement of actors from Manufacturing.

At Lightcom they have had experiences with participants from NPD who have been more comprehensive mental models of production and applied them too early in the development process[36].

> *"…but the problem is actually that if they [NPD] are too involved in the production … then when we have this concept they try to solve production problems directly. So they put too much time in it … into something that might not be the final thing…" (Lightcom.NPD.4.148)*

But in both companies there is very little involvement of Manufacturing during the concept phase. This changes during the product & process development phase.

Result of the Product & Process development: Actionable noetic template

In order to reach the preproduction series there are, as we have seen in Sections 6.4.3 & 5.4.2, some consecutive design-build-test cycles utilizing various prototypes with the involvement of actors from NPD and Manufacturing. These development activities, including synchronization of

[36] This is what Clark & Fujimoto (1991) call over adaptation and could result in sacrificing some innovative features.

their mental models, are necessary to gain enough knowledge about the product and its possible production process. By constructing the prototypes some preparatory knowledge on how to produce and assemble the product is developed[37]. At the end of this development phase the actors involved hold the firm belief that this initial knowledge is enough to make the transition to a preproduction run and that new knowledge can only arise from the next step in the process. In other words, to further synchronize the mental models between NPD and Manufacturing they need to start producing products.

> *"… the important thing is that when we end here [just before preproduction] then we think to the best of our knowledge [at that moment] that everything is OK and correct. When we come here, what we call preproduction [series] then all the things shall be OK, that is what we expect, otherwise we are not allowed to go in preproduction…" (Audiocom.NPD.5.651)*

> *"… at that time all the documentation should be 100% finished, ready to push the button for investment and then we waited I think it was some weeks, 8, 10 weeks from the documentation that was prepared till we got the first out of tool model…" (Audiocom.Mnfct.3.230)*

The state of the noetic template just before the preproduction series is called the actionable noetic template, because at that moment a kind of threshold is reached that makes it possible to start producing the real products and to involve an increasing number of people from Manufacturing.

Result of the Preproduction + 0-series: Implantable noetic template

The phase of the preproduction series is crucial for reaching the implantable noetic template that forms the start of the ramp-up.

Based on the actionable noetic template, the preproduction run begins with the production of, what is called at Audiocom, 'first-out-of-tool' products. This means that these products are the first to be manufactured with the real production tools. The newly involved actors from Manufacturing receive explicit knowledge about the new product and internalize (Nonaka 1994) it by linking this new knowledge to 'docking points' of their existing mental models, i.e. mental models that are related to the Manufacturing processes of earlier products. By active involvement in the preproduction series and by using their existing explicit and implicit knowledge, they will be able to develop the know-how (skills) for the manufacturing of the new product. This conversion takes place by necessary experimentations with the manufacturing possibilities of the new product during some consecutive preproduction runs.

As was said earlier, the first preproduction series constitutes the first-out-of-tool products and results in the further development of the action structures and knowledge structures as the following quote clearly illustrates.

> *"…The purpose was to have … to learn … to learn about the problems we couldn't see in this technology [the 100% prototype]. Now we are making the real thing.* ***OK, in the 100% prototype there are certain things you couldn't see …*** *Yes, and then we started making one piece at first and everybody who was involved from the assembly factory, the mechanical factory and the designers and the quality people were reviewing the assembly of the first product.* ***The first***

[37] According to Clark & Fujimoto (1991), there are two contrasting paradigms for prototyping: prototype as master model and prototype as early problem detector. The latter is especially useful for detecting manufacturing problems at early stages and in this way adds to the growing noetic template.

> ***out of tool?*** *Yes, they were making lists of problems … **Many lists?** Yes many lists. […] The assembly factory made lists, we were making lists, we were the … the assembly factory was the main driver in these lists and they knew continuously what was going on here. The workers that should assemble that product in the real production, they were lent out to this [pre-production] process, and they were assembling these… [products] …" (Audio-com,Mnfct.3.365)*

During these preproduction runs the number of people from NPD decreases because most of the development work is done. Although they are no longer part of the daily activities, they still have a lot of implicit knowledge and tacit understanding about the new product in the form of design considerations, such as rejected alternatives. Knowledge that, in some cases, still has to become part of Manufacturing's noetic template. For that, those from NPD might get involved to discuss the appearing problems which need to get solved in order to make further development of the Manufacturing noetic template possible. Such an interaction is part of the synchronizing process between the actors from NPD and Manufacturing.

The process of making lists and solving the associated problems continues until the state of the noetic template has reached a detailed and rich enough level to move on to the 0-series at the real production and assembly line[38].

At the start of the 0-series, thus on the real production line, the noetic template incorporates most of the knowledge which is relevant to the actions that are necessary to produce and assemble a product. What is still absent are those aspects of the noetic template that relate to the real production line. The people from Manufacturing who were involved in the first preproduction runs have learned how to put the product together but haven't done this yet on the real line. Especially the assembly line with its various stations will be new to them. At the same time, more people from Manufacturing get involved.

> *"…It is the first time we produce the products on the real line, the assembly line here in the factory. So now we are … it is a trial for the test equipment and for the main production line, to see if all our production IT is working and if all the communication in the information systems are working. And here [0-series] also starts the learning process of more people. We bring in more people now in the 0-series, so they could be educated […] and I think we had a, I don't remember what we called it, 0-series 2 or something like that, so there were also some small rework during that period in the real process and also rework to the real parts. Then we made a small series and then we went to the real production start, the ramp up…" (Audiocom.Mnfct.3.404)*

At the end of the 0-series the noetic template must have been developed into what I will refer to as the implantable noetic template. The state of the noetic template after the 0-series can be considered as an 'implant' that will be imbedded within the environment of the already existing day-to-day production activities. The new 'implant', although it runs in some aspects on its own, needs to fit within the existing system in parallel with the operation of other production lines.

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[38] I have included the 0-series to the preproduction phase, but I also considered attaching it to the ramp-up phase or to make it a separate phase altogether. Either option had points in favour, but I realized that to make a better choice than the one I have taken now, additional empirical data is necessary, data that should be collected by observing the processes and interactions going on during the preproduction series and the 0-series.

The implantable noetic template contains a large part of the necessary knowledge structures and action structures of the new product, however it has not yet disseminated to all the actors in Manufacturing. But the implantable state of the template seems to form the threshold for the involvement of all the other people from Manufacturing.

Result of the Ramp-up: Performing noetic template

The final fragments of knowledge structures and action structures will come into existence during the ramp-up and result in the final noetic template when the Manufacturing process has reached volume production. This final noetic template of the exploitative process will be called the performing noetic template.

The following quote illustrates what happens among the participants on the exploitative side of the interface during the ramp-up in order to create a performing noetic template. They have to learn to operate the assembly line properly.

> *"…I know that we had a problem with the assemblage of the main chassis in the product, because some times this place [this station] was empty, there were no workers on it, because they also should be standing here and they were not themselves able to overview the process. So they could … they knew that this [station] must not stop, because this was one of the critical stations.* ***Where the chassis was coming in?*** *Where the chassis was coming in, it was also important station and it must not stop, because if this stops some minutes, we can't do 100 [products] per day.* ***Ok, that is a very critical moment?*** *Yes, that is a critical moment, so they had much discussion in the group around the table in the morning, how do we do this, what are the details, who was making a process on …* ***And why was this station empty because they were going to another stations?*** *Yes, because they went to some other stations.* ***Why did they go away?*** *I don't know. They have not recognized the seriousness of this one…" (Audiocom.Mnfct.3.604)*

In this quote we see that the people on the assembly line need to collectively create a noetic template that performs to the desired level. This implies that they need to agree on who is doing what and why, and therefore, they need to have a certain level of understanding of the product and the assembly line. They need to align their individually held mental models about these issues, i.e. knowledge structures and action structures, into the performing noetic template. This is a learning process in which the assemblers go through learning cycles every time they assemble a product. The next quote illustrates that this takes considerable time and effort.

> *"…Yes they got a few courses … a few learning sessions to operate the system, but it is not always enough so we have to train and train and train, before it is good … and [before it is] best…" (Audiocom.Mnfct.1.257)*

In this quote we see that the people not only have to learn in a few sessions how to operate the system, but they also keep on training until they have reached a certain collective perfectionism, the learning towards a collective routine, towards the performing noetic template.

Noetic templates in summary

What I have tried to make clear here is that to reach volume production regarding a new product, an accumulation of complementary mental models, i.e. knowledge structures and action structures which encompass all the actors in Manufacturing, needs to come into existence. I have

called that confluence of mental models a noetic template that, during the preramp-up and ramp-up processes, gradually grows to maturity from a conceptual state through an actionable state that initiates the preproduction series, via an implantable state at the start of the ramp-up towards a final performing state when volume production is achieved[39] (see Figure 6.6).

This performing noetic template appears to be the operational force behind what was discussed in Chapter 4 under the steady state of the 'piling processes' (In 't Veld 1978).

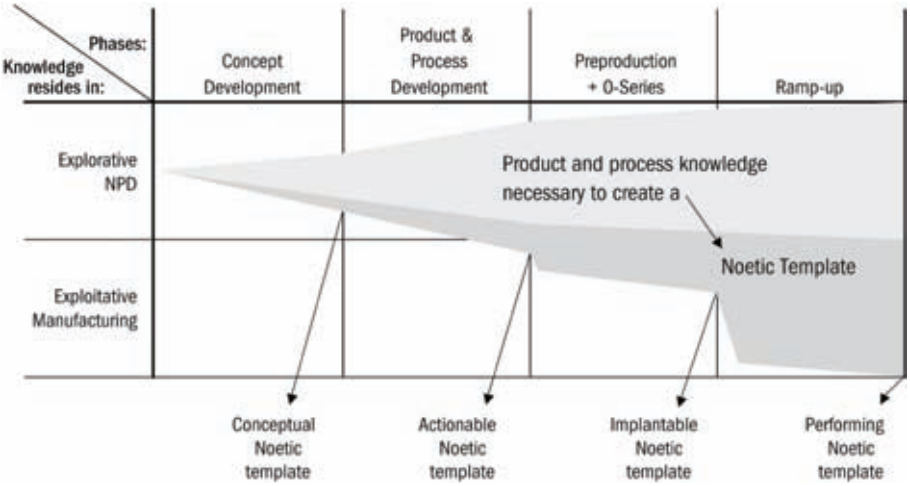

Figure 6.6 *This figure shows schematically the growth of a noetic template over the respective development phases. It also shows that the amount of knowledge increases and where the knowledge resides. Observe that the knowledge that resides within NPD is necessary for 'building' the noetic template.*

Figure 6.6 also illustrates that the 'birth' of the noetic template is initiated by NPD and through the involvement of Manufacturing personnel it slowly migrates to Manufacturing. Especially during the preproduction series and the ramp-up, an increasing amount of participants from Manufacturing become involved and merge with the maturing noetic template. In parallel to this, the number of involved actors from NPD decreases. In the end, at the state of the performing noetic template, there is no longer any involvement by NPD.

It is good to realize that there are many performing noetic templates, namely for each separate process that involves a group of people that have to act together. This could even be the case within the performing noetic template of the new product. For example, for each subgroup of participants, like the actors in electronics, in assembly or the metal shop, there will be a sub-performing noetic templates that together forms the total performing noetic template (see Figure 6.7).

[39] Note that within companies there might be many performing noetic templates, namely for each separate process that involves a group of people that have to act together. Each of these templates forms an accumulation of the mental models of the actors involved in that process.

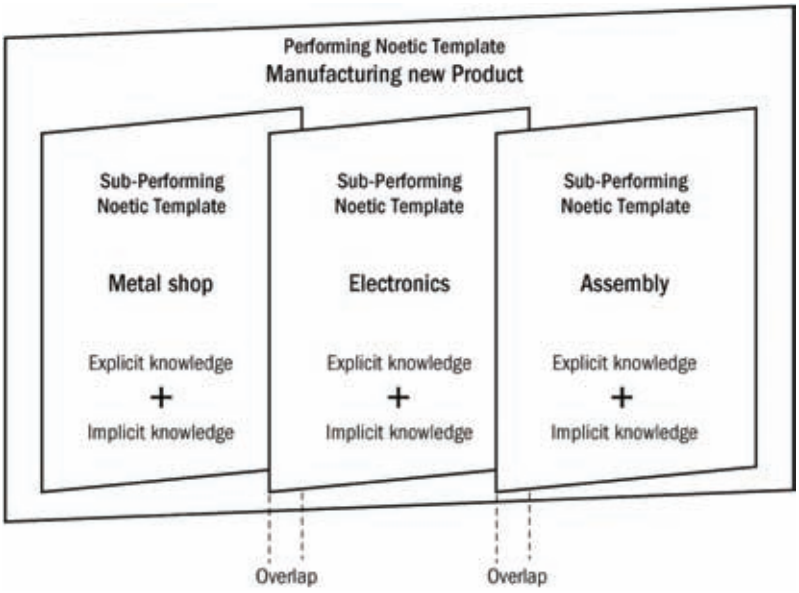

Figure 6.7 *Schematic representation of overlapping performing noetic templates that belong to the various sub-processes within the Manufacturing system. The sub-noetic templates together make up the total performing noetic template.*

Each of these templates forms an accumulation of the mental models of the actors involved in that sub-process. This implies that these sub-templates need to have some sort of connection or overlap for the total template to be able to perform. In the data collected for this research stage it is not clear what such an overlap or connection between sub-noetic templates looks like and how it comes into existence. It could be expected that on the level of explicit knowledge there is some greater overlap and similarity than on the level of implicit knowledge. The know-how, that is, the more implicit knowledge for action, will be more specific for each subgroup. This seems an interesting issue for future research which will be discussed further in the next chapter.

6.6 Influences of synchronization across the interface

In this section the focus will be on the influences that the synchronizing interactions have on the actors themselves. In this section I will first discuss the changes to the mental models of the actors that were detected in the data which were initiated by the synchronization activities (6.6.1). As such this can be seen as related to the fledgling category on *Learning* processes. This is followed by a discussion of some limitations that actors might experience in adapting their mental models (6.6.2), that is, limitations to their *Learning*. This section ends by discussing the time period that the new situation sustains after a change in the mental model has occurred (6.6.3) and relates to the fledgling category on *Disturbance*.

6.6.1 Changes to mental models during synchronization

Earlier it was mentioned that mental models consist of routines and frameworks (Kim 1993) and, as such, have a cognitive and behavioral component[40]. Let's assume here that all intentional behavioral and cognitive actions of human beings is guided by the implicit and explicit understanding that make up their individual mental models. Thus, to change their actions it is necessary to modify their mental models. Until now, in the various data segments that have been discussed, we have seen the following changes that are related to the concept of mental models and are therefore related to various forms of *learning*. Here, a division is made that I feel comfortable with:

- Cognitive level: Actors in NPD and Manufacturing increase their explicit and implicit knowledge and their deep and tacit understanding about the new product and its production processes (many quotes)
- Behavioral level:
  a. learning new skills for assembly (many quotes)
  b. building up routine behavior by repetitive actions and/or learning from experience (many quotes)
  c. changes adopted regarding a specific learning style and ability (Kolb 1984). See below 6.6.3.
- Attitude level: actors on both sides of the interface must, or should according to the other participants, change their attitude towards something (a few examples)
  a. According to Manufacturing, actors within NPD must change their attitude towards planning (Lightcom.Mnfct.1.662, see 5.4.2) and early problem detection (Audiocom.Mnfct.7.468, see 5.4.2)
  b. According to NPD, actors within Manufacturing must change their attitude towards cost calculations (Lightcom.NPD.4.482)

These are forms of individual change that happen to most of the actors involved in the product innovation process. To facilitate the learning processes during the ramp-up there are usually some instruments or training programs available. Regarding the other forms of change that must take place during preramp-up periods, there does not seem to be a lot of explicit support. Meaning that these changes occur rather implicitly.

In the next section some limitations to the actor's synchronizing activities will be discussed.

6.6.2 Limitations to synchronization

In some instances, the effort invested in acquiring a change to the mental models was not sufficient. In the following situation, Lightcom tried to create a certain new behavior using some coaching sessions, but this was clearly not enough for a routine to develop which would guarantee that the new position was internalized.

[40] In what is presented here I will be staying close to the data and to what I have seen in the data. This is to prevent getting drowned in the field of cognitive, behavioural, and social psychology or any other part of the social sciences. Making more overt connections to these fields can be done later, after the theory has emerged and described and with the help of scholars from those fields.

> *"… it was a good experience for all the guys working on this project, but we went live with the product [ramp-up] we saw some typical problems again, because they didn't have any routine in working like this. […] they just fall back to what they used to do…"*
> *(Lightcom.Mnfct.1.268)*

Changing the participant's behavior does not seem to have been realized with a remote training program as was the case in this situation. Another limiting factor is the fact that the learning undergone by the participants in Manufacturing is not always equal. Some learn faster than others.

> *"…**What kind of problems do you hear about the learning?** Typical is, that they can't make the assembly in the time set for it. So because it is too complicated, or sometimes it is the wrong person we have put in the assembly line. Sometimes we first find out when we go live, everyone has learned but two people have not learned as fast as the others, some have to make the same process 200 times before they know what to do. (Lightcom.Mnfct.1.362)*

These differences in learning speed influence the ramp-up processes. In some cases the required learning can be too demanding regarding the knowledge level and/or learning abilities of the workers. Or in other words, the new situation is too complicated regarding their ability to create an adequate noetic template. The perceived complexity of some new elements on the production line is illustrative for this situation as the next text segment shows.

> *"…Many things have been too complicated compared to the people and the knowledge of the people … it was not balanced. You have to lift it to a new level, and we stand on this level now, I think, and than we could take a step in the next [level] or we could … I think it is more a strategic question. […] I think it was … we were aiming too high…" (Audiocom.Mnfct.1.385)*

In this particular case, the new assembly line was too complex in terms of the combination of having to understand and perform the operations on the line. Meaning that the assemblers needed to go through a change process in cognition as well as in behavior that was too complex for them, at least within the limits of the ramp-up. Somehow they were not able to build up the right mental model, i.e. the right routines and knowledge structures to operate the line at volume production. It took too much effort to become a skilled performer capable of operating the line at that required level.

A similar situation was found at Lightcom where the novelty of the product was too much for the people who were involved in the production of the previous products. These people didn't have the capacity or capabilities to undergo the intended modifications to their mental models.

> *"…but […] I could not use any of the people here in the group to make this machine, because they don't have the knowledge for this product, because in normal [earlier] products it is very simple. But it is not simple in this one. It has got many rotating parts. In our simple products it is just one wheel, so it is very simple, but here it is eight wheels […] , so it is not easy. […] People from high-end here can make this product, but people from [the normal line] don't have the education for it, or interest. I think it is a big thing, having the interest for the product…"*
> *(Lightcom.Mnfct.2.369)*

In situations where the intended change crosses a boundary regarding the capabilities of the actors, the synchronizing of mental models does not seem to be adequate. If this is not recog-

nized during development then unforeseen problematic situations will occur during the ramp-up. These kinds of troubles that suddenly pop-up might be the surprises that Manufacturing perceives (Chapter 1).

6.6.3 Special synchronizing interaction: transient change

A special interaction was detected in the empirical data and is related to the length of time a new situation holds. From the interviews a continuum was identified that ranges from permanent via temporary to short. The volume production at the end of the ramp-up is considered here as being a permanent new situation and is equivalent to the concept of change that is usually addressed in the literature. The kind of change activity that occurs during a product innovation process which aims to achieve the volume production of the new product can be regarded as a change process because the existing status quo of an organization or sub-unit is altered toward a different state by "a set of sequenced planned actions or events" (Cummings & Worley 1997).

The temporary situation refers to change caused by the demands of a NPD project for instance. Actors from non-NPD departments who are involved in a multidisciplinary team could stay in that situation for weeks up to something like a year. Like the guy from Manufacturing that had his desk in the NPD department for some weeks (Audiocom.Mnfct.3.140). A new situation that holds for a short period of time, less than an hour to a day, refers to a change that comes and goes. The actors undergoing such a change go through a cycle of micro-interventions and micro-changes and then settle back to their permanent position. The modifications and the change processes resulting in the new permanent situation of volume production have been discussed at length in preceding sections. Regarding the temporary situations the interviewees didn't mention any problematic situations, apart from intimating that such a temporary situation occurs. However, a change that comes and goes or persists for a short period (hours or even less) seems to be more troublesome. I have called this 'transient' change and will discuss an example below.

This 'transient' change includes changes that people have to go through for a very short period of time and refers to incidents that were named *switch* in Chapter 5. That is, the switching process between two different types of work and thus the shift from one mental model which belongs to the performing noetic template of product **n** to a mental model of a NPD process that is creating the noetic template of product **n+1**. In the following, transient change will be discussed and illustrated by a series of quotes. The first quote was also showed in Chapter 5 to illustrate the name *switch* but will be discussed here in light of the new perspectives from this chapter.

> *"…So, you try to get feedback from these people, but that is …the problem is… is … to convince them to…. to … use time uhhh… with very little knowledge about … well to go out of their normal and everyday life what they are going … to something that is totally new and then give feedback…" (Lightcom.NPD.4.41)*

In Chapter 5 a possible relationship between *switch* and *disturbance* was mentioned. Looking at this quote more closely we see that NPD wants feedback on the unfinished design of the new product from people within Manufacturing. Because that product is still unknown to them, they first need to internalize the explicit knowledge that is presented. This requires understanding the new product by either linking the new information to docking points of their existing frameworks or to create a new framework especially for this new product. On the one hand, this depends on their former knowledge and on the other hand, the *newness* of the new product (Chapter 5). Once the

new product is understood it becomes concrete enough for them to elaborate on and give feedback. However, for proper understanding the receiver also needs to envision the future final state of the new product because we are talking here about a preramp-up interaction regarding an unfinished product that Manufacturing has to give feedback on. The explicit information they receive is, by definition, incomplete and this requires the actors within Manufacturing to mentally predict the future state of the new product with most of its details, at least those details that will inform their reflection and feedback process. Based on this possible future state they then need to imagine, i.e. create a new mental model, of how the product will fit into the Manufacturing processes. The following quote illustrates such a complex process.

> *"…Because good feedback takes time, it is… we are not talking about giving feedback in saying 'OK, here we have that prototype, look at the prototype and give your feedback on that'. That is no problem. The problem is that if we have to go a little … more their way, … they have actually to … to try to investigate to [be able to] give a good feedback. To go forward and say 'OK, how will this be in production'? For instance, to take a plate or something, that has to be punched. To be able to… to… actually say 'is this a good way…, can this be punched out in terms of … of the tools that we have, or in terms of how much time and price actually…', something like that. That will take them more time, .. than just looking and saying …. And therefore they have to invest time they have to actually go in [the design] and to give an estimate … To actually do the programming and say 'OK this takes so many minutes'. And … but the plate is not finished at that point, because if the plate will be finished it doesn't matter to give any changes … so … it is … in that phase that we want to have feedback, is were we [still] can change…" (Lightcom.NPD.4.49)*

And to give feedback they also need to reflect on that new knowledge, to transform that knowledge by intentional reflection into valuable feedback. This implies that they need a reflective and conceptual learning style, the right side of Kolb's model (Kolb 1984, Kim 1993) (Figure 6.8). That is, if their day-to-day exploitative work contains only a little operational[41] learning to improve efficiency (the left side of Kolb's learning model), they now need to switch to the opposite, more NPD-like reflective and conceptual learning style (the right side of Kolb's model (Kolb 1984)) (See Figure 6.8).

[41] Kim (1993) defines operational learning as "learning at the procedural level, where one learns the steps in order to complete a particular task" and lead to new routines. Conceptual learning "has to do with the thinking about why things are done in the first place, challenging the very nature or existence of prevailing conditions […] leading to new frameworks in the mental model" (Kim 1993, p. 40).

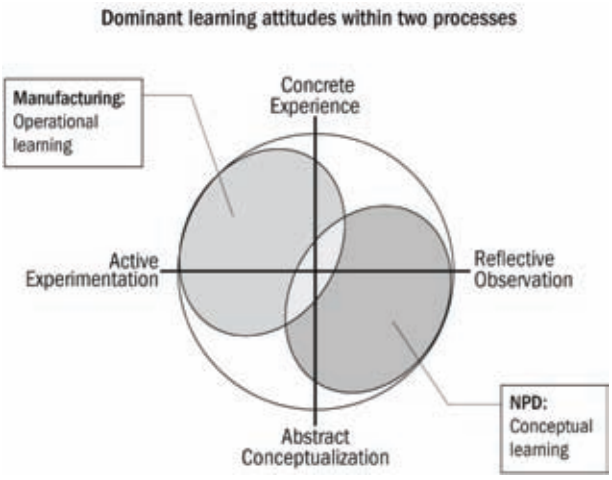

Figure 6.8 *The experiential learning model of David Kolb (1984) with the assumed dominant learning styles: Conceptual learning in NPD and operational learning in Manufacturing (based on Kim 1993).*

If that doesn't occur properly the actor from Manufacturing could overlook important product details, or misinterpret the unfinished design or simply regard the design as being finished. At such occasions the interaction might become inefficient or even ineffective.

The following quote illustrates a situation where Manufacturing considers the drawing to be the finished design of the product, in other words the actor from Manufacturing constructs or works from an inappropriate mental model.

> *"…the problem is if they get a drawing … we have drawings that they have to look at initially, if it can be produced, but let's take the drawing and go down […] We know the drawing is not finished, that was not the purpose. So they … we get a drawing back that is totally scratched all over, … that tolerances are missing, [that] this hole is not OK…, [this] tolerance we need to know … and this guy used two days of work, and we said this [drawing] is not for quality, this is only so they can check, 'can this be made'? But they see this as a finished drawing and we know that, that… half of the [information] is not there…" (Lightcom.NPD.4.834)*

In this case, because the drawing was scratched all over, NPD had to throw it away without getting a satisfactory answer to their question. Manufacturing seems to have made an abstraction leap (Senge 1990) downward by considering the design at a much more concrete, and therefore detailed, level than the actual state of the design as seen by NPD. And because all these details were (still) missing they 'added' them to the drawing. Manufacturing seems to have used the level of detail that is very much related to their daily environment, that is, the mental model belonging to that environment. In other words, they didn't change to another mental model with a more abstract NPD level of 'concreteness' for the preparation of giving feedback. Considering information on the right level of 'concreteness' is related to a mental model. If the mental model in use is too rooted in the daily environment, in this case an environment with tangible products and visible problems, then misinterpretation and misunderstanding is not surprising.

The interactions between NPD and Manufacturing in the middle of the design process are, in this level of detailed investigation, quite complex and require an actor to involve himself in a transient change, a change that comes and goes.

Below I have made a summary of a possible string of successive micro-changes on a cognitive as well as a behavioral level that represents the form of transient change that was recorded in the empirical data. The actor from Manufacturing needs to:

a. Step out of his day-to-day activities, the noetic template related to production of product **n**
b. Switch to another learning behavior
c. Understand the new product on the right level of concreteness
d. Envision the future state of the product
e. Reflect on that state and project it into the various future production processes
f. Prepare the feedback
g. Switch back to his day-to-day activities

This complex interaction between NPD and Manufacturing contains *learning* (the new product and its merits) and *disturbance* (micro interventions and micro changes). Using the idea of a noetic template, the actors from Manufacturing have to step out of their performing noetic template representing product **n** that is currently in production which has a 'defined' role for him to become part of the unfinished noetic template related to product **n+1** with a role that has not yet come to maturity (Figure 6.9).

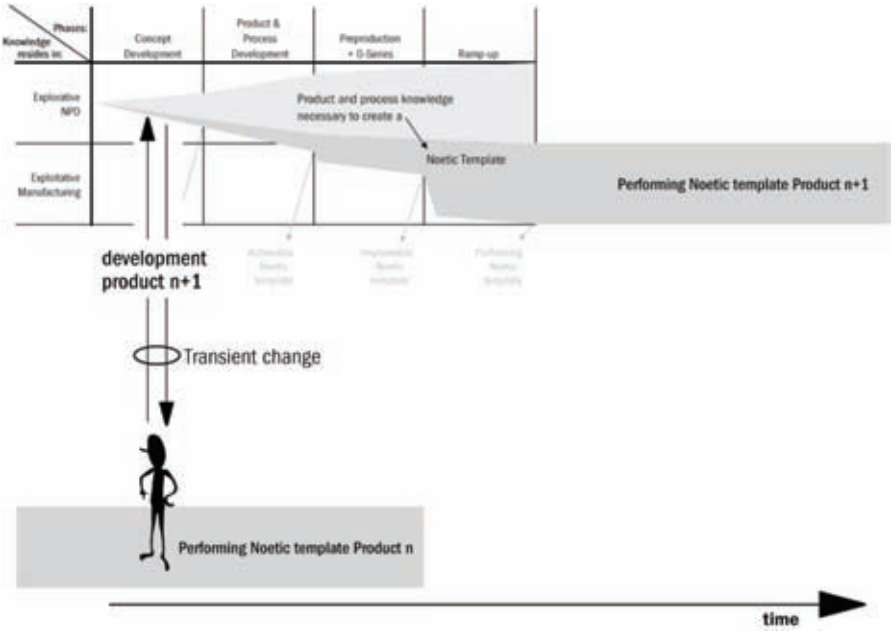

Figure 6.9 *The switching between two different mental models. The actor within Manufacturing is involved in the performing noetic template of product **n** and needs to shift to the unfinished noetic template of product **n+1**.*

Transient change is clearly visible in the data from Lightcom probably because of the geographical distance between NPD and Manufacturing. Transient change between NPD and Manufacturing also seem to occur at Audiocom but the interviewees didn't mention it as being problematic. A reason could be that within Audiocom the synchronization between NPD and Manufacturing seems to occur more frequently than at Lightcom.

Most theories on interventions and change address change processes on an organizational level and therefore aim at groups of people. The change issues of the product innovation process as a whole seems to fit the current theory. However, the identification of transient change as a factor that influences the quality of interactions between individuals within NPD and Manufacturing raises some questions around the applicability of these theories. In the next chapter the results will be presented of a small research project that was set up to explore this issue.

6.7 Finalizing the integrating stage

Before we move on to the conclusions of Chapter 7 it is helpful to reflect on this integration stage. First I will reflect on the 'results' in relation to the main research question (6.7.1). This is followed by a discussion of the results using the requisites of an emerged theory within the approach of grounded theory (6.7.2). Finally, I will reflect on the research methodology of this integrating stage and decide about the continuation of this project.

6.7.1 Has the main research question been answered?

The main research question as it was formulated in Chapter 3 was:

What happens during the interactions between the actors from NPD and Manufacturing?

The conceptual answer to that question is that the actors from NPD and Manufacturing, by interacting with each another, synchronize their incongruous mental models to grow towards a noetic template that consist of a network of complimentary and individually held mental models representing the new product and its production process. This noetic template in action, the performing noetic template, is equivalent to volume production of the new product at the end of the ramp-up phase.

The mental models of NPD and the mental models of Manufacturing are rooted in different worlds with different worldviews. These two worlds both contain implicit and tacit knowledge as well as deep and tacit understanding that is, to a large extent, incongruous. All this 'local' and individually held knowledge and understanding somehow needs to be taken into account during product and process development. The actors who participate in the development activities need to balance the constraints that are informed by the often unarticulated logics and unwritten rules from both worlds. The underlying 'truths' which reside in the individually held mental models within NPD and Manufacturing are not being challenged nor changed by products with limited newness, only added to. This implies that the mental models belonging to both areas remains essentially the same over the product innovation process and therefore also during their interactions. The expansions made to the existing mental models are in the form of new knowledge that is developed because of the new product and its production process which become introduced by the actors into their mental models through so-called docking points (Pos-

trel 2002). Meaning that new knowledge becomes relevant to someone by connecting it to individual insights and understanding which belongs to an existing mental model. The actors synchronize their individual mental models in such a way that some new knowledge or insight is developed that forms a compromise between the two mental models. This new insight or new knowledge draws the incongruous mental models together.

Thus, the actors from NPD and Manufacturing who are interacting seem to be trying to synchronize their individually held mental models. This seem to represent what the interviewees said during the ex-post interviews about their prior projects. Their retrospective description of the projects could be based on their perspective of the 'espoused theories' and not based on the actual 'theory-in-use'. However, by having multiple respondents for each project and by having the perspectives from both sides of the interface I have attempted to reduce this perceptual bias (Olson et al. 2001). However, in future research a more ethnographic approach to study the actual behavior of the actors could be beneficial to further develop the theoretical ideas presented here. In Chapter 7 the implications of this insight will be discussed further.

6.7.2 Reflection on the quality of the core category

The aim of this integrating stage was to arrive at a core category that would describe what occurs during the interactions between NPD and Manufacturing. This is what grounded theorists call the basic social process and forms the main target of their research. Therefore, such a stage is the most crucial aspect of the whole research project. But did I achieve this aim? Did I come up with a core category that "accounts for most of the variation in a pattern of behavior" (Glaser 1978, p. 93)? In the last section I made clear that from my perspective this was accomplished. Glaser & Strauss present in their original work (1967) a list of 4 requisites a theory must accommodate. The first is that the theory must **fit the substantive area**. This means that there must be a clear relation between the data and the theory. I strongly believe that I have demonstrated this. The second is that the theory must be **readily understandable** by others working in the same field. The journal publications, presentations at conferences and discussions with my colleagues, peers and supervisors indicate a good understanding of this work. The third requisite is that the theory must be sufficiently general "to be **applicable to a multitude of diverse daily situations** within the substantive area" (Glaser & Strauss 1967, p. 237, emphasis not in original). From the interviews and the selected data incidents that illustrate the synchronization process it is clear that the synchronizing occurs in many situations, from prototyping to casual discussions around the coffee table. Lastly, the theory must enable the user to have partial **control over the daily situations** that are relevant. Within the data and during my observations I have understood that a good synchronization process between the different actors gives them control over their development and production activities.

But on the other hand, this requirement is a little bit strange. If grounded theory aims to identify what actually occurs in a substantive area, then the answers to that question are not yet applicable. They only provide insights into what is happening. Of course, being aware of what is going on might help the participants somehow. In our case they might put more effort into arriving at a synchronized state. But it is interesting to step away from practice and look at the educational programs where future actors are taught to operate in that field, for example a designer who has to learn to synchronize their mental models with other actors. How can that be done? I will elaborate on this and some other questions related to this fourth requisite in the next chapter.

6.7.3 Reflection on the approach of the integration stage

This integrating stage indeed proved to be serendipitous. I made steps that were unforeseen, I got sudden new ideas and insights, and I systematically worked on the data, the categories, and the existing literature. In Chapter 3 I expressed the expectation that within grounded theory a lot of creativity was needed and this proved to be the case. During the last two stages of the project I used creativity techniques like brainstorming, sketching and personal analogy to support the inductive process. However, suspending judgment was the utmost general creativity rule that I applied. Although I couldn't plan the steps nor the time schedule it was certainly a very exiting process. Even addictive, because the new insights that emerged provided so many possibilities for further elaboration and brought to my attention other existing bodies of literature that I had to limit my wandering. Fortunately, all the new insights seem to provide a language that will guide me in my future research activities.

But what can I say about the quality of my approach to this integrating stage? I started this stage with two pillars consisting of two fledgling categories, a lot of names and/or properties thereof and some additional guiding research questions around the category *NPD deliverable.* It has been enormously helpful to review the literature on learning, disturbance, mental models and knowledge management. I was able to find some 'rungs' based on the separate bodies of literature allowing the building of 'ladders' by integrating these bodies which I used for support in the formulation of the emerging core category. And in doing so I didn't experience any forcing of 'round data into square theories'. At the same time, it was very important not to drown in those bodies of literature. A few times I had to drag myself out of the literature by reading the interviews again. The reason for this is clear from the discussion in this chapter. In order to acquire a certain level of understanding regarding the literature it was necessary to go deeper than just reading. This deeper understanding is necessary to create a (rudimentary) mental model relating to that literature and to be able to prepare this knowledge for use in the core category.

In conclusion, I can say that this integration stage is the most challenging stage within grounded theory. Identifying a core category is not at all simple. The researcher must prevent getting attached to one particular viewpoint too early in the process. At the same time I have realized that within the scope of my PhD project it will not be realistic to go through a verifying stage as well. Adding a verification stage to the research as it has unfolded does not seem to be a sensible step. The reason is that the construction of the conceptual framework is not finished enough to create verifiable hypotheses. Although there seems to be a valuable description of a social process the actors from NPD & Manufacturing are engaged in, there is not enough understanding of the properties of that process. Let alone the relation of those properties to the various specific forms of synchronizing that were found in the focusing stage such as front loading, switching and prototyping (Chapter 5). This also requires additional research activities. I believe that the insights which have emerged are interesting enough to be used in future explorative research. Therefore, in the next chapter I will present a preliminary research program that builds on these insights.

7 *On the future of synchronizing*

In this last chapter I will finish this thesis by discussing the implications of the research results for NPD's knowledge base by expressing some ideas about future research projects and by reflecting on the research process. After a brief recap of the project (7.1) I will discuss in Section 7.2 the contributions and implications of this project to the domain of NPD as described in Chapter 2 and discuss some possible future research projects. This is followed by considering the results in terms of the exploration-exploitation divide that was introduced in Chapter 1 and by providing some suggestions on a generalization process of the findings (7.3). In the subsequent section (7.4) I will speculate on some possible relations of the theoretical ideas from this project with existing theoretical constructs outside the field of NPD. The final section is a reflection on grounded theory as the chosen research approach (7.5).

This chapter ends with a brief Epilogue.

7.1 A look back

In Chapter 1 I began with the observation that the interface between NPD and Manufacturing is a crucial interface within the product innovation process because it appears to be a source of frequent friction or conflict on the level of the people involved. I wondered why. I then realized that this NPD-Manufacturing interface, at a slightly higher level of abstraction, could be seen as an interface between the **explorative** NPD process and the **exploitative** Manufacturing process. The NPD process is an explorative process that aims to renew the company's product portfolio and the Manufacturing process is an exploitative process that exploits the present portfolio on an economic basis. From the literature on organization studies I learned that this division into explorative and exploitative processes is regarded as being fundamental however problematic it is to manage. The literature on exploration and exploitation falls short on detailed descriptions in terms of interrelations and transitions.

The NPD-Manufacturing interface has a dual nature: a transitional nature within the process of product innovation and the incremental give-and-take between explorative NPD and exploitative Manufacturing (Chapter 1). The NPD literature seems to be partitioned into studies that either focus on the explorative time-to-market without addressing the NPD-Manufacturing interface in detail or on the exploitative diffusion of products once they are in production and introduced onto the market. The NPD literature that focuses on the interface mainly considers it on a level that is abstracted from the actual participants. These observations led me to the conclusion that the interface and interactions between NPD and Manufacturing on the level of the actors would be interesting to explore. This subsequent research project aimed at exploring the process of interactions between NPD and Manufacturing until volume production is reached. This required an inductive research project that uses empirical observations to arrive at theoretical conceptualizations which describe these interactions. Grounded theory (Glaser & Strauss 1967) was chosen as the most appropriate research approach given the aim and the circumstances of this project. The objective of grounded theory is to identify a basic social process in a substantive field of research, in this case the social process among actors from NPD and Manufacturing. The following main research question and guiding questions were formulated.

What happens during the interactions between the actors from NPD and Manufacturing?

- *What fledgling categories with what properties make a description of the interactions between NPD and Manufacturing possible?*
- *How are the categories and properties related?*

The theoretical sampling following the method of grounded theory (Glaser & Straus 1967, Glaser 1978 & 1998) has resulted in conceptual answers to the sub-questions in Chapter 5 and the main research question in Chapter 6. In order to achieve this, additional guiding questions were posed in all research stages. The social process among the actors that was conceptualized by an interpretation of the processes that were identified in the empirical data is termed **synchronizing incongruous mental models**. The description of this social process forms the present answer to the main research question and is explained as follows:

The individually held mental models on both sides of the interface have been built up by many years of experience and provide the respective actors with valuable explicit & implicit expertise, insight and intuition that they need for an efficient and effective performance regarding their re-

spective day-to-day activities. Because the work of NPD and Manufacturing is very different, needs to be different and must remain different, the respective mental models related to their activities can be considered to be incongruous. The implicit knowledge and tacit understanding of the individuals on each side needs to get synchronized to achieve an efficient and effective product innovation process. From the empirical data collected in this research project it becomes clear that the synchronization process among the actors is a mutual process that is difficult to regulate.

To be able to describe the social process among the actors some additional facilitating research questions were formulated at the beginning of the integration stage (Chapter 6). These questions concentrated on the goal as well as on the outcome of all the interactions between NPD and Manufacturing and resulted in describing the notion of a **noetic template.** A noetic template is defined as an accumulation of individually held and complimentary mental models that make the production of the new product possible. The noetic template gradually grows and matures over various stages of development into the final **performing** state by the end of the ramp-up period (volume production). This is the result of the synchronizing and other social processes between the NPD and Manufacturing participants. Based on the changing activities of actors from NPD and in Manufacturing over the various stages of development, I have formulated three possible intermediate states of the performing noetic template: a **conceptual**, an **actionable** and an **implantable** noetic template.

In this chapter I will elaborate on these conceptual ideas by discussing the implications and contributions to the literature in the domain of the scientific study of NPD that was introduced in Chapter 2. In the same section (7.2) some possible implications for educational programs and some ideas for future research projects are given. In Section 7.3 I will reflect on the exploration-exploitation divide, as introduced in Chapter 1, and suggest some possibilities for generalization with the results obtained in the substantive area of the NPD-Manufacturing interface. Section 7.4 describes some speculative linkages of the theoretical notions that were conceptualized in this research to existing theoretical constructs in the fields of organizational sciences. I end this chapter by reflecting on the research method of grounded theory in the light of the research process that I have been through (7.5).

7.2 Implications for the domain of New Product Development

This section highlights the significance of the conceptual insights for the domain of NPD. First I will present the contributions to the existing literature on NPD using the three perspectives from Chapter 2. Second some suggestions for the education of designers will be discussed. The section ends by briefly presenting some ideas for future research.

7.2.1 Contributions to the existing knowledge base of NPD

In this section I will discuss the contributions of this research to the existing knowledge base of NPD using the process, information and structural perspectives on the NPD-Manufacturing interface that served as a guide in Chapter 2 for discussing the present literature.

Contributions to the process perspective

In the literature that was discussed in Chapter 2 I found four stages within the actual development phase: clarification of the task, conceptual design, embodiment design and detail design.

The development phase is then followed by the ramp-up. In the empirical data these stages were more or less identified. Sometimes they were named differently and sometimes there were other divisions, but generally speaking they were all detected in the data. Based on the empirical observations of this research and the concept of a **growing noetic template** over the respective stages, an extra stage was introduced between the detailed design and the ramp-up: **preproduction series**. This preproduction series stage, including the 0-series just before the ramp-up, seems to be an important step for the actors involved and results in the growth of the noetic template from an actionable state to an implantable state. The position in the development process of this stage is similar to what Ulrich & Eppinger (1995) call 'testing & refinement' and is aimed at the "construction and evaluation of multiple preproduction versions of the product" (Ulrich & Eppinger 1995, p. 17). This research extends their focus on product quality to include a focus directed toward the quality of the combined actions of the people involved. Meaning, the growth of the noetic template that belongs to those actors from NPD & Manufacturing who are involved in the preproduction series.

In Chapter 2 I concluded that the majority of the NPD process literature has treated the NPD process from the perspective of the rational-analytic paradigm and consequently does not pay much attention to the social processes the NPD project participants are involved in. That the NPD process is a social process is not new (Bucciarelli 1988, Lloyd 2002) and is affirmed by this research. Bucciarelli (1988), who looked at high-tech engineering firms, mentions that the "decisions made across disciplines are best seen as negotiations among parties who, […] hold different interests" (1988, p. 168). According to him these differences are informed by the different 'object worlds' they work in. Although his research doesn't address the NPD-Manufacturing interface, what he calls an 'ethnographic perspective' on design, comes close to what has been revealed by this project and termed **synchronizing incongruous mental models.** The synchronization process as introduced in this thesis adds to the current knowledge in the form of providing a more detailed conceptual framework that helps to describe what is going on between explorative NPD and exploitative Manufacturing.

As was mentioned in Chapters 5 & 6, **understanding** the meaning of information supplied by actors from NPD to actors from Manufacturing (and vice versa) plays an important role during the synchronizing of their respective mental models. The recent work on NPD teams (Valkenburg 2000, Kleinsmann et al. 2005) aims to clarify the notion of shared understanding among the team actors and appears to show some similarity to this work. However, I hesitate to call the form of understanding that I observed as also being 'shared understanding' because I see an important difference related to these two kinds of understanding. Within NPD teams the actors need to have a form of shared understanding that relates to the reciprocal dependency of their individual development tasks. They have to share with the team their individual fragments of achieved progress in order to arrive at an integrated design. This is not the case during the synchronizing activities in the preramp-up period since NPD and Manufacturing are sequentially dependent (Chapter 1) and the actor from the exploitative Manufacturing process is not engaged in developing the design but is used by the NPD team mainly as an expert because of his knowledge (explicit and tacit understanding) about Manufacturing issues. This synchronizing process leads to a form of understanding by NPD participants about Manufacturing issues that is different from the understanding the actors from Manufacturing have about the same issues (and vice versa) because of their incongruous mental models. However, a form of mutual **empathic understanding** of each other's mental model might help the synchronizing process in terms of capturing the meaning of

the received information faster or more effectively. Future research might focus on the various forms of understanding related to (product) innovation processes.

There did not seem to be one clear moment of **implementation** at Audiocom and Lightcom. Implementation is a process which begins at the moment the concept is decided upon and a conceptual noetic template is originated. From that moment on the noetic template starts growing. This means that, in fact, the implementation process begins at the concept state and matures through the various states until the performing noetic template is established.

From the data collected at Audiocom and Lightcom it becomes clear that these companies have a lot of trouble with the concurrent development of the **software and the testing equipment** of the new products. I frequently heard statements like "Software is always late" and "test equipment is unfinished" and similar remarks. The models that deal with integrated product development and concurrent engineering should pay some extra attention to these subjects.

My final remark regarding the process perspective has a more speculative character. The two concepts identified in this research exercise, the process of synchronization and the maturing noetic template could have implications for the theoretical basis and the literature on **stage gate models**. Since part of the outcome of exploration is a social process it might be a fruitful idea to supplement the criteria for going onto the next development stage with criteria that are related to the growing noetic template. This is perhaps not the case for the first conceptual state of the noetic template, but the actionable and the implantable states seem to be more important for advancing to the next stage of development. However, some additional research aimed at identifying ideas about the thresholds associated with the actionable and implantable state might then be necessary.

Contributions to the information perspective

In discussing the information perspective in Chapter 2, we started by discussing the **Design for 'X' theories** (DFX) that focus on the incorporation of possibilities and constraints of downstream (Manufacturing) processes in upstream development processes. Typically 'X' stands for Manufacturing (DFM) or for Assembly (DFA) and seems to cover what was named (in Chapter 6) the explicit knowledge structures of the designer's mental models. This research suggests that this knowledge about the production process plays an enabling role during the synchronizing activities they participate in with actors from Manufacturing. Having specific knowledge about production seem to help the actors from NPD understand the implicit knowledge structures of the actors who represent Manufacturing.

In Chapter 2 I expected that **prototyping** would be an important interface bridging activity. From the empirical data and what was discussed in Chapter 5, it becomes clear that this is indeed the case. Prototypes play an important synchronizing role in making the transition from NPD to Manufacturing that should not be underestimated and might, as Bucciarelli (2002) suggests, be regarded as what Star & Griesemer (1989) mean by 'boundary objects' that connect different social worlds.

Therefore, what Clark & Fujimoto (1991) call 'hidden manufacturing' when they point to the production of prototypes could also be seen as explorative activities that inform portions of the noetic template. Similar remarks can be made about the prototypes that serve as starting points for assembly-time studies that, in their turn, are also related to the growth of the NPD-

Manufacturing noetic template. Based on these insights it would be interesting to further investigate prototyping and the ideas behind boundary objects in future research that aims to elaborate on and reach a deeper understanding of this synchronization process.

The literature on the **NPD deliverable** mainly mentions the factual information about the new product and the operational plans for Manufacturing and other functions (e.g. Roozenburg & Eekels 1995). In Chapter 6 we have seen that there is **no final deliverable** of the NPD process in terms of handing over something concrete or executable. Although there are many interim deliverables in the form of drawings, models and part lists, there is nothing tangible delivered by the end of the ramp-up. The results of this research suggest that the **performing noetic template** forms the outcome of the explorative processes. This noetic template constitutes the human side of what emerges from exploration and is, in fact, a **social process**. This implies that NPD does not deliver the new product, but that the new product is delivered by the performing noetic template that operates the technical Manufacturing system with its machines, tools and assembly lines.

Although some practitioners may be (tacitly) aware of this perspective because of their own experience, the NPD literature is not. Of course NPD does develop the product and the production tools in all its details, but at the end of the NPD activities there is no product, only a new manufacturing process that, in its turn, delivers the new product. The performing noetic template with its subnoetic templates (e.g. other operational functions) contains a capacity for work that can be seen as the 'kinetic energy' of the Manufacturing process. The length of the ramp-up, that is the process from an implantable to a performing noetic template, forms an indication of how smoothly the kinetic energy was built up and consequently the **momentum** of the process. The empirical data collected here points to three manifestations of this momentum. Firstly, minor disturbances inside the process like an empty assembly station ruins the momentum and causes, at the very least, the assembly process to come to a halt.

Secondly, easing one of the participants away from the performing noetic template for a temporary involvement in another process is not that simple as we have seen with **transient change**. The *dynamic cohesion* of individuals within a performing noetic template seems to influence their ability to **switch** from one kind of work to another.

Thirdly, changes to a product in terms of introducing a new variant does not seem to be possible while preserving the existing momentum of the Manufacturing process at the same time. The subjective perception of the **newness** of such a variant by the participants in relation to the existing performing noetic template influences this and often leads to a new ramp-up period.

A final remark regarding the information perspective is related to the **information stream** between NPD and Manufacturing. In Chapter 2 I wondered if some of the knowledge necessary to achieve volume production is not part of what is developed during the NPD process by people from NPD, but only becomes available to Manufacturing participants during the 0-series and the ramp-up. The results of this research seems to suggest that the development processes continue until the ramp-up is finished and the noetic template has reached the performing state. It also suggests that the actors from **Manufacturing become involved in the explorative activities** by developing their noetic template and by making use of knowledge they obtained from earlier products. It is good for ramp-up managers to be aware of this and support the workers' learning process as they go through these development cycles.

Contributions to the structural perspective

From the empirical data that was discussed in Chapter 5, it became clear that the ex-post interviews as conducted in this research couldn't provide any insight into the implications of specific organizational setting on the interactions between NPD & Manufacturing. I concluded that one would need to do a more ethnographic or action type of study to see what actually happens before, during and after interactions between the actors. Therefore, there are only minor contributions to the structural perspective in the NPD literature.

The results of this project seem to support the findings of Clark & Fujimoto (1991) that **face-to-face** communication enables the integration between NPD and Manufacturing by suggesting that the synchronizing of incongruous mental models is the basic social process among the actors. For example, the geographic distance between NPD and Manufacturing at Lightcom does not favor the synchronizing process whereas the spatial arrangement of **NPD and Manufacturing on one site** at Audiocom does seem to facilitate the synchronization by allowing more frequent face-to-face interactions.

In Chapter 2 **interdepartmental integration** was described as two distinct processes, one being formally coordinated interactions like routine meetings and the other being a collaborative kind of process among the participants (Kahn 1996). It was then hypothized that the social interactions observed within this research project would be found in both interdepartmental processes. Based on this research it is still hypothetical, but it has become more likely that the social process of synchronization occurs during formal meetings as well as during collaborative activities. At the same time the results of this research in the form of the growing noetic template intimates that, using the distinction introduced by Kahn, the early phases of product innovation show a higher density of formal interactions (e.g. scheduled meetings) whereas during the preproduction series and at the start of the ramp-up there are more collaborative processes. Both appear to serve the interdepartmental integration which takes place around the new product.

Then there is one interesting finding that possibly favors the synchronizing activity: **job change**. Within Audiocom some of the interviewees have spent part of their career in the other process and not only actors from NPD spend time in Manufacturing, but also the other way around. According to these interviewees the knowledge that they have acquired during their work within the other process helps them to better understand their former 'colleagues' once they have left that process. In the terminology used here, job change seems to enable the synchronizing process between participants from both processes because actors who have spent some time on the 'other side' seem to posses a better and more profound mental model of that other side.

Concluding on the contribution to the knowledge base of NPD: the flip side of the coin

The main contribution of this research to the existing knowledge base is by adding a social-interactive perspective on the **NPD process** and the **outcome of NPD.** The present NPD literature is dominated by the rational-analytic perspective on the NPD process by focusing on steps, stages and tools for 'getting the design right' and ending with the design and the plans for production and other operational processes (Buijs 2003). The social-interactive perspective, consisting of descriptions of the synchronizing process and of the growing NPD-Manufacturing noetic template, presents a glimpse of the flip side of the same NPD 'coin'. At the same time, these conceptual notions appear to span the divide in literature between operational plans and the final situation of an implemented Manufacturing process.

These concepts could also provide some footholds for further development of the social-interactive perspective. It is now possible to address some of the problematic interactions between people from NPD and Manufacturing explicitly using words like **synchronizing, mental models, switch, transient change, noetic templates and momentum**. We are now able to use the conceptual meanings behind these words and insights as a pair of social-interactive glasses for future research focusing on the work of designers in their business context.

7.2.2 Implications for NPD education

The insights of this study might have some implications for educational programs aimed at educating designers. Here I will discuss two subjects that relate directly to this work. (1) how to improve social-interactive abilities (2) what must Design students learn about manufacturing technologies.

(1) From the insights gained by this investigation it becomes clear that NPD practitioners might benefit by having improved **social-interactive abilities** that would help them in synchronizing incongruous tacit understandings. This implies that designers must explicitly learn the additional abilities that support the synchronizing process. The phrase 'deep listening and slow judgment' sort of captures my thoughts about these abilities. Through deep listening the designer tries to extract the tacit understanding of other people and by asking questions followed by paraphrasing what he heard, the designer slowly tries to reach a final interpretation. Social-interactive behavior can't be learned from a book. One has to engage in social situations with people who have incongruous mental models. Involving students in multidisciplinary teams working with students who come from other faculties could achieve this. And not only other technical faculties, but also faculties like economics, psychology and organizational sciences. Ideas about gaming and role-play might also improve empathic abilities. In parallel with the active involvement in teams one could think of teaching the students some theoretical psychological elements and some basics about social processes. It would be very useful to identify some more specific social-interactive abilities in future research activities.

Not educating students explicitly in social abilities and solely focusing on the rational-analytic elements is like educating 'flatlanders' in a three dimensional world and leaving the development of these abilities to, for instance, the coincidental richness of their social life (inspired by Buijs 1988).

(2) What must students learn about Manufacturing processes? In some university curricula of Industrial Design Engineering, the students learn how to operate milling machines, welding machines, injection molding, etc. As discussed in this book, designers need to be able to synchronize their mental models with different mental models that exist within the exploitative processes. To be able to understand what Manufacturing is talking about they need to make connections to their own existing mental models about Manufacturing. Therefore, it is good to develop the student's mental models by teaching them on the most relevant production technologies during their educational programs and to let them build some products they have designed themselves. This implies that students would go through cycles of product conception, development, construction and testing. That is, if the educational program aims to educate designers who want to play a major role during the whole product innovation process.

These two ideas can be integrated if a student (or group) has to build the product that is designed by another student.

7.2.3 Suggestions for further research in the substantive field of NPD

Based on the insights gained during this research it would seem a good idea to begin some additional research projects in the substantive field of NPD to enrich and further develop the conceptual notions we have obtained. In this section I will briefly describe some ideas for such future projects.

I recommend a further investigation of the conceptual notion of **synchronizing** by observing actors from NPD and Manufacturing while they discuss various forms of prototypes. Questions that could direct the research might be: What is the synchronizing like during these interactions? What synchronizing strategies do participants apply? How do the various stakeholders react to each other? Are they really synchronizing or are they arguing their own case?

As we have seen, the notion of **transient change** exhibits a complex string of micro-interventions and micro-changes that succeed each other. This kind of change seems to have received little attention in theory as well as in practice. The existing theories on change and interventions mainly address higher levels of aggregation within organizations and are concerned with (semi) permanent change and are not on the level of the individual participant. This raises the following question: Do micro-interventions and micro-changes conform to the existing theories on change? Based on some earlier insights from this project and in parallel to this study, an explorative empirical research project was started in a large company of fast moving consumer goods to investigate that question. The results of that project (Smulders, De Caluwé & Van Nieuwenhuizen 2003) make clear that the micro-interventions fit current change theories to a certain degree and that further investigations along the same line could be useful.

The notion of **noetic templates** is based on the data from this project and is therefore still very conceptual. It is necessary to create a better understanding of this concept that enables a more detailed description of what they are and how they mature. Additional research could look in a more detailed way at the product innovation process during the preproduction series and the ramp-up, that is, after the actionable noetic template has been reached. Questions could be: What exactly happens during these preproduction series regarding the growth of the noetic template? What are differences in the quality of the noetic template between the preproduction series and the 0-series? Is it possible to take the various states of the noetic template as an additional indication that a certain stage gate has been reached? But also: How are the sub-noetic templates linked to each other?

Possible research approaches:

To utilize these ideas for future research on **synchronizing & noetic templates**, I would suggest an ethnographic research approach as I have already mentioned in Chapters 5 & 6. The Reasons for this are: (1) these concepts still lack sufficient detail to be tested in a hypothetical-deductive approach, (2) the retrospective method of investigating the interface interactions is not appropriate for these next research steps, (3) we still need to take a neutral position regarding NPD & Manufacturing. (4) To investigate these constructs it is necassary to get closer to the action. According to Lloyd & Deasley (1998) ethnography is a very suitable technique for describing the social form of design and looks upon groups of people as “texts to be read”. It allows the researcher to become part of the system and to observe things that the actual participants are perhaps unaware of. Finally, it provides the freedom to let the data speak for itself, which is still necessary at this point.

Transient change: One could think of first applying a hypothetical-deductive approach as a possible research project because change theories are sufficiently available to develop the theoretical constructs and to test these empirically (De Caluwé & Vermaak 2004). In parallel or as a follow-up to such a step, one could also undertake an action research project that concentrates on the identification, development and/or refinement of strategies belonging to the various micro-changes as mentioned in Chapter 6. An action research approach, and especially a reflective action study as Boonstra proposes (Boonstra 2004), are particularly useful in generating new knowledge and new methods on specific subjects. Transient change looks like a good candidate.

7.3 The explorative and exploitative divide

In the first Chapter I made clear that the interface between NPD and Manufacturing in the kind of companies that I chose to investigate could be seen as an interface between explorative processes and exploitative processes. In this section, the focus will be to first elaborate on the insights of this study in the light of the transition from exploration to exploitation (7.3.1). Then I will discuss some possibilities for generalizing the conceptual substantive theory (7.3.2).

7.3.1 From Explorative NPD to Exploitative Manufacturing

In Chapter 1 two problematic issues related to the exploration-exploitation divide were mentioned: the balancing of the two processes and the transition from exploration to exploitation. The balancing issue, that is, attuning the efforts spent on exploration and exploitation, is related to strategic issues and these were not the subject of this study. The transformation issue more or less was. What can be concluded about this transition now that I have put the NPD-Manufacturing interface under the microscope?

During the last two stages of this investigation the concentration was on product innovation projects that had in fact made the transition from exploration to exploitation, from concept to volume production. To describe this transition a new theoretical element was introduced in Section 6.4.2: the notion of a noetic template. This noetic template grows gradually from a concept state, via an actionable state and an implantable state to a performing state when volume production is reached. Thus, the performing state is equivalent to exploitation and the beginning of concept development is considered to be full exploration.

In parallel with the maturing noetic template, the amount of freedom within the explorative process decreases. During the concept stage there is still a relatively large amount of freedom, possibly limited only by the strategic direction and the technological capabilities of the company. The explorative activities that lead to the actionable noetic template by the end of product & process development are very much focused on getting the product and production processes ready to make the first products during the preproduction series and to arrive at the manufacture of the 0-series on the real production and assembly line. The main aim of the explorative activities during the preproduction series could be seen as the further growth of the noetic template until the implantable state at the start of the ramp-up. The interviewees mentioned that in between the preproduction series and the 0-series and in between the 0-series and the ramp-up some time is reserved for possible design iterations (rework) to refine the product. When these improvements are finished or other solutions have been worked out, the ramp-up begins with the implantable noetic template that, from this moment on, disperses to all the actors in Manufacturing. During

the ramp-up explorative activities can be seen as 'fire-fighting' to weed out the inefficiencies that hamper the increase of the production volume, in other words, the elimination of inefficiencies that hamper the fulfillment of the performing noetic template.

7.3.2 Possibilities for generalization

In Chapter 3 I briefly discussed the three common levels of a theory: substantive theory, formal theory and meta-theory. The research presented here only aimed at the identification of a substantive theory for the NPD-Manufacturing interface in the case of the interface between explorative and exploitative processes. For the purpose of generalizing I will remain close to this perspective by only addressing similar interfaces between exploration and exploitation.

In Section 7.2.3 I described ideas for future research in the substantive area that we started with. In this section I present some ideas that could help in a generalization process of the core category by investigating interfaces that, in my opinion, are congruent with the interface between NPD and Manufacturing.

The NPD-Operational chain interfaces

Considering the interfaces from NPD to other parties within the operational chain, like Logistics, Quality, Sales (Hultink & Atuahene-Gima 2000) and Purchasing could form the first generalization step. In the empirical data collected at Audiocom and Lightcom we have seen that some of these operational departments are involved in the interactions with NPD during the development activities. Is their any synchronizing between NPD and those other parties? And what other social processes are going on?

Interfaces within the Fuzzy Front End of NPD

The inception of product innovation projects is the explorative process that starts with a preliminary idea about a future product or future business and ends with defining the project. Because this 'front end' lacks a defined team, concrete plans and in most cases also adequate funding it is experienced as being **fuzzy** and in literature is referred to as the Fuzzy Front End (FFE) (Buijs 2003, Cagan & Vogel 2002, Koen et al. 2001, Nobelius & Trygg 2001).

The interface of the FFE with other parties can also be seen as an interface between **free exploration** and the ongoing exploitation of the present business. Similarly to the field of NPD, the rational-analytic perspective which provides phase models and project management structures, dominates the literature on the FFE (e.g. Koen et al. 2001). Some preliminary empirical results of a study parallel to this work that focused on the interfaces between different processes in the Fuzzy Front End indicate that the initiators often struggle to align all the necessary actors for the project and to keep the explorative process going. In this case, it was not only actors on the same level of hierarchy but also actors residing on other levels. Especially middle management seemed to be 'sandwiched' into immobility between the FFE actors and the top management levels (Van Haarlem & Smulders 2005). These results are promising enough to continue with these investigations using the social-interactive perspective that has been developed here.

The university-business environment interface

Outside the substantive NPD area and in a more speculative vein, the interface between technical universities and private business could be seen as analogous to the NPD-Manufacturing interface. In their fundamental research, universities explore and develop new technological knowledge

which is clearly an explorative activity. The activities of companies in the business environment are generally speaking dominated by exploitation. The transfer of new knowledge from universities to the business community is seen as a major challenge and usually takes a long time, if there is any transfer at all. With the concepts generated in this project I suggest that close cooperation between university and business is necessary in order to achieve sufficient synchronization which would allow the growth of noetic templates within the business environment. It could be that without such cooperation the transition of scientific knowledge solely depends on the companies themselves. An interesting example to investigate is the successful transition of the new and innovative fiber-metal laminate called GLARE that recently found its first large scale application in the fuselage of the new Airbus A380. GLARE was developed by Delft University of Technology over a period of twenty-five years in close cooperation with various business partners, like Airbus, Stork, Fokker, AKZO, ALCOA, Structural Laminates, etc. (Vlot 2001). Has synchronization occurred and how was it organized? What enabled the growth of a noetic template at Airbus or Stork for instance?

7.4 Relating new theoretical constructs to existing literature

By following a grounded theory approach I have been through a mainly inductive process, meaning that it was an escalating process from empirical data towards the core category and related theoretical elements. These new theoretical constructs which have emerged, like the concepts of noetic templates and synchronization, have shown their relevance in explaining what happens between the actors from NPD and Manufacturing. These constructs emerged out of the empirical data with the help of some existing literature. For future research it would be fruitful to relate and interweave the insights from this study with existing and relevant theoretical constructs and anchor it to the fields of organizational sciences, social sciences and psychological sciences. In other words, the insights from this research project needs to be 'synchronized' with existing theories. However, it is good to realize that the kinds of change and learning that occurs within the Design-Manufacturing interface are not as far-reaching as is mentioned in most literature about changes in culture, norms, values, etc. At the same time, the transition from Design to Manufacturing is influenced very much by all the rigid and explicit boundary conditions from the manufacturing process and the concrete aim of reaching volume production than the more abstract level of change the literature addresses.

Here I will briefly and impressionistically make some connections to other literature that should be taken into account to inspiration and support in future research activities.

The NPD-Manufacturing Transition and Co-creation of change

In a recent publication Wierdsma (2004) describes the transactional organization that interweaves activities, relationships and meanings and indicates that such organizations are capable of **co-creating change**. He uses the metaphor of a 'trek' to describe this co-creation process that is dominated by alternating action and reflection which aims to achieve a shared vision of the future. What is mentioned about this method and its 'construction and intervention rules' displays many similarities with inherent elements of the transition from explorative NPD to exploitative Manufacturing as was found in this study. It could be interesting to compare this co-creation concept with the concepts developed here to see how these ideas could build on each other.

Synchronization and literature on sense making

Synchronization is what the actors from NPD & Manufacturing seem to do. For that to happen each individual needs to understand what the other party means or tries to convey. This looks like the activity of **sense making** as defined by Weick (1995). He recently defines sense making as the "ongoing retrospective development of plausible images that rationalize what people are doing" (Weick et al. 2005, p. 409) and this tends to occur when the expected state of the world is different from what is currently perceived. This clearly relates to what individual actors go through during the synchronizing activity. Although his descriptions of sense making appears to represent an individual activity, according to Weick it concerns both the individual activity as well as the social activity. Therefore, the large body of literature on this construct needs to be taken into account in future research activities.

Noetic template and literature on organizational routines

Here, a noetic template is defined as a network of complementary mental models that contain knowledge structures and action structures (Section 6.5) and shows similarities with **organizational routines** that are defined as "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors" (Feldman & Pentland 2003, p. 95). As such, the definition of organizational routines seems to correspond with what I call the performing noetic template. A further elaboration of the concept of the noetic template and its maturing nature might benefit from the existing literature on organizational routines.

Transient change and literature on change and interventions

The sub-core category 'disturbance of ongoing processes' put me on the track of **intervention and change** processes. Section 7.2.3 described an idea for a further investigation of the notion of transient change and mentioned a small project done on that issue. During that project we made use of a generic theory on change that integrated the large body of literature on change into a more coherent theory providing five different perspectives on change (De Caluwé & Vermaak 2003). A further application of these perspectives to the various states of the growing noetic template might make it possible to use and test (action research) explicitly the many intervention tools that are available.

Mental models and literature on organizational cultural issues

The construct of mental models is ambiguous in terms of what they are exactly, how they evolve or how different mental models within one individual are linked to each other. Also, the threshold between the conscious and subconscious is far from clear. To enrich the synchronizing process, future research projects should incorporate the work related to theoretical constructs that relate to the notion of mental models. Schein (1996, p. 236) for instance defines culture as "the set of shared, taken-for-granted implicit assumptions that a group holds" which seems to touch on the implicit aspects of mental models that was discussed here. Also the notion of **thought worlds** refers to different perspectives with little or no overlap wich belong to different communities of work (Doucherty 1992). Each thought world is considered to be internally consistent and seems to be closely related to mental models. Similar considerations can be noted here about the idea of **object worlds** as introduced by Bucciarreli (1988) and that are believed to guide/rule the thoughts and actions of participants. And finally there is the related idea of **occupational cultures** like engineers and operators within individual firms who have different but likewise internally consistent and rational perspectives that might result in conflicting interpretations of the same technology (Schein 1996, Von Meier 1999).

There are, in my opinion, many more connections to make, like connections to the learning organization or to knowledge management, but it is not my intention here to provide a comprehensive overview. It is just to indicate that I have realized that after 'resurfacing' from a grounded approach in the field of NPD, it is necessary that future research in the same field or in related fields using the ideas from this project needs to establish connections to theories from the social, organizational and psychological sciences. This was deemed neither necessary nor possible within the scope of this PhD project.

7.5 Grounded theory in retrospective

In Chapters 5 & 6 I already reflected on the research approach within the respective stages. Here I will reflect on the total research process in relation to the method of grounded theory and in relation to the research topic.

First of all, grounded theory was chosen because it fulfilled the requirements that were formulated based on the aims of this research project and the research topic. Secondly, it seemed a practical approach given the time constraints of this project. Based on the results attained during the three consecutive research stages I think that choosing a grounded theory approach worked out fine because I was able to arrive at a first concept of a substantive theory that explains the social process which is what I hoped to achieve. What I did differently from the method §advised by Glaser & Strauss (1967) is that I performed only two successive rounds of theoretical sampling instead of the funnel-like collecting of data that is increasingly theoretically driven. However, the fact that I had 265 pages of data from Audiocom and Lightcom made it possible to go through an extensive and recurring process of constant comparison using additional guiding questions. Quite a number of data incidents were identified or renamed after the initial analysis and during the successive rounds of constant comparison. But in retrospect I would say that the theoretical sampling, as well as the constant comparative activities, could have been done more efficiently if I had the opportunity to walk in and out of different companies for successive rounds of theoretical sampling.

Let us reflect briefly on the requirements that led me to choose grounded theory. It brought the level of analysis down to the level of actors and I was able to keep a neutral position regarding NPD and Manufacturing. However, it is interesting to note that my supervisors, both having an NPD background, commented during the writing of this book that my perspective was too predisposed to advocate the viewpoint of Manufacturing. However, I expect readers from the Manufacturing field to contend the opposite. This supports the incongruity of the mental models on both sides of the interface rather than it questions the neutrality of my position during the course of the project. The third requirement, the ability to reveal theories, is inherently associated with grounded theory along the line Glaser advocates and has led to a conceptual explanation of the social behavior in the substantive area, that is, I have arrived at a substantive theory.

Some people may say that grounded theory is easy to carry out because it refers to what many people do in their everyday life, that is, trying to find out what is going on. However, to apply grounded theory and report the findings on a scientific level, the researcher needs to acquire more proficient qualities. And according to Glaser (1998), there is only one way to achieve that, 'just do it'. It is like designing, everybody can create something, but to become a good designer one needs to acquire and develop new knowledge and skills and to internalize these by action and

reflection. Reading the literature on grounded theory helps, but you can't really understand what is written until your own research process is on its way and you begin to make connections to the principles of grounded theory. In the terminology used in this book, understanding grounded theory requires a new mental model to be built up by practicing, reading and reflecting iteratively on grounded theory.

In addition to acquiring this new knowledge, for me it has also meant going through a transition from looking at the NPD-Manufacturing interface through the eyes of an (aerospace) engineer to looking at the interface through social-interactive glasses. This meant that I was also making my first empirical steps in the world of the social and psychological sciences. Although the choice of making the interactions between the respective actors the subject of this study already implied and required a social view on this interface, the reality of creating this portrait surprised me in terms of its richness. During this transition I started to realize that I knew little about the social and psychological sciences which is, according to Glaser, an advantage when doing grounded theory. He means that it is helpful to not have too much knowledge of existing theories which could seduce the researcher into making assumptions, or even worse, forcing the social behavior under study into these preconceived theoretical boxes. On the other hand, in grounded theory the researcher needs to have some **theoretical sensitivity** formed by his existing knowledge in order to be able to theorize and conceptualize.

Looking at what was uncovered in this study and reflecting on what I have been through, it is perhaps helpful to split the theoretical sensitivity in to a **social sensitivity** and a **conceptualizing ability**. I will briefly review these two qualities because, in my opinion, these are the most important qualities of a grounded theory investigator.

A researcher doing social research needs to have some sensitivity for social processes. This sounds like stating the obvious but what is meant by this kind of sensitivity is not explicitly mentioned in the literature on grounded theory. What I have experienced in doing grounded theory is that I had to be receptive for as long as possible for new insights to emerge. A perceptive attitude as opposed to a more judgmental attitude makes such openness possible (Myers 1962). This receptiveness implies a constantly questioning process aiming at revealing the psychological processes of the actors that somehow make up the social processes that are being observed. The researcher needs to stay curious and prepared to alter and modify theoretical concepts based on new psychological and social insights coming from the empirical data. Therefore, to some degree the researcher must be able to empathize with the different actors who are being studied, meaning that he must be able to place himself in the position of these actors in order to develop some sensitivity to their behavior.

In a recent publication Glaser (2002) focuses extensively on conceptualization as being the core activity within grounded theory. The most important property of conceptualizing is that the researcher aims to abstract away from the real-life elements made up by time, place and people in his efforts to name the emergent social pattern in the field of research. Grounded theory uses the 'voice' of the participants (it does not try to literally describe it) to arrive at an explanation of the behavior which is driven by their need to resolve their main concern. This abstraction from time, place and content also occurred in this research, where the particulars of the product innovation projects and their companies, the people engaged in the activities and the moment in time when these projects ran, evaporated during the analysis leaving the essential social patterns I was looking for. Although Glaser doesn't mention much about the conceptualizing abilities of the re-

searcher, I see a clear relation to the abilities that designers need for concept development. In my reflections in Chapter 6, I mentioned some of the creativity techniques that were applied in the *integrating stage* that now in retrospect can also be related to activities that are necessary for conceptualizing. The difference between conceptualizing within design and within grounded theory is formed by their point of departure which informs both processes and by the differing direction of the reasoning process. Concept design starts with perceptions about a presumed consumer need whereas the conceptualizing in grounded theory starts with perceptions about a social process. The main direction of conceptualization within design is what Roozenburg & Eekels (1995) call 'in-noduction', from a functional description to a form. Within grounded theory the main direction is inductive, that is abstracting from time, place and people (empirical observations) to theory. What they have in common is the creative leap and the constant verification of the emerging concepts being 'concept testing' with consumers and 'constant comparison' with the empirical data respectively. At this moment and in this book I would stray too far from the main subject by 'philosophizing' on this notion any further.

So was it the right choice to follow the original work of Glaser & Strauss (1967) and the later works of Glaser (1978, 1998, 2002) instead of the work from Strauss & Corbin (1990). In Chapter 3 I said that the more rigid approach of data analysis that Strauss & Corbin (1990) propose would hamper the necessary creativity and flexibility that I felt was important in this first exploration of the underresearched NPD-Manufacturing interface. Looking back, I can now say that the approach chosen worked out fine. I used what Glaser & Strauss wrote (and Glaser wrote later) many times during my research to link up to the principles of grounded theory and at the same time to increase my understanding of them. However, I will never know if choosing the more rigid approach of Strauss & Corbin would have resulted in similar results. But my impression is that the creative and designer-like approach that is necessary for a rewarding conceptualization doesn't fit the rigid coding structures that Strauss & Corbin propose and might even be counter-productive in that it could lead the investigation to end up with too many codes without any relationships between them (Glaser 1998). But still, it is strange that two researchers working and writing books together have such a different view on their own 'products'. Glaser even wondered in 1992 after the book of Strauss & Corbin was published if he had ever really understood his colleague and friend regarding his perspective on grounded theory. Glaser now encourages researchers using grounded theory to concentrate on his simple and orthodox views as written in the original work from 1967 and his later works because "grounded theory methodology has been written already" (Glaser 1998, p 40). The researcher should not burden him/herself with the complexities that have arisen in the accounts of others who have rewritten grounded theory.

7.6 Epilogue

The writing of this book has been a design process. Every chapter is designed. Although there was no large variation in concepts for each chapter, there were numerous iterations[42] necessary to refine its content. However, by using the grounded theory method it is not at all clear how to best present the research process and its results to the academic community. I hope that the structure that I have chosen for this book was helpful for the reader to understand the research process and the results of this project. It has been extremely difficult to find the right words in English. Many times my thinking process was blocked because of the limits of my vocabulary. On such oc-

[42] "How do I know what I think until I see what I have written" is what Miles & Huberman (1994, p. 299) mention to indicate the importance of the reporting process as being part of the analysis and thinking.

casions it was also not possible to continue in Dutch because my whole line of thought was now grounded in English. Therefore, I am rather envious of native English speaking scientists.

I wanted to write a book that is easy to read and that would not be too long. I always said to myself, if your thesis is much longer than 150 pages then you are not ready yet. So, it looks like I am not ready and that this book only indicates a 'pause' in my research process. I hope that I have written enough for the reader to get synchronized with the mental model that I have developed during this research project. But "Knowledge acquired from implicit learning procedures is knowledge that, in some raw fashion, is always ahead of the capability of its possessor to explicate it" (Reber, A.S. (1989, pp 229 op cit. Leonard & Sensiper 1998). I am sure that 'I can tell more then I have written down' (paraphrasing Polanyi 1966).

I am truly looking forward, and regard it as a challenge, to engaging in academic discussions on the concepts introduced in this book, to enrich these concepts with the complementary knowledge from the organizational and social sciences and to do all this in cooperation with colleagues in future research projects.

Appendix I – Recurring obstructing events

This appendix contains the top-3 of recurring obstructing events from all the interviews that were performed in the scanning stage (first research stage, Chapter 4). The tables show the selection of obstructing events that were taken for further analysis because of their assumed relationship with the NPD-Operations interface.

Table 1 *R&D Telecom: Obstructing events of six NPD-teams linked to the possible involved parties*

Table 1	**Parties involved:**		**Possible parties outside NPD-project:**			
Obstructing events 1st company	Only inside NPD-project	Also outside NPD-project	NPD department	Strategic Top	Operations	Users & Suppliers
First NPD-team						
Not enough people with right knowledge on team		X	X			
Project structure is too weak		X	X			
Subject of many projects is too operational		X			X	
Too many projects at the same time		X	X			
Second NPD-team						
Miscommunication about agreements within team	X					
Internal client interferes with process of NPD		X			X	
Poor acceptance of individual working habits	X					
Third NPD-team						
Internal client (= B.U.) doesn't know what he/she wants		X			X	
Poor team atmosphere	X					
No clear time target and planning		X			X	
Fourth NPD-team						
No or vague project goals (internal client = B.U.)		X			X	
Poor or no planning of NPD-project	X					
Poor documentation on NPD-subject		X	X			
Fifth NPD-team						
Unclear goal of project (internal client = research)		X	X	X		
Late changes of target (internal client = B.U.)		X			X	
No concentration of effort, too many projects		X	X			
Sixth NPD-team						
Reinvent the wheel every time a project is started	X		X			
Internal client (= B.U.) is not interested in results		X			X	
People get removed from project by management		X	X	X		

Table 2 *R&D Adhesives: Obstructing events from NPD and management team linked to the possible involved parties.*

Table 2	**Parties involved:**		**Possible parties outside NPD-project:**			
Obstructing events Case 2	Only inside NPD-project	Also outside NPD-project	NPD department	Strategic Top	Operations	Users & Suppliers
First NPD-team						
Too many projects		X		X		
No prioritizing of NPD-projects		X		X		
No clear objectives				X	X	
Second NPD-team						
No or no clear teams		X	X			
No 'champion'		X		X		
No possibility to get rapid customer feedback		X			X	X
Third NPD-team						
R&D trials have no priority in plants		X			X	
No clear definition of project		X		X	X	
Poor knowledge of market		X			X	X
Leadership team						
Lack of ownership		X		X		
Trial & error while product on market		X			X	X
Bad cost benefit, cost of product too high		X			X	

Table 3 *NPD Escalators: Obstructing events from parties on both sides of the interface and the possible involved parties.*

Table 3	Parties involved:		Possible parties outside NPD-project:			
Obstructing events 3rd Company	Only inside NPD-project	Also outside NPD-project	NPD department	Strategic Top	Operations	Users & Suppliers
NPD-department						
Changes of goals (NPD's responsibility)		X	X			
Changes in priorities of NPD projects		X		X		
Other departments are inflexible		X			X	
Head NPD-department						
To much changed introduction dates		X			X	
Poor information sharing with other departments		X			X	
Unclear responsibilities team members	X					
Head Marketing department						
Unrealistic planning and inadequate control		X	X		X	
Designs are too complex		X	X		X	
Not enough testing before market intro		X			X	X
Production						
NPD is too late, unrealistic planning		X	X		X	
Spec's are too late		X			X	
Unclear list of parts and components		X			X	
Purchasing						
Too late involvement of production		X			X	
No or poor tuning between NPD and rest of company		X			X	
Poor pursuit of test results with suppliers		X				X
Service department						
Too late involvement of parties from operations		X			X	
Bad project management		X	X		X	X
Market introduction unfinished products		X			X	X

Appendix II – Obstructing events explained by literature

This appendix shows the relations between the recurring events from the scanning stage (first research stage, Chapter 4) and the literature on the inherent differences between explorative and exploitative processes.

Exhibit 3 *The obstructing events of NPD with operations explained by the differences found in literature.*

R&D Telecom: Recurring events between NPD & operations	**Explanation of events by using the literature on differences between exploration and exploitation.**	**Authors used**
1. Wrong type of project, too operational	Participants of NPD are likely to be trained or selected on their ability to cross borders (think out of the box) (Kirton, 1976). Project with an adaptive character is not challenging enough.	Kirton, 1976
2. Internal client interferes with process of NPD	Process remarks that are good for piling processes are not good for growth processes.	Van der Goot & Malotaux, (In 't Veld)
3. Internal client (within operations) doesn't know what he/she wants	Internal client is focused on continuation of present process and has the tendency to wait for instructions. Might overlook stimuli for initiation of NPD. Avoidance of innovation.	Hage & Aiken, Burns & Stalker, Perrow.
4. No clear quality/ time planning	At beginning of 'growth' process clear deliverables are hard to describe. Participants of NPD tend to identify new problems that can be solved to make the product better; a tendency to keep on 'growing'.	Van der Goot & Malotaux
5. No or vague project goals (internal client B.U.)	See, event 3	Hage & Aiken, Burns & Stalker, Perrow.
6. Late changes of target (internal client = B.U.)	People from the operations underestimate the reciprocity of NPD. They think that one can just change the target of something that isn't there yet.	Thompson
7. Internal client is not interested in results	Results from NPD disturb the present and threat the efficiency of the operations.	Perrow, Hage & Aiken
R&D Adhesives: Recurring events between NPD & operations	**Explanation of events by using the literature on differences between exploration and exploitation.**	**Authors used**
8. No clear objectives, definition of project	See, event 3	Hage & Aiken, Burns & Stalker, Perrow.
9. No possibility to get rapid customer feedback	Customer is most likely 'piling', difficult to ask them to join the 'growth process'.	Van der Goot & Malotaux (In 't Veld)
10. R&D trials have no priority in plants	Disturbance of system goal of operations, efficiency.	Hage & Aiken
11. Poor knowledge of market	This complain concerns the interface of Sales with the users/market. This is outside the scope of this paper.	
12. Trial & error while product on market	NPD is not ready (unpredictability), but forced to deliver. This causes mixture of 'piling' and 'growth' processes.	Perrow, Van der Goot & Malotaux (In 't Veld)
13. Bad cost benefit, cost of product too high	NPD as a non-routine organization has no eye for making profit.	Perrow

NPD Escalators: Recurring events between NPD & operations	Explanation of events by using the literature on differences between exploration and exploitation.	Authors used
14. Other departments are inflexible (NPD)	Operational departments tend to avoid changes.	Perrow, Hage & Aiken
15. Too much 'false downs', changed introduction dates (NPD)	If NPD is forced to come up with hard dates at beginning of project, they will probably overdue. Non-routine processes are hard to predict.	Perrow
16. Poor information sharing with other (operational) departments (NPD)	People from operations tend to wait till the work is done, then they start. They also might wait till the design is frozen. Their perspective is sequential dependence.	Perrow, Thompson
17. Unrealistic planning and inadequate control (Marketing)	Not really a question of control. It is more that a tight and inflexible schedule that is too causes non-routine processes to exceed the term.	Perrow
18. Designs are too complex (Marketing)	Innovators within NPD tend to keep on growing and participants within operations tend to wait to long.	Kirton, Perrow
19. Not enough testing before market intro (Marketing)	See event 12	Perrow, Van der Goot & Malotaux (In 't Veld)
20. NPD is too late, unrealistic planning (Production)	See event 17	Perrow
21. Spec's are too late (Production)	See event 17 and participants of operations have tendency to wait for instructions	Burns & Stalker
22. Unclear list of parts and components (Production)	Participants of NPD have different perspective of what is obvious, than participants of operations. 'a pinch of salt'.	Kirton
23. Too late involvement of production (Purchasing)	Innovators have the tendency to avoid adapters, they bring in too much boundaries. Innovators seem to postpone the tuning of their work with operations, because they think that what they have done is all very logical. Participants of operations don't really look for the changes coming up, they tend to wait.	Kirton
24. No or poor tuning between NPD and rest (Purchasing)	See event 23	Kirton
25. Too late involvement parties from operations (Service)	See event 23	Kirton
26. Market introduction unfinished products (Services)	See event 12	Perrow, Van der Goot & Malotaux (In 't Veld)

Appendix III – List of interview subjects

This appendix shows the interview issues that were used as guidance and inspiration during the interviews at Audiocom and Lightcom in the focusing stage (second research stage, Chapter 5).

Interview aim

- During the interviews two different NPD-projects will be discussed. One project that has been fluently regarding the implementation into production/operations and one project that has known difficulties during implementation phase.
- In the interviews I want to find out what has occurred during the interactions and cooperation between the parties and how things were organized and what the difficulties were.
- In both companies I want to interview people from both sides of the interface (NPD and Manufacturing). And about two projects: one with relative smooth transition and one with relative troublesome transition.
- The smooth project was probably on time and on target. No or minor (late) changes to the product and no or minor calamities within the implementation process in production. The trouble some might have caused delays, conflicting interactions, iterations, etc.
- Questions below serve as guidance during the interviews and to check if subjects have been discussed. There is no intention to ask these questions as they are formulated.

Process of interview

- Introduction of me, the backgrounds and aims of my study and the interviewee.
- Position of interviewee, type of work, education, history. Experiences within the organization. Other functions. Etc.
- Interview subject is product X. What was your involvement in that project?

General information about project X

- Open question on factors that are important for implementation.
- Also focus on transfer of knowledge from NPD to operations.
- What kind of elements are discussed during coordination interactions?
- What is your general image of NPD/Production regarding your cooperation?
- What is your general image of NPD/Production regarding their attitude towards cooperation?
- What must NPD deliver to you in order to satisfy you?

Development team setup

- Who were involved with development?
- Are these the usual people to work on development project?
- How are people assigned to the project? Is that normal (procedure)?
- What was the involvement of production or assembly people?
- Cooperation, easy, difficult?
- Do you remember special situations during the cooperation?
- How are functional walls broken down?
- Are there any ‘walls’ between the development of components? (e.g.tube, frame, housing)

Project setup

- What was the assignment of this project like?
- To whom do teams have to report about progress of development?

- Who is ordering (client) the development projects?
- What were the design issues/challenges?
- And challenges in cooperation with other party?
- What was/were the new elements of this product?
- Can you describe the phases of this development project?

About the product X

- What are differences of this product regarding previous ones?
- What was the complexity of the product in relation to other products within your company?
- Were there new production technologies involved?
- How many parts did this product have? More or less than usual?
- What was % of new parts in this product? Is that more than usual?

Cooperation and interface interactions

- How was the cooperation with NPD/Manufacturing?
- What issues are being discussed during interactions with parties outside development team? How was Manufacturing getting involved?
- What are difficulties during these interactions?
- Can you describe such a meeting?
- Is there somebody who is responsible for the implementation?

Prototype

- Who is responsible for the manufacturing and testing of the prototype?
- Was there a prototype build? More than one? For what purposes?
- How was the prototype build? In other words, what is the representativeness of the prototype production in relation to the full scale production?
- Who is involved in the prototype (build-test) cycle?
- What was the quality of the prototype in relation to the commercial product? Lower-higher? To what extend was the prototype representing the real product?
- For what purpose was the prototype build? (master model (≈to be copied by the production model and there for is perfect), problem detector for product & process, tool for proving product design, combi's of these? (C&J p179). Design check?
- In what way are Design Change Orders handled? Is that a formal or informal process?
- What kind of communication (with who about what) is going on during prototype construction testing and prototype evaluation? Example?

Process engineering

- What is the earliest moment they have started thinking about the manufacturing process? How is information transferred from the upstream phases (design, prototype, etc.) to this phase?
- How much time is spent on process engineering?
- Is process engineering stopped at start of pilot runs?

End of Process engineering/transition to production

- What is considered to be the deliverable of last stage of NPD? Is there a final sign-off on the design by the engineering organizations?
- What is delivered to operations by people from development?
- What do you consider as the most important output of the NPD-process?
- Who is responsible for this transition to production? NPD or production.

Pilot run

- Who is responsible for pilot run? (NPD or production)
- Was there a pilot run? Describe setting of pilot run? What of full production was in place? Realistic enough? Who, where, amount of products, etc.
- Is pilot on volume production line or pilot on separate lines within volume plant or outside and different people?
- How many pilot runs? What locations?
- How is it managed on the volume line? Mixed model assembly? Other products around it, or is line shut down? How are differences in productivity absorbed? 'Empty hangers'?

Planning

- How was time span?
- Did project proceed according to the planning?
- Was planning different from other projects?

Production fit

- What was the complexity of the production of this particularly product in relation to the complexity of production with other products within your company?
- How did the design fit the existing production machines?
- How did design fit the existing production routines?

Production logistics

- How did design fit the existing production logistics? Supply chain?

Assembly lines, ramp-up

- How is the volume line accelerated to full production? (shut-down, block intro, step-by-step).
- How long did it take to reach full production? What is difference with other products?
- How many defects turned up?
- Are there any special measures taken during ramp up? E.g. ramp-up team, assignment on temporary basis of trouble shoot engineers, etc.?
- Relative amount of defects detected per product during initial production? Compared to other products?
- Assembly defects?

Problems?

- What were the early appearances/symptoms of the implementation problems?
- Were there more symptoms with one root cause?
- How and by whom are problems solved? NPD and/or Manufacturing?
- Can you describe historically what happened during these problems? Iterations, alterations?
- Was there any kind of 'snowballing' within this problematic situation? One problem and/or solution caused many other problems?
- Or 'iceberg' situation? First a little problem, but later was discovered that there were many problems? Not necessary related to each other.
- What questions had to be answered? Or what problems need to be solved?
- Was it necessary to have all these problems? Could they have been prevented?

Appendix IV – Publications by Frido Smulders related to this thesis

Journal publications

- Smulders, Frido (2004). Co-operation in NPD: Coping with different learning styles. *Creativity and Innovation Management, 13* (4), 263-273.
- Smulders, Frido, De Caluwé, L. , & Van Nieuwenhuizen, O. (2003). Last stage of Product Development: Interventions in existing processes. *Creativity and Innovation Management, 12* (2), 109-120.
- Smulders, Frido, Boer, H., Hansen, p. H.K., Gubi, E., & Dorst, C.H. (2002). Configurations of NPD-Production interfaces and interface integration mechanisms. *Creativity and Innovation Management, 11* (1), 62-73.

Conference proceedings

- Van Haarlem, L., & Smulders, F. (2005). Interface interactions in the Fuzzy Front End of Product Innovation. *Transformations. Proceedings of 9th European Conference on Creativity and Innovation.* Lodz: The Academy of Humanities and Economics. (in print)

- Smulders, Frido (2005). Interactions between product development and production I: Clashes in cross-cultural learning. In B. Jöstingmeier & H.-J. Boeddrich (eds.) *Cross-Cultural Innovation. Results of the 8th European Conference on Creativity and Innovation* (pp. 113-130). Wiesbaden: Deutscher Universitäts-Verlag. (Best Paper Award)

- Smulders, Frido (2005). Interactions between product development and production II: Clashes in cross-cultural abstraction levels. In B. Jöstingmeier & H.-J. Boeddrich (eds.) *Cross-Cultural Innovation. Results of the 8th European Conference on Creativity and Innovation* (pp. 131-148). Wiesbaden: Deutscher Universitäts-Verlag.

- Smulders, Frido (2004). NPD and Manufacturing: Clashing mental models. *Proceedings of 11th International Product Development Management Conference.* Dublin (Ireland): European Institute for Advanced Studies in Management (EIASM).

- Smulders, Frido (2002). Implementing integrated systems: Can we use theories of change? In R. Gonçalves, R.Roy, & A. Steiger-Garçao (eds.) *Advances in Concurrent Engineering. Proceedings of 9th ISPE conference on Concurrent Engineering*. Cranfield, University of Cranfield, 27-31 July.

- Smulders, Frido, Gubi, E., Hansen, p. H.K., Dorst, C.H., & Boer, H. (2002). A typology of supplier-involved interfaces between new product development and production. *Proceedings of 9th International Product Development Management Conference.* Sofia Antipolis: European Institute for Advanced Studies in Management (EIASM).

- Smulders, Frido, Boer, H., Hansen, p. H.K., Gubi, E., & Dorst, C.H. (2002). A typology of interfaces between new product development and production. In J.A. Buijs, R. Van de Lugt, T. Rickards, & J.D. van de Meer (eds.), *Idea Safari. Proceedings of the 7th European Conference on Creativity and Innovation* (pp. 325-342). Enschede (NL): Twente University Press.

- Smulders, Frido, De Caluwé, L., & Van Nieuwenhuizen, O. (2002). Last stage of NPD-Project: Intervention in existing processes?!. In J.A. Buijs, R. Van de Lugt, T. Rickards, & J.D. van de Meer (eds.), *Idea Safari. Proceedings of the 7th European Conference on Creativity and Innovation* (pp. 343-356). Enschede (NL): Twente University Press. (Best Presentation Award)

- Smulders, Frido (2001). Interface Problems: Exploring the relevance of inherent differences between New Product Development and Operations. *Proceedings of International Conference, The future of Innovation Studies.* Eindhoven (NL): Eindhoven Centre for Innovation Studies (ECIS).

- Smulders, Frido (2001). An exploration of the differences between multifunctional NPD and the primary process. *Proceedings of 8th International Product Development Management Conference,* Enschede (NL): European Institute for Advanced Studies in Management (EIASM).

- Smulders, Frido (2001). The interface between New Product Development and the Line Organization, an empirical study. In L. van Geffen, & T. Rickards (eds.), *Fit for the Future. Proceedings of the 6th European Conference on Creativity and Innovation* (pp. 213-229). Enschede (NL): Twente University Press.

Appendix V – Remaining names from focusing stage

This appendix discusses the 10 names form the focusing stage (second research stage, Chapter 5) which were not taken for further analysis during the integration stage.

Late adjustments

This name is related to adjustments/modifications that are made to the product during the development process, meaning that the first design solution is later changed to another design solution. During iterative NPD processes this seems to happen a lot.

> *"…I think that is mainly the problem and the development department …well the problems they have, they are making corrections in the last minute.* ***They do?*** *Yes they do, they do a lot!* ***What kind of corrections?*** *It could be surfaces, it could be process problems, so that we have to make corrections, it could be design problems, the designer have seen a prototype and said 'ahh I like this corner maybe a little bit different…'…" (Audiocom.Mnfct.6.89)*

However, the problem is that other development processes done by other people base their activities on this first design solution. The later solutions might cause adjustments problems if these two separate solutions exhibit some kind of serial dependency.

> *"…but the problem is that the functionality isn't the same at this moment and in this …* ***so the functionality of the software in the construction verification is not similar to the real software in the zero series?*** *Yes, therefore we can have the problem with the test equipment between the device and the test. So we have to update and come with the latest version to the constructor…" (Audiocom.NPD.1.715)*

These late changes or overdue availability of details could cause time problems for other sequential dependent activities. In this example it is about testing and we have seen earlier in this chapter that there are many other problems related to testing. Although we are talking here about an NPD-NPD interface, these late adjustment also causes belated iterations during the early stages of the ramp-up and therefore influences the NPD-Manufacturing interactions.

Balanced design

The name of *balanced design* refers to the balancing among the various requirements of a new product which takes place during the NPD process. It is normal for NPD processes to end up with a compromise regarding the various, often conflicting, demands. It is not always clear to people on the Manufacturing side that NPD can't fulfill all the conditions that make a smooth and easy assembly possible.

> *"…the costumer here is thinking of functionality and the production is thinking how easy this is produced. But you never can make a product that covers all of these. You have something in the middle, either you….you can fill in this….It is a compromise and people don't see that in the factory, they can not see if you take,… if we do this we can not do that. For them they say 'OK, we need,… why can we not just buy very expensive ball bearings?' Yes we can do that, triple the price and you have no production problems, but the costumers… we can not sell it to the costumers, they will just buy another product. They just think about…. they don't see the whole cost problem…" (Lightcom.NPD.4.861)*

But there could also be situations when an upgrade or improved version of an existing product causes problems downstream because the original considerations are forgotten or overlooked.

> *"…So that is where you actually…..because it is so similar that product, you only change one module, you forget that why …..is this….to implement that thermal switch ….because you don't go back to the initial thoughts of 'what happens if this was …', 'what should we do if that happens?' And that you have not focused so much on the actual first specification of the product…" (Lightcom.NPD.4.199)*

Although there is a connection to interface interactions, the incidents behind *balanced design* do not seem to be very influential on the interactions between NPD and Manufacturing.

NPD attitude

In some of the data incidents I saw that the attitude of the NPD people played a role regarding the interactions with Manufacturing. Although this name might be company specific, there might also be elements that are generally connected to the characteristics of the participants in NPD processes. In some instances there appears to be a link to the tentative category that concerns the *target* of the new product.

> *"…Here we freeze the specifications, we should do.* ***Should…?*** *….[however] everybody keeps adding something to… then we should have a link connection, we should have different colors, we should have different stands, we should have … Everything adds to, nobody is taking anything away. So the price keeps growing…" (Audiocom.NPD.2.194)*

Another aspect of the NPD attitude seems to show a connection to *planning* and being ready on time for the start of Manufacturing processes. Changing an attitude is obviously not done overnight.

> *"…They are working on it, they are really working on it, because they are aware of it themselves, so it is like when you were at school and you had a mathematical task you have to deliver next Friday, and you should sit on a Tuesday night working on it, instead of on Thursday evening. Because you have to deliver tomorrow…" (Lightcom.Mnfct.1.674)*

The last feature that I found to be associated with the NPD attitude is their eagerness to begin the development of a new product after the 'old' one has been delivered to Manufacturing.

> *"…They have because they know it is necessary, but they rather go to the next product, to make a new development instead of solving problems, but they know they have to and they do it. We get the support we need, let's say that, but they are more interested in the next product…" (Lightcom.Mnfct.1.810)*

As such, *NPD attitude* has a clear tie to the *inherent differences* that we discussed in Chapter Four. Parts of this attitude seem to influence the quality of the interactions between NPD and Manufacturing. However, to obtain a clear view on this matter and to gain a clear understanding of the direct influence on the interface interactions, an ethnographic or action research approach is more appropriate. Our ex-post approach only provides some indirect influences.

Customers

The role of *customers* in the interface between NPD and Manufacturing is small. Normally customers are important to set the initial targets of a new product, identifying the functionality and features that customers want. Customers are also important during the development process in terms of making decisions about how the functionalities are realized and materialized, for instance, the ergonomics of the product. But in the case of Audiocom, the customers seem to play yet another type of role: the quality level is influenced in the customer's name without their actual participation.

> *"…There is very deep feeling that we can not leave any tests undone and we can not leave out anything. We can not have small scratches on the surface, even though the costumers will never notice it…" (Audiocom.NPD.2.983)*

> *"…Yes, one of the reasons why it [=electro-magnetic interference] is problematic because you can end up and have to make changes in the circuit printed boards. So although you are running fast, you had to stop up and make those changes. You can't see it on the picture, but nevertheless, it gives a lot of disturbances in the project…" (Audiocom.NPD.5.305)*

The Quality department within Manufacturing is responsible for developing some of the test procedures and establishing the quality levels (see later in this appendix). They seem to use the customers (without their actual voice) to set higher quality levels that in their turn NPD must realize.

NPD Philosophy

The *NPD philosophy* is a company related issue and forms more or less the back bone of the *NPD attitude.* In Lightcom the actors within NPD design the products in such a way that anybody will be able to assemble it.

> *"…so we try to… of course to develop products that actually can be, what we call 'thrown in by a shovel'. … [interviewee laughs at his own remark] … Actually it is more that we should not rely on the operator skills…* ***the assembly skills of the people?*** *Yes, so we try to eliminate that…" (Lightcom.NPD.4.382)*

This philosophy sounds belittling but the mind-set behind this causes the developers to implicitly reckon with Murphy's law[43]. And the deep rationale behind Murphy's law is that applying this principle will prevent downstream problems. Not considering possible mistakes that could be made during the future manufacturing process might result in unnecessary interactions between NPD and Manufacturing during the ramp-up period or even later. At Audiocom there was a similar but more explicit philosophy regarding the prevention of ambiguity during assembly.

> *"…I think that the most important thing to understand when you are in development that is that everything can go wrong, that is what you have to think, you do not … you should not think of the*

[43] "If there are two or more ways to do something, and one of those ways can result in a catastrophe, then someone will do it."
Edward A. Murphy, Jr. was one of the engineers on the rocket-sled experiments that were done by the United States Air Force in 1949 to test human acceleration tolerances. One experiment involved a set of 16 accelerometers mounted to different parts of the subject's body. There were two ways each sensor could be glued to its mount. Of course, somebody managed to install all 16 the wrong way around. Murphy then made the original form of his pronouncement, which the test subject (Major John Paul Stapp) quoted at a news conference a few days later. "Murphy's Law" finally reached the Webster's dictionary in 1958. http://www.geocities.com/murphylawsite/

positive thing. You should always think of the negative thing. That is the most important lecture I can say about it. Then your possibility to be correct the first time is the best…" (Audiocom.NPD.5.1452)

But *NPD Philosophy* is richer than that. At Audiocom there seems to be an overriding focus on the quality of the products.

"…It is a problem in Audiocom to make cheap products…" (Audiocom.NPD.2.184)

If the dominant philosophy is to deliver products that are perfect and contain all possible features, then it becomes difficult to alter such a philosophy in order to design cheap products. The more explicit *NPD attitude* at Audiocom to keep on adding new functions and features, as was mentioned earlier, results in a kind of *momentum* on the explorative side of the company that can not easily be changed. And because of such fundamentals the development of a relatively cheap product might influence the NPD-Manufacturing interactions if this inexpensive target is not reached, as was discussed under the tentative category *target* in Section 5.4.2.

Functioning

The name *functioning* refers to problems with the functionality of the product and where NPD and Manufacturing seem to be involved. In the text segment below we can read that there are troubles with some of the functions of a combined DVD and CD player/recorder.

*"…we had some, what we call playability problems, some thing to do with playing both DVD records and CD records as a normally sit in audio [equipment]. We had some…..**They both fit in there?** Yes, you can do both DVD recording and it also functions as a normal audio CD player. And that is quiet different and separated, the electronics and also I think the optical system is different and therefore we saw some different kind of behavior, some behavior regarding the DVD…in a playback situation and other behavior regarding the CD audio behavior. But in both cases we saw some playability problems, some special kind of CD that could not be played back […] and we needed a quiet long period where we did some analysis to identify the reason for that problem. Analysis in the production area and also with the involvement from the engineers from development." (Audiocom.Mnfct.7.342)*

We can also see that, although the problems occurred during ramp-up, NPD is still involved in trying to get grip on the problem and to solve it. In the next quote we see that during the modification phase, the phase in Lightcom before the 0-series, that both parties are involved in improving the functionality and the quality of the new product.

"Than in the modification phase we are improving the constructions that we have seen in the prototype, […] some small improvements. Typically it could be functionality improvements or quality improvements and sometimes cost improvements. But very often we don't do anything to improve the production cost. So it is typical functionality and quality improvements [of the product] and sometimes cost improvement on the material side." (Lightcom.Mnfct.1.149)

It seems that during that phase the costs are of minor importance. It is more getting the design right for the 0-series.

Purchasing

The *Purchasing* department seems also to be an influencing partner regarding the NPD-Manufacturing interactions. Especially regarding their involvement of the selection of suppliers.

> *"… the suppliers are chosen in cooperation between the designer, the purchasing department and also the quality engineer from our department…" (Audiocom.Mnfct.7.119)*

This involvement of Purchasing seems to be logical. However, the actors from NPD first contact suppliers to get the parts for the prototypes that are involved earlier in the process in order. But then it is of crucial that NPD passes the necessary information to Purchasing.

> *"…the R&D department forgot to inform the purchase department about all the arrangements for ordering the product parts. They [R&D] made the first contacts and arrangements for the first products [prototypes], but the daily production arrangement with the Purchase department was forgotten or neglected." (Lightcom.Mnfct.2.407)*

In this case there were not enough parts at a certain moment during the ramp-up which caused a production stop. From the interviews it seems to me that the role of Purchasing is changing because of the increased involvement of suppliers in the NPD-process. To keep up with these changes Purchasing need to get involved as well and therefore they might need to acquire additional abilities (Nijssen et al. 2002).

Revision

The *revision* of parts or subassemblies can sometimes cause problems. If NPD makes the revisions when the product is in production, then this implies that the new parts should be keep separated from the parts already in stock. This requires al kind of coordination and interactions in order to prevent the old parts to be assembled into the new products without NPD knowing that. But also the other way around, Manufacturing is not allowed to change parts or components without informing NPD.

> *"…the production is only allowed to change something that doesn't effect the functionality and that is because ... they don't have the knowledge about what it could be affecting, […] not the quality but the functionality and we don't actually know it [ourselves]. We have also have to … to try it and make a prototype, do heat measurements and do a lot of things to actually secure that this can be running … maybe to do field tests and anything, even if it is a little change." (Lightcom.NPD.4.636)*

From this it becomes clear that also after the ramp-up NPD needs to interact with Manufacturing.

Culture

The culture of the company influences the cooperation between NPD and Manufacturing. At Audiocom we already saw that there seemed to be a cooperative culture involving all key players in the development of the new product. It is not surprising that this is different at Lightcom because of the geographical distance. There seems to be a culture to not be too friendly and too cooperatively towards one another. NPD "owns the design" are perceived to be more important by the people from Manufacturing as the following quote shows.

> *"I think they [Manufacturing people] feel less than people from R&D.* ***Is it because they have had less education?*** *No, it is the same education, but R&D is always been the kingdom within [Lightcom]". (Lightcom.Mnfct.7.332)*

However, it could be that this split is enhanced by the increase in formality over the last years as an interviewee from NPD mentions.

> *"The problem is that earlier on the tone, the daily tone in the company would be more informal like 'it would be so nice if you can do that'. 'Oh OK,' Totally informal. But now it is much more formal. 'If you want that', 'OK, the consequence is that here you can see if we could do that, that means one week in development, that means you postpone that, because that take…". (Lightcom.NPD.5.597)*

From the interviewees this increase in formality was due to the rapidly growing business and subsequent increased number of employees at that time. Therefore they choose to formalize some of the processes.

Quality department

There is one thing that we have noticed to play a role in revealing product details, the role of the Quality department. At Audiocom we have seen that the Quality Department define part of these details and at Lightcom we have seen that the Quality department have their own view and targets on the quality of the end product irrespective the ideas of NPD. In both companies the *Quality department* seem to have considerable influence. At Audiocom it is Quality that decides if the products during early production stages are OK for the market.

> *"…Because the initial test [during 0-series] is not done by the production, because then they can say [too easily] ' ahh, it is OK'. They produce the TV's and it is in [favor] of the production people that it goes through. But it is not them [production people] that decide it that it is OK, that is another person. That is the quality department that do that." (Audiocom.NPD.5.919)*

Quality at Audiocom also is responsible for the development of the subjective parameters. They have a special group of quality people that are 'looking' through the eyes of the customer.

> *"…it is a group that are taking care of all the subjective parameters and they decide… they see as the costumer and they say when is it OK and when is it not. And they set the limits for the subjective parameters and decide when is it OK." (Audiocom.Mnfct.7.175)*

This special quality group seems to form an intermediate position between NPD and Manufacturing concerning the final quality of the product that comes of the line. The members of this group are very experienced and therefore seem to posses that specific feeling for the subjective thresholds.

> *"… they have a lot of experience and normally they have been in the company for some years and seen a lot of different products and have the knowledge about the responses from the market. There are also some people from our service department in [that] group. So they know what the costumers are responding on…" (Audiocom.Mnfct.7.191)*

In Lightcom the Quality department also is influential, maybe even a bit too much as the following quotes seems to suggest.

> *"… But I think the quality department here, at this factory, and this is my point of view are setting higher quality demands than R&D.* ***On the product?*** *Yes, which is a big problem, as I think, sometimes they create a quality problem here at this plant which is located by us, the product shouldn't do this and this and that. The features of the product, which are described by R&D and our quality department,* ***so they put other quality measures (targets)****? Sometimes, or R&D didn't specify them. […] And the quality guys do not focus on problems, [but] give us problems, even small problems. "O shit this can ...[be improved]…" But maybe it was not the idea from NPD. Do you want a Skoda or a Rolls-Royce I guess the quality department wants a Rolls-Royce all the time." (Lightcom.Mnfct.7.496)*

It appears that within Lightcom the interactions between NPD and the Quality department within Manufacturing could be improved because of these misinterpretations and seemingly unnecessary high quality levels as this last quote illustrates.

> *"…the quality department stopped a deliverance because of some nuance difference in the color of a plate.* ***Inside?*** *Inside, and nobody could see it and the customer gives a damn, but they stopped this order and it was a big scandal. When we have a shipment, going through customs, we have to sent all the products, we can't miss one, then you have to stop all the deliverance, because it is in the container. When there fit 20 products in the container, then there have to be 20! If there are 19, they can not do [send] it, you have to take it back and wait and this was one of the huge orders that was stopped. And it was one plate on one product. (Lightcom.Mnfct.7.536)*

From these two companies I have learned that the role of the Quality department is important regarding the transition from exploitative NPD to exploitative Manufacturing and could therefore be an interesting one to investigate in future studies.

Summary

Get Synchronized! Bridging the Gap Between Design and Volume Production
PhD Thesis by Frido Smulders, 2006

Introduction
The research which this book presents concentrates on the transition from product development to production. In particular, the relationship between designing and making of a new product by companies that deliver consumer goods (such as televisions) in large quantities to the market. This relationship, referred to here as the Design-Manufacturing interface (also known as New Product Development (NPD)-Manufacturing interface), is an important component of the product innovation process which consists successively of the conception, development, manufacture and introduction onto the market of a new product. This innovation process serves to adapt the present product portfolio of a company to changes that are taking place in the company's competitive arena. In this way, companies ensure that they are able to either maintain or strengthen their competitive position. It is therefore of crucial importance that these innovation processes progress effectively and also, in view of the present shortened product life cycle, efficiently.

The changeover from product design to production is one of the transitions within the product innovation process that frequently causes problems and delays. The design is not ready on time, is not of the required quality, contains surprises for the production people, is too complex, or misses essential details, etc. This transition is, for the class of companies researched here, the interface between exploration and exploitation on a more abstract level. Exploration is the process whereby companies identify, invent, and develop new business opportunities, such as products. Exploitation is the process whereby companies put these products into the competitive marketplace, as it were, to exploit them. This research is directed at the interface between product development and production as the transition is made from exploration processes to exploitation processes and seeks to answer the question of to what happens between the participants of the two different processes.

Theoretical embedding
The literature concerning product innovation concentrates either on the exploration activity with its goal of bringing the first product onto the market as quickly as possible (known as time-to-market studies) or on exploitation activities which have the quick dispersion of the product in the market as the goal (known as market diffusion studies). One expects that the theory aimed at the time-to-market of a new product would also address the interface between product development and production, since the new product must be produced before it can go on the market. This is not the case. The literature concerning the Design-Manufacturing interface is partly geared towards the incorporation of criteria connected with the producibility of the new product. This happens with the help of 'design for manufacturing' (DFM) and 'design for assembly' (DFA) strategies, among others. Another class of the existing literature, referred to as Design-Manufacturing Integration (DMI), concentrates on mostly structural integration mechanisms that aim to bring Manufacturing knowledge embedded in the minds of the production people into the design process. Apart from these tools and mechanisms there is no detailed description of the interactions between the designers and 'producers' in the process from product concept to volume production as being interactions between two distinct processes: exploration and exploitation. There appears to be a gap in the literature between the drawings, part lists and plans that designers deliver and the implemented production system that

delivers the new products. Scientific researchers seem to have overlooked this interface from the perspective of the actors who are responsible for the transition from exploration to exploitation. Knowledge and insight into what takes place during these interactions appears to be of interest in order to further streamline the product innovation process and to support the changeover from product development to production. This fact together with the inherent problems mentioned earlier formed the impulse to explore this interface with a research project that aims to gain insight into the social process between developers and production people during this transition.

The empirical exploration

In order to find out what happens between designers and production people an empirical approach was chosen which aims to create a social perspective on this interaction process that is grounded in field data. This approach, called 'grounded theory' (Glaser & Strauss 1967), is originally a sociological research method that uses a process of inductive reasoning to arrive at a framework of theoretical terms that will form an abstract report of what actually occurs in the research field. Grounded theory does not aim to achieve a complete and precise description of the area of interest, nor does it state how often something occurs. It is above all concerned with the development of a theory that will give a supplementary perspective about the relevant behavior of the actors involved. In the case of this study, this perspective will also be supplementary to the existing theoretical insights concerning product innovation processes and the transition from exploration to exploitation. An important characteristic of this inductive method of research is the essential use of creativity by the researcher during the conceptualization which is the integration of the discovered concepts into a more compact theory.

The research process of this study had three stages: scanning, focusing, and integrating. The goal of the scanning stage was to develop a feeling for the relevant problematic situations regarding the interface. Therefore, a total of 65 people in three companies were interviewed, primarily in group settings. The interview protocol, which was based on the nominal group technique, resulted in 26 regularly occurring obstructive situations concerning the researched interface. A first induction stage with these 26 situations resulted in five preliminary theoretical categories. A second induction stage using these five concepts produced one extra 'umbrella' category that seemed to encompass all five concepts. The 'umbrella' concept concerned the inherent differences between exploration and exploitation at the level of the processes, the personnel and the management system. Literature about these differences mainly aims to illustrate the contrast and was therefore helpful in the creation of some insight into the factors lying behind the problematic situations. However this still shed no light on what happened between the actors during their interactions. Therefore, it was indeed a possible explanatory framework for the named incidents, but no help in the identification of the social process. The first five concepts and the sixth 'umbrella' concept were helpful in the second, focusing, stage of the research.

During the second stage a total of 14 in-depth interviews were held in two companies (seven per company) concerning two recent product innovation projects per company (a total of 4 projects). Both companies are of average size (1000-2400 employees) and global players in their niche, respectively high-end consumer electronics and high-end lighting systems for events (pop festivals) and night clubs. The interviewees, working either in design or manufacturing, were all questioned individually in semi-structured interviews lasting 1.5 hours. During the interviews, the main topic was their collaboration with the other party, with the product innovation project being used as a 'vehicle'. The transcripts of the interviews (265 pages) were subsequently analyzed and interpreted with an open mind whereby previous categories (from literature and the first research

phase) were considered to be possibly relevant. A first exhaustive inductive examination resulted in 1310 text incidents related to the researched interface between development and production, and classified a total of 37 concept categories (including the previous categories). A further analysis resulted in two related central categories, one on learning and learning styles and the other on changes and interventions. Many of the other categories appeared to have relationships with these two. The 'umbrella' category that spanned the differences between exploration and exploitation (the 1st stage) was discovered in the data in far smaller quantities than had been expected. It is possible that by addressing the Design-Manufacturing transition during the interviews I perhaps landed in the 'eye of the storm' where the differences appeared in a far more subtle way than was found in the first stage.

The third and integrating stage of the research aimed to bring together the two central categories and interrelated properties into one core category. Given the abundance of empirical data assembled in the second stage, it was decided to use these for the third stage as well. In order to increase the theoretical sensitivity, use was made here of a number of existing theoretical concepts from the literature about learning and about change management. These existing concepts worked as a source of inspiration for the conceptualization process in this last inductive stage. This stage is the most important one for arriving at an answer to the research question and it requires creativity from the researcher in order to be able to make the inductive leap, or series of leaps. The conceptualization process itself encompassed numerous iterations between conceptual propositions and empirical data to ensures its groundedness.

The theoretical concept

The object of the interaction between the developers and production workers is to achieve as smooth a transition as possible from the design phase to the production phase with the ultimate goal of reaching the desired production volume (number per day) in a previously planned period (referred to as ramp-up). In order to reach this desired production speed, a lot of new knowledge is necessary for the developers as well as the production workers. This knowledge grows during the process under the influence of conscious and subconscious learning, as well as through planned and unplanned interactions between the actors, until the required interdependent routine behavior by production workers is reached. The image of this future situation at the end of the ramp-up seems to be an important driving force for the actors and affects their actions, behavior and attitudes during the interactions.

The knowledge that must be developed is partly explicit in the form of, among others, drawings, dimensions, production and assembly procedures and partly implicit in the minds of those involved on both sides of the interface. Nevertheless, at the end of the ramp-up, the explicit knowledge has been largely incorporated in production moulds, machine settings and production lines, etc. Some implicit knowledge remains with the developers in the form of, for example, design considerations, problems and solutions of options and alternatives that were not selected. Another part of the implicit knowledge is present in the individuals of the production line after the ramp-up and consists of knowledge about the product, the way of producing & assembling, and testing of parts and sub-assemblies, etc. Each actor within production has built up their own *mental model* about the new product, the related production process and the activities that they carry out, including their relationships with the activities of other actors in their direct environment. All these pieces of individual knowledge, including the interrelation of the individual knowledge of all the actors in the immediate area, accumulate to form a network of connecting mental models. This network of knowledge is referred to in this study as a **noetic**

template because the most important part exists in the minds of the actors and needs to form a template, so to speak, in order to produce the new product.

This noetic template is considered to be the implicit and social-interactive result of the explorative process and supplements the explicit results that consists of production and marketing plans but also the information supplied by drawings, models, part lists, etc. During the development process and in parallel with the increase in the explicit knowledge, the noetic template grows and develops through a number of states. In the empirical data from this research four intermediate states of the template were identified: **conceptual**, **actionable**, **implantable**, and **performing**. These states are similar to the known process stages in the literature that are mainly aimed at the product:

- *concept development* is equivalent to the **conceptual** noetic template
- *product & process development* lead to the **actionable** noetic template
- *preproduction + 0-series* together results in the **implantable** noetic template for the ramp-up
- *volume production* at the end of the ramp-up is equivalent to the **performing** noetic template.

Now that we have an idea that the end result of exploration will be in the form of a performing noetic template we have a foundation that can be used to introduce the social process between the actors in development and production.

According to the literature, a mental model is composed of explicit and implicit knowledge (tacit understanding) and can belong specifically to a context, for example the sort of work that we do. A mental model is built up through conscious and subconscious learning processes that take place during education, training or work. This enables us to carry out our work effectively and efficiently. Because of the totally different work situations between explorative product development and exploitative production in terms of activities, goals, time frames, assumptions and orientation, the mental models of the respective actors seem to be **incongruent**. Such a discrepancy in the specialized mental models is necessary to attain competitive effectiveness and efficiency within each process. This dissimilarity also means that the actors do not specifically aim at making their mental models coincide during the interactions. However, they do try to share the information stored in the individual mental models with each other while developing their product. This social process is a sort of **synchronization** process, a two-sided process whereby both parties attempt to introduce the other to the understanding that resides in their own mental model. This is actually a difficult and complex process since the participants need to use their own subconscious tacit knowledge, tacit understanding and tacit routines that have become deeply ingrained over the years. It also appears to be difficult when actors have to **switch** for a very short period (a few hours) from one process to another (for example, from production to development) in order, to perform a task outside their usual work (to give feedback on a specific design solution, for example). This specific form of synchronizing incongruous mental models consists of a complex process of consecutive micro-interventions and micro-changes that are referred to here as **transient change**. What does appear to help with the synchronization process are the rudimentary mental models of the other process that has been built up during education, through experience in earlier projects or through previous working experience on the other side of the interface. These rudimentary mental models of the other process advance the development and application of **empathic understanding** during interactions. Finally, it is stated that drawings, renderings, prototypes and, eventually, the real product are considered to be **boundary objects** in this interactive process that appear to facilitate the synchronization process.

During the initial phases of product development the synchronization of incongruous mental models will be aimed more specifically at the transfer of understanding from production to design, although during the preproduction series and the ramp-up this will be the other way around. The mental models necessary to produce the new product, and therefore the noetic template, will grow during the whole development process. At the same time the number of actors from the production side involved with the process will gradually increase and they will create their own mental model in synchronization with their own area in such a way that they will eventually determined their own place in the noetic template.

Concluding on the contributions to the Design knowledge base

The results of this research are the theoretical concepts mentioned above and connect the engineering sciences with the social sciences and could therefore be useful as a type of tool for further elaboration of the social-interactive perspective within the field of new product development. These theoretical concepts, related to the process (synchronization of tacit understanding) and to the result (noetic template) of exploration, seem to bridge part of the gap that exists in literature between the design plans and the implementation in the form of volume production. They are, therefore, complementary to the rational-analytical descriptions of product innovation that focus more on the development of, above all, the material and tangibility of product and process. It also appears that the results of this research have established an interesting relationship with research streams such as empathic and participatory design, where developers and users work together to incorporate the tacit understanding, knowledge and action structures of users into new products.

Future research

This research was intended to be a first exploration of the Design-Manufacturing interface at the level of the actors and the results must be viewed as conceptual. Continuing research should be targeted at strengthening and further developing the theoretical concepts uncovered in this investigation. I see two possibly fruitful research tracks, the first concerns research within the same interface but then concentrated on specific aspects such as (1) the *synchronizing* of incongruous mental models during development discussions of, for example, drawings, models, prototypes or 0-series. (2) The further study of the concept of *transient change* concerning the actors who are involved in production innovation on a part-time basis, and (3) the theoretical concept of a *noetic template* as a gradually increasing network of complementary mental models.

The second research track concerns the generalization of the concepts found here: firstly, research into the applicability of the concepts discovered here within other interfaces between development and other operational processes, such as the interface with purchasing, logistics or sales. Secondly, there might be comparable interface interactions at the beginning of the product innovation project, before it becomes a formal project (the 'fuzzy front end'). The lack of boundary objects or a great difference between the mental models of the actors who have the new idea and the actors who need to join the effort to make it a viable project could play an important role in this front-end process.

Third, an interesting interface that is relevant to generalize from the perspectives discovered here is between the university (exploration) and the business community (exploitation). Many universities struggle to transfer their knowledge to business, and many businesses have difficulty with acquiring necessary new knowledge that is developed by universities. The results from this

investigation seem to suggest that for efficient transfer, close cooperation is necessary in order to allow synchronization to appear and a noetic template to grow.

Last but not least, the concepts presented here need to be related to, and embedded in, existing theoretical concepts in the organizational, social and psychological sciences. The inductive method that has been applied in this project could result in theoretical concepts that show similarities to existing concepts with other names in other research fields.

Samenvatting

Get Synchronized! Bridging the Gap Between Design and Volume Production
Proefschrift van Frido Smulders, 2006

Inleiding
Het onderzoek waar dit boek over rapporteert gaat over de transitie van productontwikkeling naar productie. De aandacht richt zich met name op de relatie tussen het ontwerpen en maken van consumenten producten (zoals TV's), die in grote series geproduceerd worden. Deze relatie, hier de ontwerp-productie interface genoemd, is een belangrijk onderdeel van het productinnovatieproces dat achtereenvolgens bestaat uit het bedenken, ontwikkelen, in productie nemen en op de markt introduceren van een nieuw product. Dit innovatieproces dient er voor om het huidige productportfolio van een bedrijf aan te passen aan veranderingen die zich in de concurrentie omgeving van dat bedrijf afspelen. Op deze wijze zorgen bedrijven er voor dat ze hun competitieve positie kunnen behouden of versterken. Het is daarom van cruciaal belang dat deze innovatieprocessen effectief en, onder invloed van de huidige korte levenscycli, ook efficiënt verlopen.

De overgang van productontwikkeling naar productie is één van de transities binnen het productinnovatieproces die frequent aanleiding geven tot problemen en vertragingen. Het ontwerp is niet op tijd klaar, is niet van de gewenste kwaliteit, bevat verrassingen voor de mensen in productie, is te complex, mist essentiële details, etc. Het hardnekkig karakter van deze problemen vormde aanleiding om in deze studie te concentreren op de actoren aan beide zijden van die interface.

Deze transitie is, voor het soort bedrijven hier onderzocht, op abstracter niveau te beschouwen als een interface tussen exploratie en exploitatie processen. Exploratie is het proces waarbij bedrijven nieuwe bedrijfsmogelijkheden (bijv. producten) identificeren, bedenken en ontwikkelen. Exploitatie is het proces waarbij bedrijven deze mogelijkheden op een economische manier inzetten in het competitieve veld, deze als het ware exploiteren. Deze studie richt zich op de ontwerp-productie interface als overgang van exploratie processen naar exploitatie processen en zoekt een antwoord op de vraag wat er zich afspeelt tussen de participanten van die twee verschillende processen.

Theoretische inbedding
De literatuur aangaande productinnovatie concentreert zich óf op de exploratie activiteiten met als doel het zo snel mogelijk op de markt brengen van het eerste product, de time-to-market studies, óf op de exploitatie activiteiten met als doel een snelle verspreiding van het product in die markt, de markt diffusie studies. Ogenschijnlijk omvat de theorie gericht op de time-to-market van een nieuw product ook de interface tussen productontwikkeling en productie. Het nieuwe product moet immers geproduceerd worden voordat het op de markt komt. Echter, feitelijk is de literatuur daar waar het de interface met productie betreft hoofdzakelijk gericht op het incorporeren van criteria verbonden aan de maakbaarheid van het nieuwe product. Dit gebeurt met behulp van onder andere design-for-manufacturing (DFM) en design-for-assembly (DFA) strategieën. Een ander deel van de literatuur richt zich op een organisatorische integratie van ontwikkeling en productie (Design-Manufacturing Integration, DMI) met als doel om de kennis uit productie binnen het ontwerpproces te brengen. Afgezien van deze mechanismen en 'gereedschappen' lijkt de aandacht voor de interacties tussen de mensen (hier actoren genoemd) komende van ontwikkeling als exploratieproces en de actoren komende van productie als exploitatieproces vóór, tijdens en na de productiestart aan de interesse van de wetenschappelijke onderzoekers te zijn ontsnapt. Als zodanig lijkt er in de literatuur een 'kloof' te zitten

tussen de door ontwerpers opgeleverde tekeningen, onderdelenlijsten en plannen voor productie en het geïmplementeerde en werkende productiesysteem dat uiteindelijk de nieuwe producten moet afleveren. Wetenschappelijke onderzoekers lijken geen aandacht te hebben gehad voor deze interface vanuit het perspectief van de actoren die verantwoordelijk zijn voor de transitie van exploratie naar exploitatie. Kennis en inzicht over wat er zich afspeelt tijdens deze interacties lijkt van belang om het productinnovatieproces verder te stroomlijnen en de overgang van productontwikkeling naar productie te ondersteunen. Dit gegeven vormde de aanleiding om deze interface aan een 'exploratie' te ontwerpen met een onderzoek dat gericht is op het opbouwen van een inzicht aangaande het sociale proces tussen ontwikkelaars en productiemensen tijdens deze transitie.

De empirische exploratie

Om er achter te komen wat er zich afspeelt tussen ontwikkelaars en productiemensen is gekozen voor een empirische aanpak, waarbij vanuit de empirie inductief naar een in onderzoeksgegevens gefundeerde theorie is gezocht die hun sociale proces weergeeft. Deze aanpak, in het Engels 'grounded theory' genoemd (Glaser & Strauss 1967 & 1976), is een van oorsprong sociologische onderzoeksmethode om uit empirische data door een systematische en vergelijkende analyse te komen tot een theoretisch begrippenkader dat een geabstraheerde weergave vormt van wat zich afspeelt op het onderzochte terrein. Het gaat daarbij niet om een volmaakte en precieze beschrijving van het veld van onderzoek en ook niet om aan te geven hoe vaak dat iets voorkomt, maar vooral om het ontwikkelen van een theorie die een aanvullend perspectief geeft van het relevante gedrag van de actoren in het veld. In het geval van dit onderzoek zal dit perspectief ook een aanvulling op de bestaande theoretische inzichten aangaande productinnovatieprocessen geven en de overgang van exploratie naar exploitatie. Een belangrijk kenmerk van deze inductieve onderzoeksmethode is het noodzakelijke gebruik van creativiteit door de onderzoeker bij het conceptualiseren en integreren van de gevonden begrippen in een meer compacte theorie.

Het onderzoeksproces dat in deze studie is doorlopen kende drie fasen: een verkennende, een gefocuste en een integrerende fase. Het doel van de verkennende fase was om een gevoel te ontwikkelen van de relevante problematische situaties aangaande de onderzochte interface. Daartoe zijn bij een drietal bedrijven in totaal 65 mensen in hoofdzakelijk groepsettings geïnterviewd. Het interviewprotocol, dat gebaseerd was op de nominal group technique, resulteerde in 26 regelmatig voorkomende problematische situaties rond de onderzochte interface. Een eerste inductiestap met deze 26 situaties resulteerde in vijf voorlopige theoretische begrippen en een tweede inductiestap met de vijf begrippen in één extra overkoepelend begrip. Het overkoepelende begrip betrof de inherente verschillen tussen exploratie en exploitatie op het niveau van de processen, de personen en het management systeem. Literatuur over deze verschillen is hoofdzakelijk gericht op het illustreren van die verschillen en was daarmee behulpzaam in het creëren van enig inzicht in de achter de problematische situaties liggende factoren. Dit gaf echter nog geen inzicht in wat er zich zou kunnen afspelen tussen de actoren tijdens de interacties. Dus wel een mogelijk verklarend kader voor de genoemde incidenten, maar geen hulp bij de identificatie van het sociale proces. De eerste vijf begrippen en het zesde overkoepelende begrip zijn behulpzaam geweest bij de tweede meer gefocusseerde onderzoeksstap.

Tijdens de tweede fase van het onderzoek zijn binnen twee bedrijven in totaal 14 diepte interviews gehouden (7 per bedrijf) rond twee recente productinnovatieprojecten per onderneming (totaal 4 projecten). Beide ondernemingen zijn middelgrote (1000-2400 werknemers) en mondiale spelers in hun niche, respectievelijk high-end consumenten elektronica en high-end lichtsystemen voor evenementen (popfestivals) en nachtclubs. De geïnterviewden, werkzaam in ontwikkeling of in

productie, zijn individueel geïnterviewd. De interviews waren semi-gestructureerd en duurden ± 1.5 uur. Tijdens de interviews werd vooral gesproken over de samenwerking met de andere partij waarbij het productinnovatieproject als 'draaggolf' werd gebruikt. De transcripts van de interviews (265 pag) zijn vervolgens met een open-mind geanalyseerd en geïnterpreteerd waarbij eerdere categorieën (uit literatuur en 1e onderzoeksfase) werden meegenomen als mogelijk relevant. Een eerste grondige inductieve beschouwing resulteerde in 1310 tekst incidenten gerelateerd aan de onderzochte interface tussen ontwikkeling en productie en ondergebracht in totaal 37 conceptuele categorieën (inclusief de eerdere categorieën). Een verdere analyse resulteerde in twee samenhangende centrale categorieën, een over leren & leerstijlen en een over veranderingen & interventies. Veel van de andere categorieën leken hier een verbinding mee te hebben. De overkoepelende categorie over de verschillen (1e fase) werd in veel mindere mate teruggevonden in de data dan verwacht. Geopperd is dat door zo midden in de interface te interviewen we misschien wel in het 'oog van de storm' zijn beland waar de verschillen op een veel subtielere manier voorkomen dan in de eerste fase gevonden was.

De derde en integrerende fase van het onderzoek had tot doel de twee centrale categorieën en gerelateerde eigenschappen in één core categorie te laten samenkomen. Gezien de rijkheid van de in de tweede fase verzamelde empirische gegevens is besloten deze data ook voor de derde fase te gebruiken. Om de theoretische sensitiviteit te verhogen is hierbij gebruik gemaakt van een aantal bestaande theoretische concepten uit de wetenschappelijke literatuur over leren en over veranderingsmanagement. Deze bestaande concepten werkten als inspiratiebron bij het conceptualiseren binnen deze laatste inductieve stap. Deze stap is de belangrijkste om te komen tot een antwoord op de onderzoeksvraag en vereist de nodige creativiteit van de onderzoeker om de noodzakelijke inductieve sprong of reeks van sprongen te kunnen maken. Het conceptualiseren bestaat uit ontelbare iteraties tussen conceptuele proposities en empirische data met behulp van propositionele gedachten en garandeert daardoor de 'gegrondheid' van het uiteindelijke concept.

Het theoretisch concept

De interacties tussen ontwikkelaars en productiemedewerkers beogen een zo soepel mogelijke overgang van de ontwerpfase naar de productiefase mogelijk te maken met het uiteindelijke doel om in een vooraf geplande periode (ramp-up) de gewenste productiesnelheid (aantallen per dag) te bereiken. Om deze gewenste productiesnelheid te bereiken is veel nieuwe kennis nodig bij zowel de ontwikkelaars als de productiemensen. Deze kennis groeit gedurende het proces onder invloed van bewuste en onbewuste leerprocessen als mede door geplande en ongeplande interacties tussen de actoren totdat de ingelopen productielijn met wederzijds afhankelijke en routinematig handelende productiemedewerkers is bereikt. Deze beoogde situatie aan het eind van de ramp-up lijkt de belangrijkste drijfveer voor de actoren en beïnvloed handelingen, gedrag en attitudes van de actoren tijdens hun interacties.

De kennis die ontwikkeld moet worden is deels expliciet in de vorm van onder andere tekeningen, dimensies, productie- en assemblageprocedures en deels impliciet in de hoofden van de betrokkenen aan beide zijden van de interface. Echter aan het eind van de ramp-up is de expliciete kennis voor het grootste deel verwerkt in o.a. productiemallen, machine-instellingen en productielijn layout. Een deel van de impliciete kennis is achter gebleven bij de ontwikkelaars in de vorm van o.a. ontwerpoverwegingen, ontwerpproblemen en ontwerpoplossingen als mede niet gekozen alternatieven. Een ander deel van de impliciete kennis is na de ramp-up aanwezig in de individuele hoofden van de actoren in productie en bestaat uit kennis over het product, de manier en handelingen van produceren en assembleren, testen, goed en afkeuren van te verwerken onderdelen en

sub-assemblies, etc. Iedere actor binnen productie heeft een eigen *mentaal model* opgebouwd over het nieuwe product, het bijbehorende productieproces en de door hem te verrichten werkzaamheden inclusief de relaties met de werkzaamheden van actoren in zijn directe omgeving. Al die stukjes individuele kennis inclusief de relaties met de individuele kennis van de actoren uit de directe omgeving vormen geaccumuleerd een netwerk van aaneengeregen mentale modellen. Dit netwerk van kennis is in deze studie een **noëtisch sjabloon** genoemd omdat het belangrijkste deel daarvan in de hoofden van de actoren zetelt en als het ware een sjabloon vormt voor het te produceren nieuwe product.

Dit noëtische sjabloon is te beschouwen als het impliciete en sociaal-interactieve resultaat van de ontwikkelingsprocessen en is aanvullend aan het expliciete resultaat dat bestaat uit productie- en marketingplannen maar ook uit tekeningen, dimensies, modellen etc. Gedurende het ontwikkelingsproces en parallel aan de toename van de expliciete kennis groeit het noëtisch sjabloon over een aantal stadia naar wasdom. In dit onderzoek zijn aan de hand van in de empirische data geïdentificeerde overgangen een viertal tussenstadia van dit sjabloon gevonden: **conceptueel**, **uitvoerbaar**, **implanteerbaar** en **presterend**. Deze stadia zijn gelijk aan de in de literatuur bekende fasen die hoofdzakelijk op het product zijn gericht:

- *concept ontwerp* is gelijk aan het **conceptuele** noëtisch sjabloon,
- *product en proces ontwerp + detail ontwerp* leiden tot een **uitvoerbaar** noëtisch sjabloon
- *pre-productie + nul-serie* samen resulteren in het **implanteerbare** noëtisch sjabloon vlak voor de ramp-up
- *volume productie* aan het eind van de ramp-up bestaat uit het **presterende** noëtisch sjabloon.

Nu we een idee hebben van het eindresultaat van een ontwikkelingsproces in de vorm van een noëtisch sjabloon hebben we een fundament om het sociale proces tussen de actoren van ontwikkeling en productie te introduceren.

Volgens de literatuur is een mentaal model opgebouwd uit expliciete en impliciete kennis-, begrip- en handelingstructuren en kan specifiek verbonden zijn aan een context, bijvoorbeeld het soort werk dat we doen. Een mentaal model wordt opgebouwd door bewuste en onbewuste leerprocessen die plaatsvinden tijdens bijvoorbeeld opvoeding, opleiding en in het werk. Het maakt mogelijk dat we ons werk effectief en efficiënt kunnen doen. Door de totaal verschillende omgevingen tussen productontwikkeling en productie in termen van activiteiten, doelen, tijdsassen, gerichtheid en aannames zijn de mentale modellen van de respectievelijke actoren aangaande hun eigen specialisme noodzakelijkerwijze **incongruent**. En dat moet ook zo blijven, want dat kenmerkt het specialisme en bevordert de effectiviteit en efficiency binnen de respectievelijke processen. Deze incongruentie maakt ook dat de actoren er tijdens interacties niet specifiek op gericht zijn om de mentale modellen gelijk te maken. Wel zullen zij proberen om de kennis opgeslagen in de individuele mentale modellen met elkaar in verband te brengen rond het in ontwikkeling zijnde product. Dit sociale proces is een soort **synchronisatie proces**, een tweezijdig proces waarbij beide partijen trachten bij de ander in relatie tot het onderwerp van de interactie het begrip aan te brengen dat hoort bij het eigen mentale model. Dit is met name een lastig en complex proces als de actoren daarbij gebruik dienen te maken van hun eigen dieper gelegen impliciete kennis-, begrip- en actiestructuren (tacit knowledge, tacit understanding, tacit routines) die zich over de jaren in hun mentale model genesteld hebben. Ook lijkt het lastig als actoren voor een uiterst korte periode (enkele uren) van het ene proces naar het andere proces (bijvoorbeeld van productie naar ontwikkeling) moeten '**switchen**' om bijvoorbeeld feedback op een bepaalde ontwerpoplossing te geven. Deze specifieke vorm van synchroniseren bestaat uit een complex van elkaar opvolgende micro

interventies en micro veranderingen die hier vooralsnog '**transient change**' is genoemd. Wat wel lijkt te helpen bij het synchronisatieproces zijn de rudimentaire mentale modellen van het andere proces die zijn opgebouwd door opleiding, ervaring bij eerdere projecten of door in het verleden werkzaam te zijn geweest aan de andere kant van de interface. Deze rudimentaire mentale modellen over het andere proces bevorderen de ontwikkeling en toepassing bij de interacties van **empathisch begrip**. Als laatste is geconstateerd dat tekeningen, 'renderings', modellen, prototypes en uiteindelijk het echte product in dit interactieproces te beschouwen zijn als '**boundary objects**' die het synchronisatie proces lijken te vereenvoudigen.

Gedurende de eerste fasen van de ontwikkeling zal het synchroniseren meer gericht zijn op het overbrengen van begrip van productie naar ontwikkeling, terwijl tijdens de pre-productie series en de ramp-up dit andersom zal zijn. Gedurende het gehele ontwikkelingsproces groeien geleidelijk de mentale modellen benodigd voor het produceren van het product en daarmee dus ook het noëtisch sjabloon. Tevens worden ook gaandeweg steeds meer actoren van productiezijde betrokken bij dit proces en creëren zij al synchroniserend met hun omgeving hun eigen mentale model op een zodanige wijze dat ze uiteindelijk hun eigen plaats in het presterende noëtische sjabloon hebben bepaald.

Conclusies over de bijdrage aan de kennisbasis productinnovatie

De belangrijkste bijdrage van dit onderzoek zijn de zojuist genoemde theoretische begrippen die de ingenieurswetenschappen verbinden met de sociale wetenschappen en als een soort gereedschappen behulpzaam kunnen zijn bij het verder uitwerken van het sociaal-interactieve perspectief op het veld van productinnovatie. Deze theoretische concepten, gerelateerd aan het proces (synchroniseren van impliciet begrip) en het resultaat (noëtisch sjabloon) van exploratie, lijken een deel van de kloof te overbruggen die in de literatuur bestaat tussen het productontwerp met haar operationele plannen en de situatie van volume productie. Ze zijn daarmee aanvullend aan de rationeel-analytisch beschrijvingen van productinnovatie die meer gericht zijn op de materiële en planmatige kant van product en proces. Ook lijken de resultaten van dit onderzoek een interessante relatie te leggen met onderzoeksstromingen als 'empathic & participatory design' waarbij ontwerpers en gebruikers samenwerken om de impliciete begrip-, kennis- en handelingstructuren van de gebruikers in nieuwe producten te verwerken.

Toekomstig onderzoek

Dit onderzoek betrof slechts een eerste exploratie van de ontwerp-productie interface op het niveau van de actoren en de resultaten moeten beschouwd worden als hypothetisch. Vervolgonderzoek zou zich dan ook met name moeten richten op het verstevigen en verder uitwerken van de hier blootgelegde theoretische concepten. Ik zie twee mogelijk interessante onderzoeksassen. De eerste as betreft onderzoek binnen dezelfde interface maar dan geconcentreerd op specifieke aspecten zoals (1) het *synchroniseren* tijdens discussies rond bijvoorbeeld tekeningen, modellen, prototypes en nul-series. (2) Het verder onderzoeken van het begrip van *transient change* rond de part-time bij productinnovatie betrokken actoren, en (3) het theoretische concept van een *noëtisch sjabloon* als een geleidelijk groeiend netwerk van complementaire mentale modellen.

De tweede as betreft het generaliseren van de hier gevonden begrippen. In eerste instantie het onderzoeken van de toepasbaarheid van de hier gevonden begrippen binnen andere interfaces tussen ontwikkeling en de operationele processen, zoals de interface met inkoop, logistiek en verkoop. In tweede instantie, zijn de interface interacties aan het begin van het productinnovatieproject, voordat er een formeel project is (fuzzy front end) mogelijk vergelijkbaar. Het ontbreken van boun-

dary objects of te grote verschillen tussen de mentale modellen van de betrokken actoren zouden wel eens belangrijke rol kunnen spelen in dit front-end proces.

De laatste gedachte voor generalisatie van de hier gevonden perspectieven betrfeft de interfaces tussen de universiteit (exploratie) en het bedrijfsleven (exploitatie). Veel universiteiten kampen met de transfer van hun kennis naar het bedrijfsleven en veel bedrijven hebben moeite met het acquireren van de benodigde nieuwe kennis die aanwezig is bij de universiteiten. De resultaten van dit onderzoek lijken te suggereren dat voor een efficiënte transfer goede samenwerking nodig is om synchronisatie te krijgen en om een noëtisch sjabloon te laten groeien.

Last but not least, de hier gepresenteerde begrippen dienen gerelateerd te worden aan en ingebed te worden in bestaande theoretische begrippen uit de organisatie, de sociale en de psychologische wetenschappen. De inductieve onderzoekswijze die hier gehanteerd is kan met zich meebrengen dat de blootgelegde theoretische begrippen verwantschap vertonen met in andere onderzoeksvelden al bestaande begrippen met andere benamingen.

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I met Kees Dorst when I joined the University in 1993. At that time he was a PhD researcher in design methodology and I had no idea of what that could be. During the Delft protocol workshops I started to develop some feeling about this methodological perspective on design and the designer. This initiated discussions in which we looked for common ground that we finally found in doing some consultancy projects together. Making me your paranymph marked my 'initiation' into the field of science, but it also established the start of your role as my coach. Kees, you were able, by mirroring, asking philosophic questions and giving inspiring feedback to help me understand explicitly what I was feeling intuitively. During these challenging discussions you increased the level of my conscious thought. I am glad to hear from you that this was, in some respect, mutual and I hope that we will continue our professional and scientific exploration. But you must realize that what you did with me and for me is unforgettable.

I would like to thank the members of the Promotion Committee for their willingness to get involved and for their valuable comments which helped me to increase the final quality of this book.

I thank my two paranymphs, my brother Freek and my friend Bart Jan Brandt, for supporting me during the last months and final steps. They will sit in front and stand behind me and I know that they will cover my 'tail' when necessary.

Then there are my many friends that sometimes had to spend time with me as a 'zombie' who could only think and talk about one subject, if I was there at all. Dear friends, please keep in mind that your patience with me was good 'for science'. But also to my family, you all have been extremely flexible and empathetic with me and I could really feel your positive energy. Thank you!

This was even worse for my mother who is, of course, proud of me, but at the same time she had to control herself in calling me and asking me to visit her. Ma, I am extremely pleased with the fact that you will be witnessing my defence and that you will see me becoming a doctor. I have dedicated the book to Pa, but I will give it to you.

Yes, dear reader, what you read next is about love. I don't really know how to put it into words, but without my wife Joma I would not have been capable of accomplishing this 'expedition'. I don't know how she did it besides her work as a creative florist, but Joma was the one that managed my energy level. Joma, you have been able to give me new energy by putting Michelin star dishes in front of me. Not the same kind of special dish over and over again, but new recipes were constantly tried out in our kitchen. You kept on making prototypes of new dishes to surprise me with yet another creation. And while eating these energizing meals there was plenty of time to discuss the things that I was struggling with. Joma, I admire you for your courage in joining me on this exploration, but also for your flexibility in serving as a 'lightning conductor' and as a 'synchronizer' to help me organize my subconscious thoughts. You organized the house around me and filled it with a warm and 'flowerful' atmosphere. Because of all this and the many hours of our free time this project took, it is completely clear to me that you are fully entitled to be called 'Frau Doctor' wherever you go.

Thank you all, Frido
Delft, February 14th 2006

Get Synchronized!
Bridging the Gap Between Design & Volume Production

The interface between Design and Manufacturing forms a locus of frequent interpersonal conflict. Misunderstandings, unwelcome surprises and planning problems are the rule rather than the exception. Within companies that deliver consumer goods in large quantities to the market this interface is also the transition from exploration (seeking new business opportunities) to exploitation (profiting from those consumer products).

This thesis reports on a first exploration of the Design-Manufacturing interface on the level of the participants from both processes using the method of Grounded Theory. This book conceptually describes how these actors bridge the gap between Design and Volume Production and portrays their social process in detail. The insights presented here are to be seen as a social-interactive perspective on the process of product innovation and are complementary to the rational-analytic viewpoint that focuses on the material and tangibility of product and process.

The kind of research that this book presents reflects the increased attention of academic researchers towards the human dimension of the product innovation process. Over the last decade the focus of design researchers has widened from individual designers, via teams of designers towards design teams in corporate settings. This movement increasingly views design as a social process which connects the engineering sciences with the social sciences.

Technische Universiteit Delft


PHOTO: THEO BOS

Biographical Note

Frido Smulders (1955) was trained as an aerospace engineer at Delft University of Technology.

After what can be seen now as a bachelor degree in Aerospace Engineering, he worked as a freelance science & technology journalist and as a concept engineer at SBM-Offshore in Monaco. He then obtained a Master's degree, also at Delft University of Technology, by specializing in fiber metal-laminates, such as ARALL and GLARE (now used in the fuselage of the Airbus A380).

He briefly worked with the Aluminum Company of America (Alcoa) in Pittsburgh before he began a career as a consultant for innovation, creativity & technology with the Innovation Consulting Group TNO. The main line of projects concerned new business development, R&D assessment and training programs on creativity and innovation management. An example of that was a six-week Innovation & Technology Management training program for Greek management consultants.

In 1993 he joined the faculty of Industrial Design Engineering at Delft University of Technology as an assistant professor and combined this with his own consulting company, Mosaic Research & Consulting, where among other activities he was a core lecturer for a post graduate course 'Master of Innovation'. At the university he teaches a third year course on Corporate New Product Development and is involved tutoring Masters students with their final thesis.

His future ambitions are to continue the blending of practice & theory and research & teaching on various levels of abstraction in the field of design & innovation.